PRICING WITH CHANGING WELFARE CRITERION: AN APPLICATION OF RAMSEY- WILSON MODEL TO URBAN WATER SUPPLY

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ABSTRACT

Tariff rates based on Ramsey - Wilson model of changing welfare criterion satisfying equity and efficiency have been estimated for three categories of consumers of an urban water supply in India. The design necessitates values of marginal cost and price elasticity. Paucity of data severely restricts estimation of marginal cost compelling to use breakeven as proxy. Price elasticity is obtained from household expenditure data by applying recoverability theory suggested by Pollak and Wales. The effect of household composition on elasticity has been eliminated by expressing variables on a per capita basis using adult equivalent scale (AES). Calculation of AES for water is based on Prais-Houthakker incremental method. The scale indicates that it is totally different from Amsterdam scale, the AES of food.

Maximum welfare is given to small quantity consumers by charging a rate below breakeven combined with a subsidy arising from the surplus generated in the markup of large quantity consumers. The middle group is charged only the breakeven rate. The model can be generalised to any number of groups by assigning different welfare weights ranging from zero to one. The model breaks down if the rate exceeds stand-alone cost.

JEL Classification : H41, D4, Q25

Key words: tariff rates, second best prices, adult equivalent scale, welfare weights, stand alone cost.

Introduction

Developing world confronts two challenges today in the provision of drinking water. While the first concern is to reach the uncovered millions in the shortest period, the second is to improve the quality and quantity of already existing supply. The resources needed for meeting the above conflicting challenges are beyond the reach of most of these countries, mainly due to: (i) an unscientific tariff design; (ii) flows of subsidy with very little economic rationale on equity; and (iii) very little political will to generate resources within the sector. As a result quite often the commodity is being charged only at a nominal rate, much below the cost of production, leaving the burden entirely on the public exchequer. Realizing the gravity of the problem, the "Earth Summit" has called for treating water as an economic good in all its uses and appealed to the global community to formulate policies for achieving it[1]. One of the most important elements in such a policy package is the design of appropriate user financing. But hardly any study exists that facilitates the policy makers for achieving this objective[2]. The present study is an attempt in this direction in the design of an equitable and efficient tariff rate for drinking water with a case study of an urban water supply in the state of Kerala, India.

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1 Serageldin, I; 1995.

2 Whittington, et.al. (1990) and Pushpangadan and Murugan (1977) are the few exceptions. See also World Bank (1975).

The outline of the paper is as follows. Section 2 reviews the models in public utility pricing relevant for drinking water and also develops a tariff model with changing welfare weights. Section 3 illustrates a methodology for the estimation of breakeven rate. Section 4 devises the adult equivalent scale for water consumption in order to arrive at income and price elasticities using recoverability theory. Section 5 designs a tariff rate with equity based on Ramsey prices followed by a summary and conclusion in section 6.

II

2.1 Utility pricing : a review

The theory of pricing needs to be reviewed in order to identify the principles that are applicable to drinking water. Since the commodity under consideration, especially in the urban areas, is regarded as an entitlement at reasonable rates and cannot be distributed under normal market structure, it has the basic features of public utility. Recent World Development Report (1994) also substantiates this view by classifying piped water as a public utility. From this point of view, only public utility pricing needs to be surveyed.

Pricing according to the marginalist principle is the first best way of fixing the rate of a utility, which depends on the shape of the cost function. If the cost function is of the traditional U-shape, then the application of marginalist rule depends on whether the firm is facing a decreasing, constant or increasing cost condition. The marginalist rule is applicable, as is well known, in the case of constant and increasing cost condition even though the latter generates an economic surplus. If the cost is decreasing, the first best price incurs a loss and hence other pricing methods need to be devised. In the case of urban water supply one would expect a decreasing cost function since the capacity of the system is designed taking into consideration of the future expansion of the city and the population growth. In such situations, marginal principle will be applicable only with revenue constraint as conceived by Ramsey (1927) for an efficient rate structure.

To bring out the Ramsey pricing rule in terms of elasticity and its distributional and welfare effects in the case of water, Baumol and Bradford (1970) formulation is considered.

Consider a monopolist producing 'n' commodities, $x_1,..,x_n$ with prices $p_1,..,p_n$. Let the consumers' benefit function be $Z(p_1,..,p_n)$ and profit function be $\pi\ (p_1,..,p_n) = K$. When $K = 0$, the constraint satisfies the breakeven. The efficient set of prices that maximises consumers surplus subject to profit constraint is given by[3]

$$\max_{p_1,..,p_n,\ \lambda} \ L(p_1,..,p_n) = Z(p_1,..,p_n) + \lambda\{K-\pi\ (p_1,..,p_n)\} \quad ...\ (1)$$

where λ is the Lagrangean multiplier.

First order condition for (1) is

$$\delta Z/\delta p_i = \lambda\delta\ \pi/\delta p_i \qquad i = 1,..,n \qquad ...\ (2)$$

$$\pi\ (p_1,..,p_n) = K$$

Condition (2) implies that marginal benefit of the consumer is proportional to the marginal profit cost of the producer for all goods, where the constant of proportionality being the Lagrangean multiplier. In order to express this in terms of elasticity, the welfare gain should be related to price-quantity data for which Hicksian proposition is used. According to Hicks, the derivative of the benefit function with respect to price is equal to the negative of the quantity consumed before the price change[4].

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3 See for other versions of Ramsey pricing Brown and Sibley (1986): pp.39-41. and Wilson (1993): pp.101-102.

4 See Baumol and Bradford (1970): p. 269.

i.e. $\delta Z \backslash \delta p_i = - x_i \quad i = 1,..,n$ ... (3)

Taking the derivative of profit function,

$\delta\pi/\delta p_i = (MR_i - MC_i)\, dx_i/dp_i$ ... (4)

Assuming zero cross elasticity $MR_i = p_i + x_i \delta p_i/\delta x_i$ ... (5)

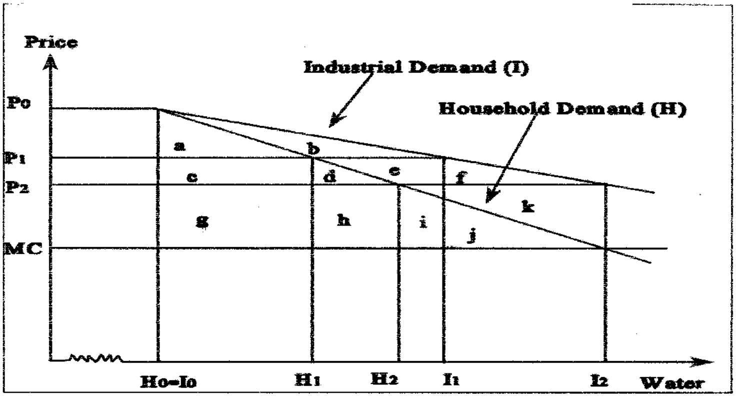
Substituting (3), (4) and (5) in (2) and rearranging the terms we have

$(p_i - MC_i)/p_i = \{(1+\lambda)/\lambda\}/\ \varepsilon_i = \alpha/\varepsilon_i$ i= 1,...,n ... (6)

where α is the Ramsey number which is equal to $\{(1+\lambda)/\lambda\}$, and ε_i is the own-price elasticity of 'ith' commodity. This is the famous second best pricing rule (Ramsey prices) for a natural monopoly. It implies that the mark-up should be proportional to the inverse of the price elasticity in order to obtain efficient set of prices[5].

But for a product like drinking water which has absolutely no substitute and is a basic necessity, Ramsey rates have serious distributional effects and efficiency aspects as demonstrated by the following diagram.

Fig. 1 Nonlinear Tariff and Welfare



5 See Baumol and Bradford (1970): . for three equivalent ways of stating the rule

For simplicity, consider the demand for water from household and industry sectors only. Obviously, the household demand is more inelastic than industrial demand since the industries respond more to a price change. In such a situation, a decrease in the price from p_0 to p_1 have different welfare gains to the consumers. More specifically consumer surplus reduces by the triangular region 'a' for household consumers whereas it reduces further by the area given by 'b' for industrial consumer. In other words, the psychic loss to the industrial user is much higher than that of the domestic user. But, Ramsey rule on the other hand suggests that a higher rate should be charged for household consumption than for industrial use. This poses a distributional problem in the sense that, the rate is low for consumers with higher ability to pay and vice versa. Hence the Ramsey prices need to be corrected for this undesirable distributional effects.

Since the demand for water per household is smaller than that of per industrial unit, a nonlinear price reduces the welfare of the former and increases that of the latter as shown in the diagram[6]. For this, consider the change from a breakeven, linear price p_1 to a nonlinear price, say, a two-part tariff. Two part tariff consist of a price p_2 plus an entry fee equal to $(p_1\text{-}p_2)I_1$. The gain of the large consumer is equal to the triangular area 'f' given in the diagram. The small consumer on the other hand looses to the tune of 'a' minus 'e'(a+c+d-c-d-e). The firm is also generating surplus to the tune of 'j' plus 'k'. Obviously the small consumer is worse off, and the large consumer and the firm are better off. If a menu of linear and nonlinear rates are given to the consumers, then the small consumer would opt for linear and the large consumer the non linear rate making everybody better off including the firm. The nonlinear price becomes acceptable to the small consumer, if a transfer

6 See Brown and Sibley (1986): p.69.

of surplus equivalent to the trapezoidal region 'e' is made from the large consumer or the firm or both to the small. However such a policy encourages conspicuous consumption if 'H1' represents the 'necessary' quantity required for the household. In such situations a nonlinear price encourages only increased consumption of a scarce commodity which needs conservation.

In addition to this water has become a scarce commodity due to population pressure, increased and rapid urbanisation, changes in technology of extraction, and other competing uses. This warrants the rate to be increasing with every increase in the consumption. For this, Ramsey prices needs to be modified using other welfare criteria as suggested by Wilson[7]. In effect, Wilson's model makes the Ramsey number dependent on the average welfare weights of those customers purchasing each unit. For this, the consumers are divided into two groups: one group consuming above a given quantity q^* and the other below it. The rates can be obtained by assigning '1' for quantities above q^* and '0' for below q^* for the Ramsey number[8]. This would mean that maximum welfare is assigned to small consumers, below q*, by charging a rate below the marginal cost and minimum or zero welfare for consumers of large quantities, above q*, by charging a monopoly price. The resulting rate is:

$$P = MC, \qquad \text{for small consumers } (q < q_{\ddagger}^{*} \text{ and } \alpha = 0); \quad \ldots (7)$$

$$= MC\,\{1/(1-1/\varepsilon)\} \text{ for large consumers } (q > q^{*} \text{ and } \alpha = 1);$$

This formula is implementable and sustainable only if the rate of the higher group is less than the cost of private arrangement.

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7 See Wilson (1993:p.107).

8 This is an extreme example of changing welfare weights. In principle any weight from 0 to 1 can be assigned in the tariff design.

In order to estimate this rate structure, we need the marginal cost and demand elasticities. Ideally one requires the cost function for deriving the marginal cost. But unavailability of data prevents us from estimating it. Hence we use the breakeven as a proxy for it. This is illustrated in the case of an urban water supply catering mainly to Thiruvananthapuram, the capital city of Kerala state, India for the year 1992.

III

3.1 Estimation of breakeven cost.

Breakeven cost of the system consists of three components: (i) variable cost; (ii) replacement cost; and (iii) other quasi-fixed cost. The details regarding the estimation of these three components are discussed below.

3.2 Total variable cost

The cost of supplying drinking water consists of expenses on production and distribution. The former includes cost of treatment, pumping and laboratory charges of raw and treated water. The latter includes maintenance of pumping mains and distribution network, and metering and allied activities[9]. However the following equation is used for the calculation of variable cost mainly due to limitations of data.

Total variable cost for year t (TVC_t) = $W_t + E_t + C_t + M_t$...(8)

where, W_t = wages and salaries of the employees;

E_t = cost of electricity for production and distribution;

C_t = cost of chemicals at destination; and

M_t = cost incurred for the maintenance, repair and upkeep of building and fixed capital.

9 See Clark and Stevis (1981): Murugan (1993) for details. Opportunity cost of water is assumed to be zero.

Since water from the scheme is used by both household and industrial consumers, the rate chargeable to household consumers should be based on that portion of the cost relating to their consumption. It is estimated that about 16 % of the total supply is being used for industrial and other activities[10]. Hence only 84% of the total variable cost in 1992 is taken for the analysis.

This portion of the total variable cost based on equation (8) is:

(a) TVC_{1992} = Rs. 109280800.

Now let us move on to the computation of the second component, replacement cost.

3.3 Replacement cost.

The annual replacement cost can be estimated if cost of fixed capital and the life span of the system are known. It should also include the interest payments if the funds are borrowed. In such situations the following methodology can be used.

Let I be the initial investment for the system with a life of 't' years. Total amount (A) that should be recovered during the life as principal and interest payment is:

$$A = I(1+r)^t$$

If the recovery of the amount is distributed uniformly over the life cycle, then annual recovery rate (R) is given by

$$R = A/t \qquad ...(9).$$

Equation (8) forms the basis for the calculation of replacement cost below.

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10 Tata Consulting Engineers (1992).

The water supply has two treatment plants; of which the life span of the first one is already over. Therefore investment on the second plant alone is considered here. Investment in plant II was completed in 1977 followed by a capacity addition in 1986. In addition to this a Dam for storage of water was also constructed in 1983. Life expectancy, according to engineering expectations, for both plants and dam is about fifty years. The amounts to be recovered as annual replacement cost after adjusting for inflation in 1992 from the investment in three different years are given below[11]:

(b) Annuity in 1992 from 1977 investment in plant = Rs. 2211672

(c) Annuity in 1992 from 1986 capacity addition = Rs. 1285693

(d) Annuity in 1992 from 1983 investment in dam = Rs. 2168700

(e) Total replacement cost [(b) + (c) + (d)] = Rs. 5666065

(f) Attributable replacement cost to household consumption {84% of (e)} = Rs. 4759495

This leaves us the estimation of any quasi-fixed cost related to household demand which is taken up next.

3.4 Quasi-fixed cost

Data on production cost contain expenses on administration and other related activities as a separate item. Since this cost is independent of the level of production, it is treated as quasi-fixed. The amount for the year 1992 is:

(g) Administrative (quasi-fixed) cost in 1992 = Rs. 3729463

(h) Attributable quasi-fixed cost {84% of (g)} = Rs. 3132749

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11 See Murugan (1993) for methodology.

The above three components can now be used for the calculation of breakeven rate for the system as shown below.

3.5 Breakeven rate

Breakeven rate for the year 1992 is obtained by dividing the sum of variable, replacement and quasi-fixed costs with the total production.

(i) Total cost {(a) + (f) + (h)} = Rs. 117173044

(j) Total annual production (Million Liters, ML) = 33883.1

(k) Breakeven rate [(i)/(j)] (Rs/ML) = 3458

The estimate indicates that a flat rate of Rs. 3.5 per Kiloliter would make the system run on breakeven. Let us examine the estimation of demand elasticities.

IV

4.1 Estimation of demand elasticity

The major difficulty in the estimation of demand function for water is that there exist hardly any time series data on quantity consumed, prices and income of the users. This is further aggravated due to infrequent changes in tariff rates arising from the unwillingness on the part of governments from time to time in the fear of eroding their popular support from the masses. Consequently there is very limited scope for estimating price elasticity from time series data. However income elasticity can be obtained from cross-sectional household survey, since enough variation exists in the income of the households and their demand. In such situations, Pollak and Wales (1978) have demonstrated that the price elasticity can be computed from as few as two cross- section surveys provided households face two distinct price situations[12]. This method is the only way left to obtain price elasticity when there is very little temporal variation of rates. This technique is exploited for the calculation of price elasticity as shown below.

4.2 Pollak and Wales method

4.2.1 Theory

The theory used in Pollak and Wales (henceforth, P-W) method is briefly reviewed in the case of Linear Expenditure System (LES). The expenditure function of the ith commodity under LES is given by:

$$p_i x_i = p_i b_i + a_i (M - \Sigma p_k b_k) \quad i=1,\ldots,n$$

where x_i = quantity of ith good consumed;

p_i = price of ith good; and

M = total expenditure on all goods.

It is to be noted that parameters, a and b, have a very special meaning in the allocation of income under this model. The model assumes that the consumer spends money for buying the 'necessary quantities', the b's, first and then allocates the remaining income among the goods in fixed proportion[13], the a's. In P-W method, a's are identified from the expenditure functions in a single period and the b's are obtained from the intersections of the two linear income consumption curves relating to two periods. The price elasticities are then calculated from the a's and b's. We use a variant of P-W method in the present case mainly due to data limitations. The method derives price elasticity from the expenditure function as shown below.

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12 See Pushpangadan (1984) for a generalised version of the model of Pollak and Wales.

13 See For details, Pollak and Wales (1978): p. 350.

Let the demand for drinking water be

$\ln x = a_0 + a_1 \ln p + a_2 \ln M$ ... (10)

Where x = quantity of water consumed

p = tariff rate of water

M = income of the household.

For a cross-section data (10) becomes

$\ln x = a_3 + a_2 \ln M$ ... (11)

It is clear from equations (10) and (11) that the intercept a_3 equals a_0 plus $a_1 \ln p$. The two unknowns, a_0 and a_1, are determined only if there are two equations which obviously require two cross section data from two time periods or data relating to two price situations in a single cross section. From the two samples, the following equations can be obtained.

$$a_0 + a_1 \ln p_1 = a_{31} \qquad \text{... (12)}$$

$$a_0 + a_1 \ln p_2 = a_{32} \qquad \text{... (13)}$$

where p_1 and p_2 are the prices facing the households, a_{31} and a_{32} are the estimates of intercepts in the expenditure functions from the two samples.

Subtracting (13) from (12),

$$a_1 = (a_{31}-a_{32})/(\ln p_1-\ln p_2) \qquad \text{... (14)}$$

Equation (14) gives the estimate of a_1, the price elasticity.

4.2.2 Estimation

Data

The estimation is based on a sample of 424 households, with metered connections from the urban system, drawn on the basis of stratified systematic sampling[14]. According to present tariff, the sample of households belongs to three consumption slabs: less than 10 Kiloliter per month (klpm); between 10 and 30 klpm; and greater than 30 klpm with corresponding rates of Rs. 1, 1.5 and 2 per kiloliter. The frequency distribution of the 424 households in the three slabs are: 21 in the first; 355 in the second; and 48 in the third. Since the households in the three sub-samples face three different prices, the P-W method becomes applicable in arriving at the elasticities. In addition to income and price effect, consumption depends on age and sex composition of the members in the households. Therefore, consumption has to be adjusted for this. In demand studies, two methods are used for overcoming this problem. In the first method, the effect is incorporated in the specification of the demand function through demographic variables. In the second method, the effect is taken out by expressing the demand variables on a per capita basis using adult equivalent scale (AES), since the consumption of an adult male is neither equal to that of an adult female nor that of a child. The second method is applied here which requires the construction of AES. AES for water is constructed using the simplest method suggested by Prais (1953), and Prais and Houthakker (1971) as follows.

Adult equivalent scale

The adult equivalent scale is obtained by expressing the consumption of each member of the household relative to that of an adult, usually male. The survey data contain total water consumed and the number of members in each household. Household size is further classified into adult male, adult female and children below the age of five years as well as between five and fifteen years. The children were grouped into two, mainly due to the change in the levels of their consumption. The first group, below five years, usually consumes lower

14 See Murugan (1993) for the details.

quantities than that of the second, since the former unlike the latter uses water mostly under the supervision of parents or other adult members. Besides, children are likely to be free from such control by the time they reach the age of more or less 15, especially females due to biological reasons. The average monthly consumption per person is secured from the corresponding figures of different household sizes using incremental method as presented in Table 1. For example, the average consumption of an adult male is obtained from subtracting the consumption of a household with one male and one female from that of a household with two males and one female. It is evident from Table 1 that the adult female consumes, on an average, the maximum amount of water.

Table 1: Adult equivalent scale for water

Household size		consumption (Klpm)		AES
		Per Household	Per Person	
(a)	1 male and 1 female	15.79		-
(b)	1 male, 1 female and 1 child < 5 years.	16.13		-
(c)	1 male, 1 female, 1 child < 5 years and 1 child 5 to 15 yrs.	16.79		
(d)	2 males and 1 female	18.53		-
(e)	1 male and 2 females	21.58		-
	Adult male [(d) - (a)]		2.74	2.74/5.79 = 0.47
	Adult female [(e) - (a)]		5.79	5.79/5.79 = 1
	Child < 5 years [(b) - (a)]		0.34	0.34/5.79 = 0.06
	Child 5 to 15 years [(c) - (b)]		0.66	0.66/5.79 = 0.11

Source: Sample Survey.

Since an adult female consumes the largest amount of water, it is taken as the numeraire for the calculation of AES. This gives the following scale: adult female = 1; adult male = 0.47; children (between the age of five and fifteen) = 0.11; and children (below the age of five) = 0.06. Let us compare AES of water with AES of food articles[15]. AES for food based on nutritional requirements is: adult male = 1; adult female = 0.92; and child below the age of fifteen = 0.52. It is interesting to note that, an adult female is equal to 0.92 of an adult male in food consumption whereas it is the other way round for water, i.e., an adult female requires twice the quantity of an adult male. This clearly indicates the inappropriateness of using AES of food for adjusting the household size effect in the demand for water. AES of water were utilised for measuring the per capita variables in the estimation of demand elasticities of water given below.

Elasticity

Application of P-W method to recover elasticities requires the expenditure functions. The functions were obtained by regressing per capita consumption on per capita floor area as a proxy for income[16]. The resulting elasticities for the three sub-samples are given in Table 2.

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15 AES of food articles, known as Amsterdam scale, is from Deaton and Muellbauer (1980): p.193.

16 Income, measured through direct method, is subject to a wide margin of error in the survey data. Hence total floor area of the household is taken to be a better proxy in order to minimise the errors in variables.

Table 2: Demand elasticities of drinking water

Size class (klpm)	Elasticity	
	Income	Price
<10	0.53	-.06
10 - 30	0.59	-.07
> 30	0.38	-.04

Source: Appendix A

The value of income elasticity clearly shows the essential nature of the commodity. Moreover the proportion of income spend on water is lower for the highest size class in the sample, a validation of Engel's law for water as well[17]. For price elasticity using P-W method, the expenditure functions with significant intercept terms were only considered. As a result, price elasticity has been estimated only for the size class, 10-30, by applying the formula given in equation (14). For the remaining two, lower and upper classes, we have utilised the proportionality between income and price elasticity implied in additive utility functions as shown by Deaton (1974). For n commodities under additive preference functions, this relationship becomes:

$$e_{ii} = \phi\, e_i \qquad i,...,n$$

where e_{ii} is the own-price elasticity, e_i is the income elasticity of the ith commodity and ϕ the constant of proportionality. In other words, if ϕ is known only one of the elasticities in a size class is needed to

17 This is valid since households with higher consumption are found to have higher per capita floor area.

obtain the other. This principle is applied for the calculation of price elasticities for the first and the last group of consumers using the constant of proportionality implied in the middle group. The estimates, given in Table 2, form the basis for tariff design with changing welfare weights.

V

Tariff structure

Rates are designed using a generalised version of Ramsey-Wilson model as given in equation (7) with varying welfare weights for different consumers. In this version we consider three groups of consumers with subsidy for the smallest group from the surplus generated in the highest group. The middle group is charged at the marginal cost. The resulting rate structure is given below.

Modified Ramsey-Wilson model

$$
\begin{aligned}
R &= MC - k/\varepsilon \qquad (q < q^*,\ \alpha = 0)\\
&= MC \qquad\qquad\ (q = q^*,\ \alpha = 0)\\
&= MC + 1/\varepsilon \qquad (q > q^*,\ \alpha = 1)
\end{aligned}
$$

Where k is the ratio of users in the two groups (lowest and highest) that distributes the surplus completely among the consumers.

This model is estimated for three groups of consumers for whom the elasticities are available in Table 2. Since MC is unknown, as mentioned earlier, breakeven is taken as a proxy. Consumers in the middle range (10 to 30 klpm) are charged at the breakeven, since they spend the largest proportion of their income among the three groups as evident from their income elasticities. This would suggest that a welfare weight of zero is assigned for the Ramsey number in equation (6). Consumers above the middle range (> 30 klpm) are charged the maximum rate by giving 'α' a value of unity. Obviously, the consumer in this group is charged the monopoly price extracting the maximum surplus. The resulting surplus is completely redistributed among the smaller quantity consumers (less than 10 klpm). Since the number of connections in both the groups are different a factor of proportion has been used for making the overall rate equal to breakeven. The tariff rate thus arrived at is given in Table 3.

Table 3: Tariff rates with varying welfare, 1992

Size Class (klpm)	Welfare weights	unit Rate (Rs/kl)	Block Rate (Rs/kl)
<10	$\alpha = 0$ with subsidy	1.7	9
10-30	$\alpha = 0$ only	3.5	70
>30	$\alpha = 1$	4.4	154

See: Appendix B

Under subsidy, the unit rate of the smallest size class has been reduced to almost half of the breakeven rate. Monopoly price charged to the largest quantity consumers comes about 26 percent more than the breakeven. Obviously the block rate penalises heavily the consumers of larger quantities. For example a monthly consumption of 31 kiloliter increases the block rate of the largest group by 120 per cent As a result this rate has high incentive to reduce consumption. Above all the rate structure satisfies overall breakeven along with increasing block tariff for conservation and equity. However the rate is not stable and sustainable if it is higher than the stand-alone cost as defined by Faulhaber (1975).

VI

Summary and conclusions.

Ramsey pricing with other welfare criteria as proposed by Wilson has been estimated for drinking water by a case study of an urban water supply system. Tariff rate based on the modified Ramsey rule requires the estimation of marginal cost of production and own- price elasticity of demand. The calculation of marginal cost is not possible due to unavailability of time series data on cost of production, input prices and output. Hence the breakeven cost is estimated and used as a proxy. In the case of demand elasticity the same data problems were confronted since no information is available on prices, quantity consumed and the level of income of the users. To overcome the paucity of time series data, Pollak and Wales method of estimating elasticities from as low as two cross section samples facing two price situations has been employed after adjusting for household composition effect. The adjustment of this effect is achieved by expressing demand variables on a per capita basis, which necessitates the construction of an adult equivalent scale (AES) specifically for water. The AES for water indicates that it is completely different from that of food articles.

Tariff rates with changing welfare weights have been designed for three categories of consumers: large, medium and small. A breakeven is charged to the middle group which assigns zero welfare weight. The rate for the largest group of consumers is the monopoly markup which assigns a welfare weight equal to one. The surplus generated is redistributed to the lowest group so that it satisfies not only the overall breakeven but also generates increasing rates for conservation of the resource.

One probable limitation of the rate structure is that it may not be sustainable if it exceeds the stand-alone cost. The three group model can be generalised to any number of groups by assigning different welfare weights ranging from zero to one.

Appendix A

Size class (klpm)	Expenditure function	
< 10	$\ln x = -1.692 + 0.531 \ln FA$ (0.63) (0.11)	$R^2 = 0.54$, n = 21 $F_{(1,19)} = 0.001$
10 - 30	$\ln x = -1.717 + 0.597 \ln FA$ (0.17) (0.029)	$R^2 = 0.54$, n = 355 $F_{(1,353)} = 0.001$
> 30	$\ln x = 0.223 + 0.373 \ln FA$ (0.35) (0.06)	$R^2 = 0.49$, n = 48 $F_{(1,46)} = 0.0001$

Where x = per capita consumption of water

FA = per capita floor area of the household.

Appendix B

The block rate is obtained by multiplying the mid-value of each size class with its corresponding unit rate. In the case of size class, greater than 30 Klpm, mid value is taken as 35 since the maximum consumption in this sample is 40 klpm. For the lowest class, it is taken as 5. The unit rate of the lowest class is calculated in order to achieve over all breakeven using the formula :

breakeven rate - [3.5 - (4.4-3.5) * 8649/4243],

where 8649 is the total number of connections in size classes (>30) and 4243 that in the lowest class.

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