Water Pricing Reform, Economic Welfare and Inequality

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ABSTRACT

Access to water has become an important policy goal in South Africa. A tariff system including free access for the basic residential water supply, and an increasing block tariff has been introduced all over the country. Water is a necessity, but for most households the marginal consumption is used for less important options. This must be reflected both in the water demand and in the pricing policy. This article introduces three different welfare functions, all including a group of rich consumers and a group of poor ones. The standard additive utility welfare, the weighted utility welfare and the Rawlsian welfare function are all used. For each of them the block tariff system is used to find the maximum welfare. We also discuss how the 'water for free' policy affects welfare, and how to set a low price segment or a free amount of water and the block tariff in each case. For each tariff system we also do comparative statistics of the parameters to study how changes in the policy approach will influence the optimal water tariff system. In conclusion the article explains how the choice of pricing policy can reflect the underlying welfare considerations.

JEL Q25, D63, H42

INTRODUCTION

In most countries, water pricing has been determined mainly on the basis of financial or accounting criteria. However, in recent times there has been growing emphasis on welfare economic considerations in order to produce and consume water efficiently, while conserving scarce resources, especially in developing countries. A great deal of attention has been paid to the use of marginal cost pricing policies in the water sector, where the World Bank has been one of the spokesmen for marginal cost pricing, eradication of subsidies and privatisation. Yet there are almost no applications of marginal cost pricing in the water sector. On the other hand, increasing block tariff (IBT) pricing structures are now the preferred tariff structure in developing countries. There are several reasons for this pricing policy. A minimum supply of water is part of the basic needs, and access to water is a main source of conflict in many areas. However, more important is the situation where water supply is an important political issue, linked to the problems of extreme income inequality in many developing countries. A system where the willingness to pay determines the distribution of fails to operate in an acceptable way if large parts of the population have inadequate money incomes to buy basic goods.

This situation is the background of this article that focuses on the distribution of residential water. Water for irrigation or manufacturing is not addressed. Increasing block tariffs in different forms are a mainstream approach to address problems of unequal income distribution. This article studies the welfare implications of this tariff system. The IBT system has been used as a measure to support fair access to water, but there appear to be very few studies of the welfare implications of this system.

A residential water pricing system can be used to promote a number of objectives or criteria. The objectives can be economic efficiency, equity and fairness (which includes fair allocation of costs, assurance of price stability and provision of a minimum level of service to meet the basic water needs of those who cannot afford the full cost). Criteria like revenue sufficiency, tariff structure simplicity and resource conservation can also be addressed.

Although equity is one of the generally recognised objectives, very few of the water demand studies reported in the literature discuss equity issues. Rietweld *et al.* (2000) conclude that a two-part pricing structure with a uniform price equal to the marginal cost of production, combined with a fixed access charge, would lead to an efficient allocation and that the IBT structure fails to achieve its aim of helping the poor in the case of Salatiga city in Indonesia. Renzetti (1992) finds that implementing a revenue constrained two-part price, which consists of a fixed charge to make up a deficit and a marginal price based on off-peak short-run and peak long-run marginal costs, results in an overall increase in welfare compared to average cost pricing. The starting premise for Renzetti, however was that marginal cost pricing will maximise social welfare. Eberhard (1999) also points out that Renzetti's method fails to analyse welfare distribution between households, a topic that is important in a developing country context.

The question of how the choice of welfare function influences the decisions on how to arrange the IBT system needs to be addressed. This brings ethics into the discussion of efficient and just water pricing tariff planning. Eberhardt (1999) reviews many other aspects of the discussion on water and welfare. The marginal cost of water supply will differ in the short and the long run, and there is no common understanding of which definition is suitable for purposes of analysis. This discussion follows later, for now it is assumed that water is supplied with a constant marginal cost. In an IBT, it is not defined how deficits of the water utility will be funded, and possible market distortions from the funding (like from a tax wedge) can influence the welfare analysis. This problem is also left for later. This does not indicate that these questions are unimportant but, the discussion will concentrate on the effects of the IBT, and to do so, the environment of the model must be made as simple as possible.

The organisation of the paper is as follows: the next section briefly describes the background on South Africa water policy and section three presents the basics for the models used. The fourth section demonstrates the welfare maximising policy suggested by three different welfare functions. Two sections subsequently discuss how the model results are influenced by different sets of assumptions. To conclude, a discussion of some possible policy recommendations from the analysis, follows.

THE SOUTH AFRICAN CONTEXT

South Africa's water resources are limited and, in global terms, scarce. South Africa's average rainfall (470 mm p.a.) is just over half of that of the world average. The situation is worsened by population growth and the demands of a vibrant economy, and compounded by inequities in allocation based largely on racial grounds and inefficiencies in use. Water resources in South Africa are not spread evenly across the country. The country suffers also from severe periodical droughts and floods. Most of the big cities and industrial centres of the country are situated far from big rivers, in several river catchments the water requirements exceed the natural availability of water. The available water resources are insufficient to meet projected demands at current usage and price levels within the next 30 years (DWAF, 1997b).

These water resource characteristics will exert a strong influence on the development of a water pricing policy in South Africa. South Africa is shifting from supply-side management to demand-side management and water pricing is playing a key role in managing the water resource in an equitable, efficient and environmentally sustainable manner. Water pricing can be used to assist in the allocation water between towards uses and users, to encourage the more efficient use of water and also promote the sustainability of the water resource. As stated in the 1997 White Paper:

There is a limit to the development of new dams and water transfers that we can afford or sustain. Our present use of water is often wasteful and inefficient and we do not get the benefits we should from the investments in our water. Water conservation may be a better investment than new dams. We will have to adopt such new approaches to water management if our aspirations for growth and development of our society in the 21st century are not to be held back as a result of limited water resources (DWAF, 1997a: 23).

With respect to water pricing and equity, the same paper submits:

It is important that the introduction of realistic pricing for water does not further penalise disadvantaged communities who were already penalised during the apartheid era. White communities were given a strong economic advantage under apartheid through access to cheap water, while economic development in black communities was restricted by a variety of factors, one of which was lack of access to affordable water. In the interests of equity and social justice, this aspect will have to be considered in the question of water pricing. The price to be levied for water reserved to meet basic needs must merit particular attention (DWAF, 1997a: 23).

The South African standard on a "basic" level of water supply, sufficient to promote healthy living, draws on the World Health Organisation standard of 25 litres per person per day. This is equivalent to about 6000 litres per household per month for a household of eight people. This volume of six kilolitres has been set as the basic target for all households in South Africa and government has decided to ensure that poor households are given a basic supply of water free of charge. There is no commonly accepted definition of poverty in South Africa and local governments will have an important role to play in defining local poverty indicators and identifying which households fall within the local definition (DWAF, 2001).

In 2002, a combination of rising block tariffs, often with a low rate for the first block, and targeted rebates to poor households is used in South Africa to provide pro-poor subsidies.

THE BASICS OF THE MODEL

We specify a model with three decision levels. *The local government* sets the rules for a *water utility*, which supplies water to *the consumers*. Since we analyse issues of equity, we concentrate on the short-run market for residential water consumption. The long-run investment decisions and the water consumption of agriculture and industry are beyond the scope of this study. We simplify the consumer group to two representative ones: One rich consumer, and one poor consumer. For many markets, including South Africa an Increasing Block Tariff (IBT) is used for pricing residential water consumption. To simplify, we use an IBT with two steps: A low price segment, and a high price segment.

The local government

The local government sets the rules for the water utility. First it specifies the welfare concept to be used for its policy. Second, it sets an objective for the management of the water utility. Third, it decides on the budget constraint for the water utility by setting the access fee for each consumer group and also the surplus/deficit restriction for the utility.

The social welfare function

Throughout the analysis we use the Marshallian consumer surplus (CS) (less the water bill) as a measure of utility for each consumer. However, since each consumer pays an access fee, this must also be deducted from the CS. We specify three main approaches to welfare, the utilitarian, the weighted utilitarian and the Rawlsian approaches. The local government must decide on which one of them to use for their water policy.

Utilitarianism

Utilitarianism originated in the writings of David Hume and Jeremy Bentham and found its most complete expression in John Stuart Mill's writings. Classical utilitarianism declares that society's welfare should be represented as the sum of the utilities of different individuals. Utilitarianism makes use of a social welfare function that measure social welfare, W. The objective of a social decision maker (if one were to exist) should be to maximise W (Perman, Ma, McGilvray, 1996: 30). An egalitarian additive utilitarian social welfare function is specified as

$$W = U^p + U^r, \tag{1}$$

where U^p and U^r denote the utility of the poor group and the rich group respectively. Sub or superscript p is used throughout the paper, for the poor group and r for the rich group.

Weighted utilitarianism

The utilitarian social welfare function is a special case of a weighted utilitarian social welfare function where the individual weights are equal. The weights determine the relative importance attached to individual utilities in determining social welfare, and must be set by the local government. The distributional weight appropriate for any one member of a group is the same as the weight of every other member of the same group. The weighted utilitarian social welfare function is an additive function of individual utilities, so that

$$W = aU^p + (1\text{-}a)U^r, \quad (2)$$

where a and (1-a) denote the weights used in summing individual utilities to an aggregate measure of welfare (Perman, Ma, McGilvray, 1996: 30).

Rawlsianism

Rawls' objection to the ethic of classical utilitarianism is based in the claim that:

> *By being indifferent to the distribution of satisfaction between individuals (and only being concerned with the magnitude of the sum of the utilities), a distribution of resources produced by maximising utility could violate fundamental freedoms and rights which are inherently worthy of protection* (Perman, Ma, McGilvray, 1996: 34).

Rawls asserts that if people had to choose principles of justice from behind a "veil of ignorance" that restricted what they could know of their own position in society, they would not seek to maximise overall utility. Instead they would safeguard them against the worst possible outcome, first, by insisting on the maximum amount of liberty compatible with the like liberty of others; and second, by requiring that wealth is distributed so as to make the worst-off members of the society as well-off as possible (the so-called Difference Principle): "[S]ocial and economic inequalities are to be arranged so that they are both (a) reasonably expected to be to everyone's advantage, and (b) attached to positions and offices open to all" (Rawls, 1992: 60).

Economists frequently attempt to infer what the Difference Principle would imply for the nature of a social welfare function (SWF). Solow argues (Perman, Ma, McGilvray, 1996: 35) that a Rawlsian SWF for a society of individuals at one point in time is of the so-called max-min form, which for two individuals would be

$$W = \min \{U^p, U^r\}. \quad (3)$$

The residential water demand

Consumers are the final users of water. This study concentrates on residential water demand, i.e. demand for general consumption in the households. Hewitt (2000: 265) suggests that we can break down household demand for water into indoor and outdoor uses. It is also generally argued that internal water uses (washing, drinking etc.) are inelastic to changes in water tariffs relative to external uses (car washing, lawn sprinkling, gardening etc.). Indoor uses are collectively known as basic needs/requirements or hygiene uses, while outdoor uses can be collectively termed recreational uses. Munasinghe (1992: 253) argues that "... many poor communities already consume only the bare minimum volume for basic human needs and would not be able to cut back on consumption to any appreciable extent."

Is price elasticity a function of household income? Table 1 shows some empirical findings, mainly from developed economies.

Table 1 The price elasticity of demand for total short-run water use in various international studies

Researcher/s	Year	Location	Price elasticity
Carver and Boland	1969	Washington D.C.	-0,1
Agthee and Billings	1974	Tucson, Arizona	-0,18
Martin et al	1976	Tucson, Arizona	-0,26
Hanke and de Mare	1971	**Malmö, Sweden**	-0,15
Boistard	1985	France	-0,17
Thomas and Syme	1979	Perth, Australia	-0,18
Veck and Bill	1998	Alberton & Thokoza, South Africa	-0,17

Veck and Bill (2000)

A study of Renwick (1996) estimated price elasticities of -0,53 for low-income, -0,21 for middle income and -0,11 for high-income groups, i.e. the lower the income, the more elastic the demand curve. Veck and Bill (2000) reported estimates from South Africa as shown in Table 2. We have to keep in mind that demand elasticities from the developed world are only of limited use because the consumers represent only the wealthier end of the consumer range, Munasinghe (1992: 253).

Table 2 The price elasticity of demand (PED) for indoor and outdoor water use grouped by income

Description of group	PED Indoors	PED Outdoors	PED Total
Upper income group	-0,14	-0,47	-0,19
Middle income group	-0,12	-0,46	-0,17
Low income group	-0,14	-0,19	-0,14

Veck and Bill (2000)

We observe that outdoor water use in upper and middle income groups is more elastic in demand than the rest of the consumption. To model this in our study, we split the consumer in two typical groups, the *rich* and the *poor*. In our theoretical approach we apply this by assuming the demand from the rich group as larger and with a less steep slope of the demand curve. In some cases this is modified this by assuming that both groups of consumers have the same marginal willingness to pay for the first litre consumed.

The short-run demand structure

A short-run partial equilibrium model is used, with the price of water the only variable affecting domestic water demand. One rich and one poor consumer represent the two groups, and they are both considered as single rational decision-making units; both are utility maximising and have a finite budget. Both utility functions are quadratic, which generate linear demand curves. Following the above discussion, we assume that the demand curve of the poor consumer is more price inelastic than the demand curve of the rich household, and of course the demand of the poor consumer is smaller than for the rich one of any price of water. Each of the two households has its own metered connection. This assumption rules out the problem of indirect purchasing.

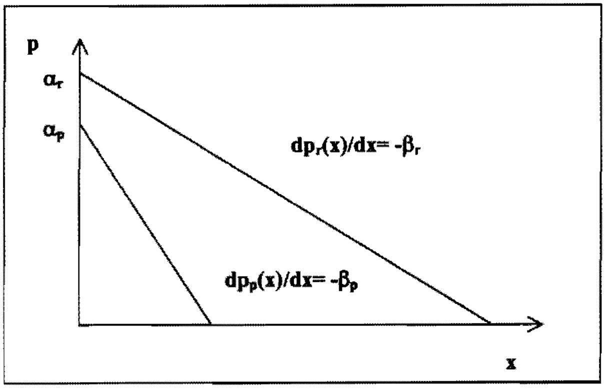
Based on our assumptions we can specify two inverse demand functions, both linear:

$$p_i\,(x_i) = \alpha_i - \beta_i x_i, \qquad i = p, r, \tag{4}$$

denoting p_i for the price and x_i for the quantity consumed.

We assume that $\alpha_p \leq \alpha_r$, and $\beta_p > \beta_r$. If so, the demand curve of the poor is always below the one of the rich, and its slope is steeper. We shall later study specifically the situation with $\alpha_p = \alpha_r$. Figure 1 shows the demand curves for the two groups of the households.

Figure 1 The demand curves of the two groups



The supply of water

Water is supplied by a water utility. The utility supplies water at constant marginal costs, c, and an additional fixed cost, f. Both seem reasonable for the short-run supply. The utility's production objective (set by the local government) is to maximise welfare, for a specified budget constraint, and a fixed monthly access fee for each group – also set by the local government. We assume that the utility has full information of the demand structure of each group. The water utility uses a two-step increasing block tariff pricing (IBT) where the first block is given to the households at a low price (lower than the marginal cost of supplying water), while the price of the second block is set to satisfy the budget constraint for the water utility. The two-step increasing block tariff pricing implicates that water utility on the margin can price discriminate between the two households. This means that the water utility must be able to prevent arbitrage among them.

The consumption in the first block is charged with a per unit price that is lower than the marginal cost while the per-unit price of the second block is set to fulfil the budget constraint. The structure is combined with a non-use component: a fixed monthly charge, a tariff for the privilege of having water on tap, i.e. an "assurance of supply" charge. The income these tariffs generate supports the fixed cost of water supply. The fixed tariff of the poor household group is lower than the one of the rich because the fixed tariff is based on level of income. We concentrate on the situation where the poor group is restricted by the price step and consumes exactly the low-priced quantity, X.

THE THREE APPROACHES TO WELFARE APPLIED FOR THE WATER MARKET

Three different welfare concepts, utilitarian, weighted utilitarian or Rawlsian may be used. First, we study the difference in the optimal solution due to the choice of welfare approach.

In the following sections the welfare-maximising IBT water pricing structures, the related optimal solutions generated by these three different welfare approaches and their characteristics are discussed. The study commences with the utilitarian social welfare function, followed by the weighted utilitarian and Rawlsian social welfare functions.

The utilitarian social welfare function

The utilitarian social welfare function used here maximises the sum of the consumer surpluses of the two household groups. The water utility is not concernned about the distribution of the water between the two groups. On the other hand, one of the very objectives of increasing block tariff pricing is to redistribute water from the rich to the poor.

The question is: how will the water utility distribute the water and what kind of an IBT water pricing structure will be used, if the utalitarian social welfare function is maximised? The maximisation problem of the utility can be written as follows, by using the welfare function (1) and substituting for the market demand from equation (4):

$$\begin{aligned} \max_{X,p1,p2} W^U &= CS_p - t_p + CS_r - t_r = \int_0^X (\alpha_p - \beta_p x - p_1)dx - t_p + \\ &\quad \int_0^{x_r} (\alpha_r - \beta_r x)dx - p_2 x_r + (p_2 - p_1)X - t_r \\ &= \alpha_p X - \beta_p X^2/2 - p_1 X - t_p + (\alpha_r - p_2)^2/2\beta_r + (p_2 - p_1)X - t_r, \end{aligned} \tag{5}$$

with the budget constraint written as:

$$(p_2 - c)[(\alpha_r - p_2)/\beta_r - X] + (t_p + t_r) - f - 2(c - p_1)X - m = 0. \tag{6}$$

The notation used is:

X = the size of the first block
x_r = $(\alpha_r - p_2)/\beta_r$ = the demand of the rich household group when the price is p_2
p_1 = the per unit price in the first block
p_2 = the per unit price in the second block
t_p = the fixed charge for the poor household group

t_r = the fixed charge for the rich household group
c = the marginal cost
f = fixed costs
m = surplus requirement for the water utility (net budget allocation from the government for the water supply).

For convenience, the surplus for the lump-sum transfers *to* the utility, s, is set as:

$$(t_p + t_r) - f - m = s. \tag{7}$$

These assumptions and notation are also used in the cases of Weighted Utilitarian and Rawlsian social welfare functions.

Solving this problem yields, the first-order conditions for maximum welfare are

$$p_2^U = c \tag{8}$$

$$\Rightarrow \quad x_r = (\alpha_r - c)/\beta_r, \tag{9}$$
$$X^U = x_p = (\alpha_p - c)/\beta_p \tag{10}$$
$$p_1^U = c - s/2X = c - s\beta_p/2(\alpha_p - c). \tag{11}$$

It is not obvious that $p_1 \leq p_2$. However[1], it is assumed that $p_1 \leq p_2$ and also that $t_i < (\alpha - p_i)^2/2\beta_i$. A non-negative s, which means a non-negative net lump-sum cash flow to the water utility, yields $p_1 \leq p_2$.

It is concluded that marginal cost pricing is always optimal for the rich group, while the price of the first step $p_1 < p_2$ for $s > 0$. The optimal solution is found where the marginal utilities for both groups are equal to the per unit price of water. For $s = 0$, both groups shall pay the same price, which in turn is equal to the marginal cost. It follows that in this case the per unit prices in both blocks are the same, and the IBT pricing structure is converted to marginal cost pricing. Welfare maximum will then be

$$W^U = (\alpha_p - c)^2/2\beta_p - t_p + (\alpha_r - c)^2/2\beta_r - t_r, \tag{12}$$

while x_p and x_r are unaffected.

The weighted utilitarian welfare function

Now, let the water utility set different distributional weights for the consumer surpluses in its social welfare function. Social welfare is defined as a weighted sum of the consumer surpluses. The distributional weights express the relative social values of increases in the water use. The distributional weight appropriate for any one member of a group is the same as the weight of every other member of the same group. In the case of unitary weights, the same optimal solution as in the case of the utilitarian welfare function is obtained. Again, we have simplified with two consumers. If the water utility gives a distributional weight equal to zero to the rich household and a weight equal to unity to the poor, we turn to the Rawlsian social welfare function studied in the next section. We assume that the decision-maker has a larger distributional weight for the consumer surplus of the poor than for the one of the rich, and neither of the distributional weights equals zero. The sum of the distributional weights is equal to unity,

$$1 > a > 1 - a > 0 \qquad \Rightarrow 1 > a > 0.5, \tag{13}$$

where

a = the distributional weight of the poor household
1 - a = the distributional weight of the rich household.

Now, the maximising problem of the water utility can be written as

$$\max_{X,\, p1,\, p2} W^W = a(\alpha_p X - \tfrac{1}{2}\beta_p X^2 - p_1 X - t_p) + (1-a)[(\alpha_r - p_2)^2/2\beta_r + (p_2 - p_1)X - t_r] \tag{14}$$

and the equations (6) and (7) still constitute the budget constraint. However, for simplification, it is assumed that s = 0. Maximum welfare is similar to the utilitarian case, and the first order conditions yield

$$X = 0 \text{ or } \lambda = -\tfrac{1}{2}, \qquad \text{and for } X > 0, \tag{15}$$

$$\begin{aligned} p_1{}^W = \{&(2a-1)[2a^2\alpha_p{}^2 - [[(2a-1)^3\alpha_r - 8a^2(a-1)\alpha_p] + (6a^2-6a+1)c]c]\beta_r{}^2 \\ &-4a^2[(2a-1)\alpha_p\alpha_r + [(4a^2-2a-1)\alpha_p - 2a(2a-1)\alpha_r - 2ac]c]\beta_p\beta_r \\ &+[2a^2(2a-1)(\alpha_r-c)^2]\,\beta_p{}^2\} \,/ \\ &\{[(2a-1)^2\beta_r - 4a^2\beta_p][4a^2\alpha_p - (2a-1)^2\alpha_r - (4a-1)c]\,\beta_r\} \end{aligned} \tag{16}$$

$$p_2{}^W = [(2a-1)(2a\alpha_p - c)\beta_r - 2a\beta_p((2a-1)\alpha_r + c)] / ((2a-1)^2\beta_r - 4a^2\beta_p) \tag{17}$$

$$X^W = x_p = [(2a-1)^2\alpha_r - 4a^2\alpha_p + (4a-1)c] / [(2a-1)^2\beta_r - 4a^2\beta_p]. \tag{18}$$

Maximum welfare in the case of the weighted utilitarian social welfare function. However, this supplies hardly any information.

The Rawlsian social welfare function

Now we turn to a Rawlsian welfare function. Rawls' 'Difference Principle' states: "[S]ocial and economic inequalities are to be arranged so that they are both (a) reasonably expected to be to everyone's advantage and (b) attached to positions and offices and open to all." (Rawls, 1971: 60). In other words, an unequal distribution is only just if all persons benefit from the allocation. In this case, it means that the water utility's welfare maximisation problem is reduced to maximising the consumer surplus of the poor. The welfare maximising problem of the water utility can thus be written as

$$\max_{X,\, p_1,\, p_2} [CS_p - t_p] = \alpha_p X - \tfrac{1}{2}\beta_p X^2 - p_1 X - t_p, \tag{19}$$

still with the budget constraint of (6) and (7), and s = 0. Solving the maximisation problem yields the first order conditions (for X > 0),

$$p_1^R = [(2\alpha_p^2 - (\alpha_r + c)c)\beta_r - 4\beta_p(\alpha_p\alpha_r + (3\alpha_p - 2\alpha_r - 2c)c) + 2\beta_p^2(\alpha_r - c)^2/\beta_r] \,/\, [(\beta_r - 4\beta_p)(4\alpha_p - \alpha_r - 3c)] \tag{20}$$

$$p_2^R = [(2\alpha_p - c)\beta_r - 2\beta_p(\alpha_r + c)] \,/\, (\beta_r - 4\beta_p), \tag{21}$$

and the optimal size of the first block is

$$X^R = (\alpha_r - 4\alpha_p + 3c)/\, (\beta_r - 4\beta_p). \tag{22}$$

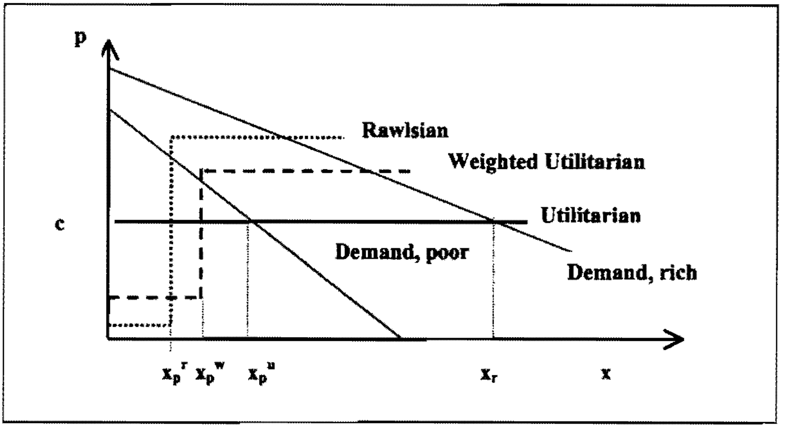
The welfare maximum will be

$$W^R = [2c^2 + 4\alpha_p^2 + 2\alpha_r c - 6\alpha_p c - 2\alpha_p\alpha_r + \beta_p(\alpha_r - c)^2/\beta r] \,/\, 2(4\beta_p - \beta_r) - t_p. \tag{23}$$

COMPARING THE INCREASING BLOCK TARIFF (IBT) PRICE STRUCTURES

Next, the three different welfare maximising IBT water pricing structures may be compared and differences between them discussed. Subscript U is used to notate the utilitarian, W the weighted utilitarian and R the Rawlsian case. It is possible to demonstrate (see Appendix) that the IBT structure for the three approaches will be as in Figure 2. The utilitarian case has a similar price for both steps, the Rawlsian a relatively small first step volume, combined with a low price and a large price difference to the second step, and the weighted utilitarian approach is in between these two extremes.

Figure 2 The optimal increasing block tariff for three welfare specifications



The quantity of water consumed by the poor group is largest in the pure utilitarian case. For the two other cases, the water utility sets the per unit price in the first block lower than the marginal cost. Observe how both the size of the low price segment and the price step differs for the three regimes.

THE COMPARATIVE STATICS OF THE MODEL

Now we turn to comparative statistics of the model. We want to find the effect of shifts in the parameters of the model, and how they will influence the endogenous variables in the different regimes. For this purpose it is convenient to simplify the model by setting $\alpha_p = \alpha_r = \alpha$, and $s = 0$. The four parameters: β_p, β_r, c and a can be shifted. Decreased β_p while α is constant, renders the demand curve of the poor more elastic, while the demand also increases. This can reflect a situation with better access to water for more than basic consumption, like a switch from bulk supply or a communal tap to an indoor tap. Decreased β_r means that the demand of the rich group is more elastic and increased, which can reflect that the rich group has easier access to outdoor use of water. The effect of increased c reflects higher marginal costs for the water utility, like a new pipeline system with higher maintenance costs per unit of water delivered, and funded by the utility. Increased a reflects a higher degree of redistribution by use of the water market. A justification of the assumption of equal α for both groups can be that this will reflect that the willingness to pay for the basic delivery of water is equal for both groups. The calculations are reported in the Appendix, and figures 3 to 6. We denote USWF for the utilitarian case, WUSWF for the weighted utilitarian case, and RSWF for the Rawlsian case.

Figure 3 The effect on the IBT price structure from increased price elasticity of the demand of the poor consumer group

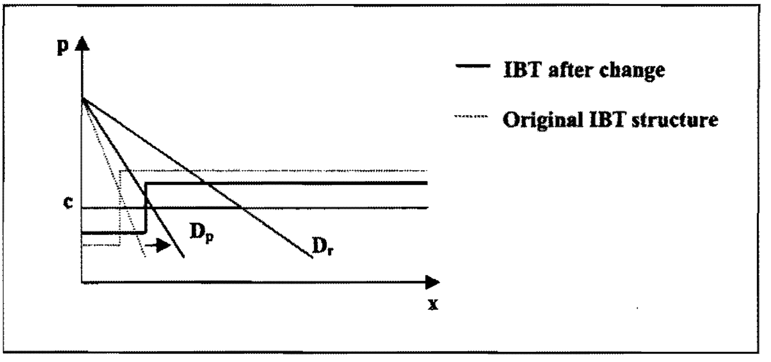
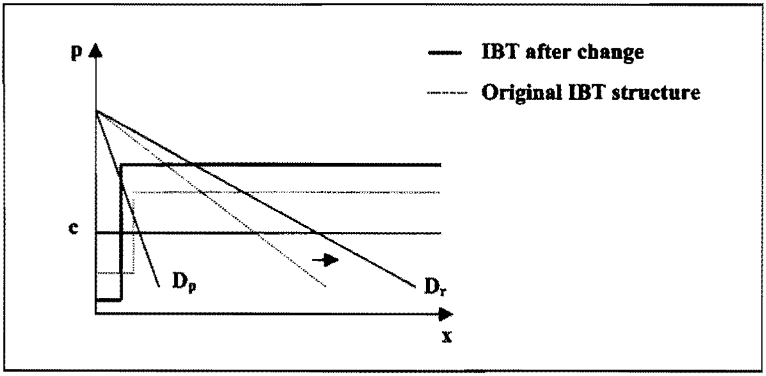


Figure 3 demonstrates that for both the WUSWF and the RSWF, the low-price segment will increase while the price difference between the two steps decreases for a more elastic demand of the poor. We also observe that the price of the first segment increases. The standard USWF is of course unaffected, since there is no price difference in this case. However, the increased demand of the poor will results in a larger total consumption.

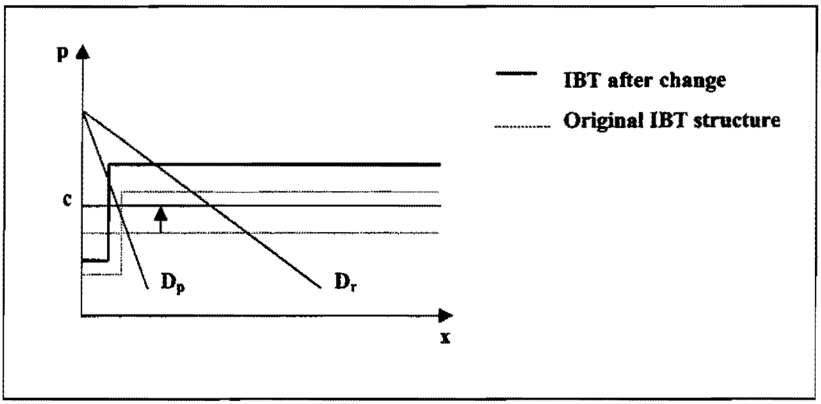
Turning to the case of a more elastic demand for the rich group, it can be seen from Figure 4 that the effects are now opposite to those of the former case. A smaller and cheaper first step is the result, while the second step is priced higher. Still, the results are only valid for the WUSWF and the RSWF case.

Figure 4 The effect on the IBT price structure from increased price elasticity of the demand of the rich consumer group



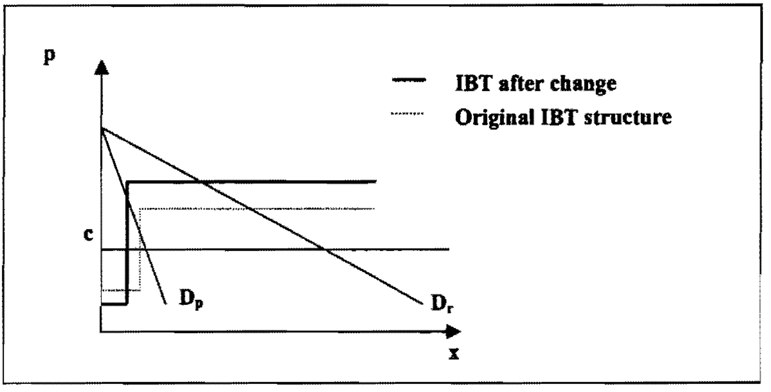
Increased marginal costs are demonstrated in Figure 5. The first step is more restricted, and the price of both steps increases. Increased c restricts the option for redistribution. The increased c works this way for the WUSWF and RSWF cases, while for the USWF the price and the consumption are restricted for both consumers.

Figure 5 The effect on the welfare optimising IBT pricing structure of increased marginal costs of supply



In the weighted utilitarian social welfare function we can also increase the distributional weight of the poor consumer, a. If so we are moving towards the Rawlsian situation. Not surprising, the price difference between the steps increases, while both the volume and the price of the first step decrease. In some way we can say that the subsidy to the poor is concentrated, as shown in Figure 6.

Figure 6 The effect on the welfare optimising IBT water pricing structure of increased distributional weight of the poor consumer group



The budget constraint of the water utility

As reported earlier, the budget restriction set to the water utility is important for the price of the first block. The important variable to study this effect is $s = t_p+t_r-f-m$, which is the net lump sum transfer *to* the utility, i.e. the allowed deficit for its running operations. If the fixed costs, f , and the surplus claimed by the local government, m, exceed the access fees, the water utility is running a deficit. For the Utilitarian case it was found that

$$p_1^U = c - s/2X = c - s\beta_p/2(\alpha_p - c), \qquad 24$$

which implies that for a negative s, the price of the first block must be higher than for the second one. A negative s reflects a situation where the water utility must support the budget of the local government more than what it recovers from its net lump sum income less its constant costs. It will always be preferable for the utility to recover the money by use of increased access fees. If funded from sales, in this case the first segment of consumption shall be most expensive, $p_1>p_2$. This means that a local government, when requesting the water utility to support the local budget, also compels the utility to charge the poor more than the rich for water. However, this may force consumers in the poor group out of the formal market.

This model may be used to study the effect of changes in s in the other two cases as well. To emphasise these effects, the demand side is simplified by setting $\alpha_p = \alpha_r = \alpha > c$. It is also assumed that t_p and t_r are both constant[2], and an increased s is interpreted as a smaller surplus claim set on the water utility. The calculations are reported in the Appendix. Solving the models for this case does not change the optimal size of p_2 and X. However, the price of the first block, p_1, will decrease for increased s in both the Weighted Utilitarian and the Rawlsian case. It is concluded that, if the local government wants to fund its budget from a surplus from the water utility, the utility will react by increasing the price of the low tariff block.

DISCUSSION AND POLICY IMPLICATIONS

This study offers some quite straightforward results for how the water utility will react to outside shifts, while maintaining its policy of maximising the aggregated welfare of households. The Utilitarian approach to welfare allows limited scope for a policy of redistribution. This welfare function attaches equal welfare value to each rand spent, and this is reflected in the reactions of the water utility. On the other hand, the Weighted Utilitarian approach to welfare sets a higher value to the consumer surplus of the poor group. This reflects their higher marginal welfare from increased water consumption compared to the rich group, and also the inequity in income distribution. The Rawlsian approach emphasises the poor group, but even in this case the water utility must remain within its budget constraint, and ensure that water must be sold to its consumers.

Some important policy implications arise from this analysis. First, using the Utilitarian approach has demonstrated that this approach always yields marginal cost pricing as the optimal solution for all consumers. The first step pricing is only adjusted for lump sum transfers needed to cover fixed costs, or to distribute lump sum transfers. This supports the mainstream rules of thumb for this approach to welfare analysis. The Utilitarian approach is mainly a focus on efficiency in the water supply, while redistribution and equity are not addressed.

The two other approaches yield more detailed policy implications. Figure 2 reveals that both the size of the first step quantity and the price difference between the two steps are influenced by the choice of welfare approach. The Rawlsian approach leads to a small low cost quantity, and a big price step, while the Weighted Utilitarian approach is somewhere between the other two. The policy of an 'increasing block tariff' is supported by the analysis as a welfare-improving way of water distribution. although 'water for free' is usually not the best policy – it is generally better to have a positive price in both segments – it is possible to include a free quantity by using a welfare function with strong emphasis on a small, extremely necessary supply of water.

Marginal costs for the aggregated supply is an important part of the factors deciding the price set to the rich consumers for all three approaches. This opposes 'historical costs' as a main decision rule for the supply of water. In the long run, all variable costs shall be included for *all* consumers. Increased variable costs due to increased supply will affect all consumers equally in the short run, and not only the new participants in the market.

This study allows an evaluation of the effects of a strong emphasis on poor households. Figure 6 shows that this will lead to an increased price for the rich consumer, and that this policy is supported by economic welfare considerations. Government must remain aware of changes in the demand structure. Better access to piped water through private taps will probably increase the use of appliances for the poor consumer, and this will influence the pricing policy of the water utility. A less steep demand curve for the poor implies less price discrimination between the two steps, while the volume of the low price segment will increase. Alternatively, a more elastic demand for the rich consumer will be reflected in a more discriminating price policy towards this group.

Knowledge of the demand structure of the groups of consumers is essential to model the optimal market policy of the water utility. It is not enough to know the cost structure of the water supply; the demand side must also be considered. The lack of data on the consumer demand structure poses a significant problem for the government.

It seems dangerous to allow the local communities to run the water utilities with a surplus. There are two reasons for this: first, an access fee can keep the poor group out of the market for water. Second, the price of the first block is a major way of funding lump sum transfers, and if the surplus requirement of the water utility is large, this will undermine the low price for the first segment.

The discussion focussed on the marketing of residential water for a water utility. The emphasis was mainly on short run effects, where the fixed investments are more or less sunk costs. The model can also supply arguments for a discussion on how to fund the fixed investment costs. The welfare distortional loss from governmental funding must be compared to the loss from funding the investment cost from the revenue of the water utility. The conclusions build on many simplifying assumptions. Further developments become possible by relaxing one or more of the assumptions. Increasing marginal costs, instead of constant marginal costs may be used. It was assumed that the poor group only consumes exact the low priced quantity. The lump sum transfers were simplified. The access fee of the poor group, t_p, may exclude them from the market, and a discussion of this is required. In the last part of the paper, demand curves were used, where the marginal willingness to pay for the first litre of water is equal for both groups. This is a fruitful simplification, but other assumptions can also be discussed. The demand structure of the two groups can be more realistically modelled. The linear demand curves approach demonstrates that the demand structure is important for the re-distributional effect of the water market. Only two groups and two different price steps were included. This probably illustrates the principles, while a multiple step approach probably is better for practical water management. And, of course, the different welfare functions can be used. The three used in this study demonstrate that welfare considerations are important for a water pricing system, and this is on its own warrants further discussion.

ENDNOTES

1 $p_1 > p_2$ if $s < 0$, i.e. if the sum of the lump sum transfers to the utility is negative. If so the first step quantity is priced higher than the second step, which is unrealistic for our discussion. The restriction to t_i is to ensure a positive consumer surplus (and hence a positive water consumption of each group).

2 It is obvious that an easy way to support the poor is by way of a lump sum transfer. Decreased t_p will work this way, and a negative t_p will work as a pure transfer to the poor.

APPENDIX

Solving the maximum problem of equation (5) (the utilitarian case) with the budget constraint (6) is easily done by use of the Lagrangian:

$$L = \alpha_p X - \tfrac{1}{2}\beta_p X^2 - p_1 X - t_p + (\alpha_r - p_2)^2/2\beta_r + (p_2 - p_1)X - t_r - \lambda\{(p_2 - c)[(\alpha_r - p_2)/\beta_r - X] + (t_p + t_r) - f - 2(c - p_1)X - s\}. \tag{A1}$$

The variable λ denotes the Lagrangian multiplier. The maximisation yields either $X = 0$ or $\lambda = -1$. For $X = 0$ the maximisation problem collapses to a one-price budget constrained delivery, and we assume $X > 0$. If so, the first-order conditions for maximum welfare are found as

$$p_2^U = c \tag{8}$$
$$\Rightarrow \quad x_r = (\alpha_r - c)/\beta_r, \tag{9}$$
$$X^U = x_p = (\alpha_p - c)/\beta_p \tag{10}$$
$$p_1^U = c - s/2X = c - s\beta_p/2(\alpha_p - c) \tag{11}$$

Setting s = 0 and substituting the results into equation (5) yields

$$W^U = (\alpha_p - c)^2/2\beta_p - t_p + (\alpha_r - c)^2/2\beta_r - t_r. \tag{12}$$

The variables x_p and x_r are unaffected.

The same exercise conducted for the Weighted Utilitarian case, maximising equation (14) with the budget constraint (6) is done the same way as above, but setting s = 0 yields the results of the equations (15) – (18). So also for the Rawlsian case, as shown in the equations (20) – (23).

To compare the prices and the volume of the first step in each case we start by comparing the price of the first block. We find from the equations (18) and (22):

$$X^W - X^R = \{4(3a-1)(a-1)[\beta_r(\alpha_p-c)-\beta_p(\alpha_r-c)]\} / \{[(2a-1)^2\beta_r-4a^2\beta_p](\beta_r-4\beta_p)\}>0 \quad \Rightarrow X^W > X^R. \tag{A2}$$

We find from the equations (10) and (18):

$$X^W - X^U = [(2a-1)^2)(\beta_r(\alpha_p-c) - \beta_p(\alpha_r - c))] / \{[(2a-1)^2\beta_r-4a^2\beta_p)]\beta_p\} < 0 \quad \Rightarrow X^W < X^U. \tag{A3}$$

We conclude that the quantity of water consumed by the poor group is largest in the pure utilitarian case, and it is smallest in the Rawlsian case.

To compare the prices of the first block, we first find from the equations (11) and (20)

$$p_1^R - p_1^U = p_1^R - c = [2(\beta_r(\alpha_p - c) - \beta_p(\alpha_r - c))^2] / [(4\beta_p - \beta_r)(\alpha_r - 4\alpha_p + 3c)]\beta_r < 0 \qquad \text{(A4)}$$
$$\Rightarrow \; p_1^R < c$$

if $4\alpha_p - \alpha_r - 3c > 0$, which must be fulfilled for X_r^* to be positive.

To find the difference between p_1^R and p_1^W we use the results for the second block. First we find by use of the equations (17) and (21):

$$p_2^W - p_2^R = \{2(a-1)[4a\beta_p + \beta_r(2a-1)][\beta_p(\alpha_r - c) - \beta_r(\alpha_p - c)]\} / \{[(2a-1)^2\beta_r - 4a^2\beta_p](\beta_r - 4\beta_p)\} < 0 \qquad \text{(A5)}$$
$$\Rightarrow p_2^W < p_2^R$$

The difference $(p_2^W - p_2^U)$ is found by use of the equations (8) and (17)

$$p_2^W - p_2^U = p_2^W - c = \{2a(2a-1)[\beta_r(\alpha_p - c) - \beta_p(\alpha_r - c)]\} / \{[(2a-1)^2\beta_r - 4a^2\beta_p](\beta_r - 4\beta_p)\} > 0$$
$$\Rightarrow p_2^W > c. \qquad \text{(A6)}$$

As $p_2^R > p_2^W$, we conclude that $p_2^R > c$. To compare the optimal per unit prices in the first block in the cases of the Rawlsian and weighted utilitarian, we can calculate the difference between the gross revenues for the weighted utilitarian case and the Rawlsian one, $GR^R - GR^W$,

$$GR^R - GR^W = 4[\beta_r(\alpha_p - c) - \beta_p(\alpha_r - c)]^2 [(2a-1)(a-1)(8a^2-5a-1)\beta_r^2 + 16a^2(a-1)^2\beta_p^2 - 16a^2(2a-1)(a-1)\beta_p\beta_r] / \{\beta_r[4a^2\beta_p - (2a-1)^2\beta_r]^2(\beta_r - 4\beta_p)^2\} > 0 \qquad \text{(A7)}$$

$$\Rightarrow \quad GR^R > GR^W$$

If the gross revenue in the case of Rawls is bigger than the one in the case of weighted utilitarian, the subsidies must be bigger too. This can be written as

$$2(c - p_1^R)X^R > 2(c - p_1^W)X^W \qquad \text{(A8)}$$

We know already that $X^R < X^W$. Together with the equation (A8) this implies clearly that $p_1^R < p_1^W$.

The comparative statistics of the model are found by partial differentiation of the three optimal solutions with respect to the parameters β_p, β_r, c and a. The results are reported in the Tables A1-A4. As explained in the main text, we set $\alpha_p = \alpha_r = \alpha$, and s = 0. Decreased β_p or β_r indicates less steep demand curves, increased c reflects higher marginal costs of supply, while increased a reflects a stronger emphasis on the poor consumer. In the tables we denote USWF for the Utilitarian case, WUSWF for the Weighted Utilitarian case, and RSWF for the Rawlsian case.

Table A1 The Effects of decreased β_p

Effect on	USWF	WUSWF	RSWF
$-\ \partial X/\partial\beta_p$	$(\alpha-c)/\beta_p^2>0$	$4a^2(4a-1)(\alpha-c)/[4a^2\beta_p-(2a-1)^2\beta_r]^2>0$	$12(\alpha-c)/(4\beta_p-\beta_r)^2>0$
$-\ \partial p_1/\partial\beta_p$	0	$-4a^2(2a-1)[2a^2\beta_p-(2a^2-4a+1)\beta_r](\beta_r-\beta_p)(\alpha-c)/\{(4a-1)\beta_r[4a^2\beta_p-(2a-1)^2\beta_r]^2\}>0$	$-4(\beta_r+2\beta_p)(\beta_r-\beta_p)(\alpha-c)/[3\beta_r(4\beta_p-\beta_r)^2]>0$
$-\ \partial p_2/\partial\beta_p$	0	$-2a(4a-1)(2a-1)\beta_r(\alpha-c)/[4a^2\beta_p-(2a-1)^2\beta_r]^2<0$	$-6\beta_r(\alpha-c)/(4\beta_p-\beta_r)^2<0$
$-\ \partial W/\partial\beta_p$	$-(\alpha-c)^2/2\beta_p^2>0$	$-a(\alpha-c)^2(4a-1)^2/2[4a^2\beta_p-(2a-1)^2\beta_r]^2>0$	$-9(\alpha-c)^2/2(4\beta_p-\beta_r)^2>0$

Table A2 The effects of decreased β_r

Effect on	USWF	WUSWF	RSWF
$-\ \partial X/\partial\beta_r$	0	$-(4a-1)(2a-1)^2(\alpha-c)/[4a^2\beta_p-(2a-1)^2\beta_r]^2<0$	$-3(\alpha-c)/(4\beta_p-\beta_r)^2<0$
$-\ \partial p_1/\partial\beta_r$	0	$4a^2\beta_p(2a-1)[2a^2\beta_p-(2a^2-4a+1)\beta_r](\beta_r-\beta_p)(\alpha-c)/(4a-1)\beta_r^2[4a^2\beta_p-(2a-1)^2\beta_r]^2<0$	$-4\beta_p(\beta_r+2\beta_p)(\beta_r-\beta_p)(\alpha-c)/3\beta_r^2(4\beta_p-\beta_r)^2<0$
$-\ \partial p_2/\partial\beta_r$	0	$2a(4a-1)(2a-1)\beta_p(\alpha-c)/[4a^2\beta_p-(2a-1)^2\beta_r]^2>0$	$6\beta_p(\alpha-c)/(4\beta_p-\beta_r)^2>0$
$-\ \partial W/\partial\beta_r$	$(\alpha-c)^2/2\beta_r^2>0$	$(\alpha-c)^2[2a\beta_p+(2a-1)\beta_r][2a^2\beta_p-(3a-1)(2a-1)\beta_r]/2\beta_r^2[4a^2\beta_p-(2a-1)^2\beta_r]^2>0$	$-(\alpha-c)^2(\beta_r+2\beta_p)(\beta_r-\beta_p)/\beta_r^2(4\beta_p-\beta_r)^2>0$

Table A3 The effects of increased c

Effect on	USWF	WUSWF	RSWF
$\partial X/\partial c$	$-1/\beta_p<0$	$-(4a-1)/(4a^2\beta_p-(2a-1)^2\beta_r)<0$	$-3/(4\beta_p-\beta_r)<0$
$\partial p_1/\partial c$	1	$[2a^2(2a-1)\beta_p^2-(2a-1)(6a^2-6a+1)\beta_r^2+8a^3\beta_p\beta_r]/(4a-1)\beta_r(4a^2\beta_p-(2a-1)^2\beta_r)>0$	$([2\beta_p^2+\beta_r(8\beta_p-\beta_r)/3\beta_r(4\beta_p-\beta_r)>0$
$\partial p_2/\partial c$	1	$[2a\beta_p+(2a-1)\beta_r]/(4a^2\beta_p-(2a-1)^2\beta_r)>0$	$(2\beta_p+\beta_r)/(4\beta_p-\beta_r)>0$
$\partial W/\partial c$	$-(\alpha-c)(\beta_p+\beta_r)/\beta_p\beta_r<0$	$-(\alpha-c)(a\beta_p+(3a-1)\beta_r)/(4a^2\beta_p-(2a-1)^2\beta_r)\beta_r<0$	$-(\alpha-c)(\beta_p+2\beta_r)/\beta_r(4\beta_p-\beta_r)<0$

Table A4 The effects of increased a (only relevant for the weighted utilitarian case)

Effect on	WUSWF
$\partial X/\partial a$	$8a(2a-1)(\alpha-c)(\beta_r-\beta_p) / (4a^2\beta_p - (2a-1)^2\beta_r)^2 < 0$
$\partial p_1/\partial a$	$-4a(\alpha-c)(\beta_r-\beta_p)^2((3a-1)(2a-1)^2\beta_r+4a^3\beta_p) / (4a-1)^2\beta_r(4a^2\beta_p - (2a-1)^2\beta_r)^2 < 0$
$\partial p_2/\partial a$	$-2(\alpha-c)(\beta_r-\beta_p)(4a^2\beta_p + (2a-1)^2\beta_r) / (4a^2\beta_p - (2a-1)^2\beta_r) > 0$
$\partial W/\partial a$	$\frac{1}{2}(\alpha-c)(\beta_r-\beta_p)(4a^2\beta_p + 3(2a-1)^2\beta_r) / \beta_r(4a^2\beta_p - (2a-1)^2\beta_r)^2 < 0$

Shifts in the budget constraint of the water utility are found by defining $s = t_p+t_r-f-m$, which is the net lump sum transfer *to* the utility, i.e. the allowed deficit for its running operations. A negative s reflects a funding of other budgets from a surplus from the water utility, and a negative shift in s indicates a smaller subsidy cum tax to the water customers. For the utilitarian case we found

$$p_1^U = c - s/2X = c - s\beta_p/2(\alpha_p - c), \qquad \text{i.e. } \partial p_1^U/\partial s < 0. \tag{11}$$

For the two other cases we set for simplification $\alpha_p = \alpha_r = \alpha > c$, and we assume that t_p and t_r both are constant. Now, the weighted utilitarian model yields for maximum welfare

$$p_1 = \{(2a-1)[2a^2(\alpha-c)\beta_p^2 + (2a^2\alpha+(6a^2-6a+1)c)\beta_r^2] - 4a^2[(2a-1)\alpha+2ac)]\beta_p\beta_r\} / \\ - \{[4a^2\beta_p - (2a-1)^2\beta_r] / [2(4a-1)(\alpha-c)]\} s, \tag{A9}$$
i.e. $\partial p_1^U/\partial s < 0$.

The Rawlsian model yields in maximum

$$p_1 = [4\beta_p\beta_r(\alpha+2c) - 2\beta_p^2(\alpha-c) - \beta_r^2(2\alpha+c)] / [3\beta_r(4\beta_p-\beta_r)] - [(4\beta_p-\beta_r) / 6(\alpha-c)] s, \tag{A10}$$
i.e. $\partial p_1^U/\partial s < 0$.

In both cases the coefficient for the effect of s is clearly negative due to the assumptions $\alpha > c$, $\beta_p > \beta_r$, $a \geq 0.5$.

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