Welfare and Distribution Effects of Water Pricing Policies

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Summary

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Keywords: Water Demand, Welfare Economics, Equivalent Variation

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Welfare and distribution effects of water pricing policies

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Abstract

In this paper, distribution and welfare effects of changes in block price systems are evaluated. A method is discussed to determine, for a Marshallian demand function, equivalent variation in case of a block price system. The method is applied to analyze welfare and distribution effects of changing water prices in the Metropolitan Region of São Paulo. Results show that there is a trade off between average welfare and income distribution. A pro-poor price system may result in lower average welfare than a flat price system, but in higher individual welfare for the poor. Moreover, there is a trade off between revenues for the water company and income distribution. Even though pro-poor price systems may not be as good for average welfare as flat price systems, their direct effects on poverty are important. Introducing pro-poor price systems, however, may have financial consequences for the water companies.

1 Introduction

A basic principle in economics is that in order to get efficient prices, they have to reflect marginal costs. As a consequence, economic theory often recommends the application of flat prices. However, for some goods, such as residential water and electricity, block pricing systems are regularly applied. Such pricing systems are said to be better for income distribution as, in case of progressive block price systems, poor households who consume less, pay lower average prices. A drawback of block pricing is, however, a potential welfare loss. Even though direct income transfers may lead to larger welfare increases for poor consumers than in-kind subsidies of the same amount, many (especially public) water suppliers employ block pricing systems as they not only try to promote efficiency but also have other objectives related to equity, cost recovery and local acceptability (Arbués and Villanúa, 2006). Moreover, particularly in developing countries, alternative systems for improving social security, like transfers through income taxes, do not function properly. Comparisons between the welfare and distribution effects of alternative pricing systems are rare in the literature as the methods to derive the welfare effects are not straightforward.

The objective of this paper is to analyze distribution and welfare effects of changes in block price systems. A method is discussed with which for a linear Marshallian demand function, equivalent variation of a change in the block price system can be determined. This method extends existing methods used for deriving equivalent variation on the basis of Marshallian demand curves so that they are applicable for block pricing systems. It is applied to the analysis of water demand, distribution and welfare effects of alternative water pricing systems in the Metropolitan Area of São Paulo. Especially the effects of changes in the price system on individual equivalent variation and social welfare will be assessed. Note that a partial equilibrium approach is adopted and that indirect welfare effects of changes in pricing policies are not considered.

An extensive literature exists on welfare measurement (see e.g. Slesnick (1998) for an overview). The correct measure to use for determining welfare effects of price changes are Hicks' measures of Compensating Variation or Equivalent Variation. Most papers dealing with this issue concentrate on determining compensating or equivalent variation in case of a linear budget line. Those considering block price systems especially focus on effects of labor taxation (see e.g. Hausman, 1980). For the case of water, there is an extensive literature on the estimation of residential water demand functions (see Arbués et al. (2003); Arbués and Villanúa (2006) for an overview). Renzetti (1992) and García-Valiñas (2005) analyzed welfare effects of reforming water price systems, but they concentrated on the use of the optimal price theory using Ramsey prices which is not the focus of the current paper. Rietveld et al. (2000) for the case of Indonesia and Hajispyrou et al. (2002) for the case of Cyprus are two of the few studies focusing on the welfare effects of block price systems for residential water use. They, however, analyzed welfare effects of a price system changing from a block price into a flat price system. The novel element of the current paper is that especially the more complex case of changes within the block price system are analyzed in order to be able to assess the effects on both welfare and income distribution.

In this paper, a method is discussed to determine on the basis of the Marshallian demand function the equivalent variation and social welfare in case of a block price system. In Section 3, a linear water demand function is estimated for the Metropolitan Region of São Paulo which is used in Section 4 to analyze the welfare and distribution effects of changes in the price system. Finally, in Section 5 a number of conclusions are drawn.

2 Marshallian demand and equivalent variation

As stated above, the correct measure to use for determining welfare effects of price changes are Hicks' compensating or equivalent variation. Compensating Variation (CV) measures 'the amount the consumer would pay or would need to be paid to be just as well off after the price change as she was before the price change' (Hausman, 1981, pp. 662). Equivalent Variation (EV), on the other hand, measures the 'amount the consumer would be indifferent about accepting in lieu of the price change' (Mas-Colell et al., 1995, pp. 82). CV is based on ex-ante utility and EV on ex-post utility. In applied economics, however, an often used measure for welfare changes is consumer surplus. It measures the consumer's willingness to pay for a price change on the basis of the Marshallian demand function instead of the Hicksian demand function. Use of the Marshallian demand function is much easier as it is directly observable in practice, and therefore can be estimated easily. A drawback, however, is that it does not compensate for income effects of price changes, which are taken into account in the Hicksian demand function. Consumer surplus equals compensating variation only under specific circumstances. Willig (1976) argued that in most cases the differences between both welfare measures are small and therefore use of consumer surplus is an appropriate approximation of welfare changes. Others, however, show that these differences may be substantial. Making a choice between both welfare measures, however, is not necessary as Hausman (1981) and Vartia (1983) showed that indirect utility and therefore compensating and equivalent variation can be determined on the basis of the Marshallian demand function. Both methods are based on linear budget constraints. In the case of kinked budget curves and especially in the case of non-convex budget curves, things change.

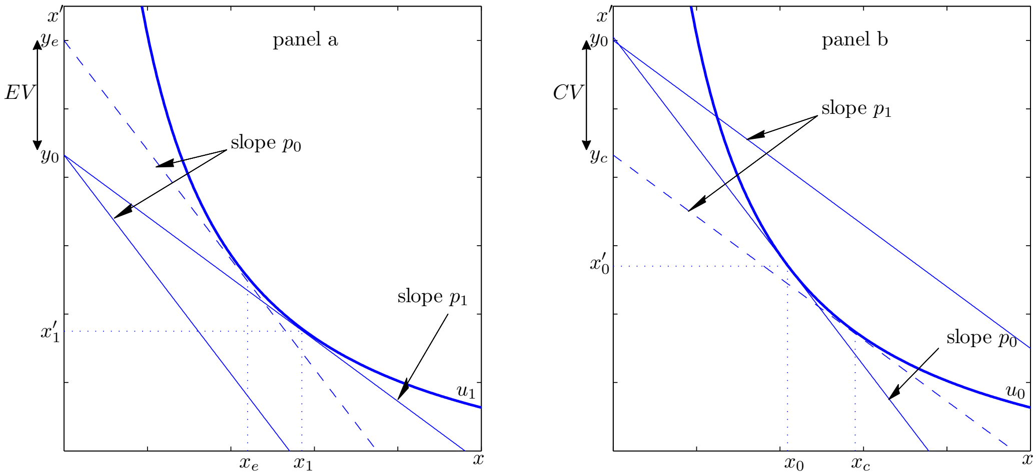

Figure 1: Schematic representation of Equivalent Variation (Panel a) and Compensating Variation (Panel b).

In this paper, the method developed by Hausman (1981) is extended in order to derive equivalent and compensating variation in a situation with a non-convex budget set. Such a situation often applies for example in labor markets (see e.g. Hausman, 1985). Similar situations also apply for electricity and water markets where progressive block price systems are combined with a high first block price (or a fixed fee) to account for fixed cost. In this section, I first briefly discuss the concept of equivalent and compensating variation, which of the two concepts should be used for ranking alternative policies and how it can be derived on the basis of the Marshallian demand function. Secondly, this method is extended for a situation with a convex kinked budget curve. Thirdly, it is discussed how to deal with non-convex budget sets. Finally, using some of the elements discussed before, a measure for social welfare is discussed that is used to assess the social welfare effects of block price changes.

Consider a two-good situation in which the second good, which can be interpreted as an aggregate commodity, is the numeraire whose price is held constant. The price vector is defined as $\boldsymbol{p} = (p, 1)$. The price of the first commodity p and income y are normalized with respect to the price of the second commodity and both commodities are assumed to be separable. At price $\boldsymbol{p_0} = (p_0, 1)$ and income level y_0, demand is equal to $\boldsymbol{x_0} = (x_0, x_0')$ and utility to $u_0(\boldsymbol{x_0})$ (see Figure 1). If the price of commodity 1 decreases to p_1, the budget line shifts outwards and becomes flatter. The equivalent income, the income the consumer would need to be as well off without as with the price decrease, is equal to y_e. Equivalent variation is defined as $y_e - y_0$. The compensating income, the income the consumer would need to be as well off with as without the price change, is equal to y_c. Compensating variation is defined as $y_0 - y_c$. Both income measures are used as a money metric indirect utility function. In case of a price increase EV and CV are equal to the welfare loss, whereas they are the welfare gain in case of a price reduction. The expenditure function at a given level of utility u_0 and price $\boldsymbol{p} = (p, 1)$ is defined as $e(p, u_o) = \min_{\boldsymbol{x}} \{\boldsymbol{p} \cdot \boldsymbol{x} \,|u(\boldsymbol{x}) \geq u_0\}$[1]. Using this, EV and CV of a price change from p_0 to p_1 are defined as

[1]For simplicity, in the definitions of the expenditure function $e(p, u_0)$, demand function $x(p, y)$, indirect utility function $V(p, y)$, equivalent variation $EV(\cdot)$ and compensating variation $CV(\cdot)$, only the price p of the first commodity is mentioned as the price of the second commodity is held constant.

$$
\begin{aligned}
EV\left(p_0, p_1, y_0\right) &= e\left(p_0, u_1\right) - e\left(p_1, u_1\right) = e\left(p_0, u_1\right) - y_0 \\
CV\left(p_0, p_1, y_0\right) &= e\left(p_0, u_0\right) - e\left(p_1, u_0\right) = y_0 - e\left(p_1, u_0\right)
\end{aligned} \tag{1}
$$

The first question is which of the two measures to use. Chipman and Moore (1980) and Mas-Colell et al. (1995) showed that not CV, but only EV can be used for ranking alternative policies with different price vectors. The reason is that in CV, the money metric indirect utility levels are based on new prices and initial utility, whereas in EV, they reflect the new utility levels that will be obtained with the new prices.[2]

The second question is how to derive from the Marshallian demand function the corresponding expenditure function. For a linear Marshallian demand function, Hausman (1981) showed that the expenditure function can be derived by using Roy's identity and the definition of the indirect utility function. Introduce a linear Marshallian demand function $x(p, y) = \alpha p + \beta y + \boldsymbol{\gamma z'}$ with coefficients α and β, row vector of coefficients $\boldsymbol{\gamma}$, and the vector of other variables affecting demand $\boldsymbol{z}$. Moreover, introduce the indirect utility function

$$
V\left(p, y\right) = max\left\{u(\boldsymbol{x})\left|\boldsymbol{p}\cdot\boldsymbol{x} \leq y\right.\right\} \tag{2}
$$

and Roy's identity according to which

$$
x(p, y) = -\frac{\partial V(p, y)/\partial p}{\partial V(p, y)/\partial y} \tag{3}
$$

For the linear demand function, (3) gives a differential equation for which Hausman (1981) proved that the indirect utility function $V(p, y)$ has the following form.

$$
V(p, y) = \exp(-\beta p)\left[y + \frac{1}{\beta}\left(\alpha p + \frac{\alpha}{\beta} + \boldsymbol{\gamma z'}\right)\right] \tag{4}
$$

It can easily be shown that this function satisfies the integrability conditions as it is continuous, quasi-convex in p, homogeneous of degree zero in p and y and non increasing in p. Homogeneity of degree zero in p and y follows directly from the assumption that both p and y are deflated by the price of the other good which is by assumption equal to 1. This proves that the linear demand function follows from a rational preference relation (Mas-Colell et al., 1995).[3] By substituting in

[2] In case a price p_0 is compared with prices p_1 and p_2, the difference in equivalent variation between both prices is $EV\left(p_0, p_1, y_0\right) - EV\left(p_0, p_2, y_0\right) = e\left(p_0, u_1\right) - e\left(p_0, u_2\right)$ and the difference in compensating variation is $CV\left(p_0, p_1, y_0\right) - CV\left(p_0, p_2, y_0\right) = e\left(p_2, u_0\right) - e\left(p_1, u_0\right)$. Chipman and Moore (1980) proved that if income does not change if prices change and if preferences are homothetic, $CV\left(p_0, p_1, y_0\right) > CV\left(p_0, p_2, y_0\right)$ if $p_1 < p_2$ and CV will rank the different policies correctly. If this assumption does not apply, however, CV not necessarily ranks p_1 and p_2 correctly but EV will (see also Mas-Colell et al., 1995, pp. 86). As will be discussed below, in the case analyzed in this paper income does change if the block price changes due to a change in implicit subsidy received by the consumers if prices change and therefore EV should be used to rank alternative policies.

[3] In this paper, a linear demand function is adopted. We make the assumption of implicit separability which justifies a demand curve with only one price (Arbués et al., 2004) and due to which the quasi indirect utility function (based only on the single good demand curve) can easily be derived and gives the same measure of equivalent variation as the actual, many good, indirect utility function (Hausman, 1981). Regularly, linear demand functions are criticized as they would only apply for restrictive assumptions on the preference ordering. Given the assumptions made above, however, it is shown that in our situation this does not pose any problems (see e.g. Hausman, 1981; LaFrance, 1985; Arbués et al., 2004; Beattie and LaFrance, 2006). Linear demand functions are also criticized as they imply a choke price for which demand is zero (Al-Qunaibet and Johnston, 1985), which is inconsistent with water being a necessary good. On the other hand, linear demand also implies a satiation level at low prices, which is intuitively correct (Arbués et al., 2004). In much of the empirical literature, functional forms are chosen that best fit the available data, without considering the underlying preference structures or related utility function. In the empirical analysis on water demand, the linear demand function is regularly applied and for a study in Spain, Arbués and Villanúa (2006) show that the linear demand function is the most appropriate functional form. Moreover, it can be argued that the demand function does not have to be linear over the full range of prices, as long as it is (approximately) linear over the range of prices considered. It is left for future research to find out how deriving Compensating Variation in case of a kinded budget curve would change if other functional forms

(4) income y by expenditures $e(p,u)$ and $V(p,y)$ by u, the corresponding expenditure function follows

$$e(p,u) = u\exp(\beta p) - \frac{1}{\beta}\left(\alpha p + \frac{\alpha}{\beta} + \boldsymbol{\gamma z'}\right) \tag{5}$$

As a consequence, using (4) and (5), EV in (1) can easily be calculated if the Marshallian demand function is known.

Let us now turn to the question how to determine equivalent variation in case of a kinked budget curve. Consider for the moment for commodity 1 a two-tiered block price system with block prices $\boldsymbol{p^b} = (p^1, p^2)$,with p^i the price in block i and in which price jumps from p^1 to p^2 if demand exceeds $\bar{x}$ (see Figure 2). Assume for the moment a convex budget set with $p^1 \leq p^2$. Note that still the price of the second commodity is equal to 1, so that the price vector for the two commodities is $\boldsymbol{p} = (\boldsymbol{p^b}, 1)$. For this situation, equivalent variation for a price change from $\boldsymbol{p_0^b}$ to $\boldsymbol{p_1^b}$ is, just as in (1), defined as

$$EV\left(\boldsymbol{p_0^b}, \boldsymbol{p_1^b}, y_0\right) = e^b\left(\boldsymbol{p_0^b}, u_1\right) - y_0 \tag{6}$$

with $e^b\left(\boldsymbol{p_0^b}, u_1\right)$ the expenditures in case of a block price system. These expenditures reflect the income needed to reach a utility level u_1 if the price vector is $\left(\boldsymbol{p_0^b}, 1\right)$. Call x_e the demand level at which there is tangency between the indifference curve $u_1 = V\left(\boldsymbol{p_1^b}, y_0\right)$ and the kinked budget curve characterised by prices $\left(\boldsymbol{p_0^b}, 1\right)$ and income $e^b\left(\boldsymbol{p_0^b}, u_1\right)$ (for an exact derivation of u_1, see the Appendix). The definition of $e^b\left(\boldsymbol{p_0^b}, u_1\right)$ depends on the segment of the budget line on which x_e is located. Three different cases can be distinguished: x_e is at the first segment of the budget curve, at the second segment, or at the kink. Hausman (1985) proved that in case of a convex budget set and a quasi-concave utility function, there is a unique level of x_e, so that only one of the three cases will apply. First, consider the situation if x_e is at the first segment of the budget curve. In that case, the situation is like in Panel (a) of Figure 1 and the expenditures are like in (5) with p substituted by p_0^1. In other words,

$$e^b\left(\boldsymbol{p_0^b}, u_1\right) = e\left(p_0^1, u_1\right) \qquad \text{if } x\left(p_0^1, e\left(p_0^1, u_1\right)\right) \leq \bar{x} \tag{7}$$

and in that case $EV\left(\boldsymbol{p_0^b}, \boldsymbol{p_1^b}, y_0\right) = e\left(p_0^1, u_1\right) - y_0$, see (6). Note that for this situation $x_e = x\left(p_0^1, e\left(p_0^1, u_1\right)\right)$.

Secondly, if x_e is at the second segment, as in Panel (a) in Figure 2, the expenditure function is different. In that case expenditures $e^b\left(\boldsymbol{p_0^b}, u_1\right)$ are not determined by substituting p_0^2 in (5), as an amount $\left(p_0^2 - p_0^1\right)\bar{x}$ less is needed to purchase the quantity x_e. The expenditures $e(p_0^2, u_1)$, as determined by (5), are also called virtual expenditures. They are the expenditures necessary to purchase x_e if the price were p_0^2 throughout and utility is u_1. Using this, for a block price system $\boldsymbol{p_0^b} = \left(p_0^1, p_0^2\right)$, expenditures to purchase x_e are $e^b\left(\boldsymbol{p_0^b}, u_1\right) = e\left(p_0^2, u_1\right) - \left(p_0^2 - p_0^1\right)\bar{x}$. In this definition, $\left(p_0^2 - p_0^1\right)\bar{x}$ is an implicit subsidy for consumers in block 2. It is the difference between expenditures if p_0^2 were the price and the actual expenditures in the block price system. It follows that if prices change from $\boldsymbol{p_0^b} = \left(p_0^1, p_0^2\right)$ to $\boldsymbol{p_1^b} = \left(p_1^1, p_1^2\right)$, expenditures are equal to

$$e^b\left(\boldsymbol{p_0^b}, u_1\right) = e\left(p_0^2, u_1\right) - \left(p_0^2 - p_0^1\right)\bar{x} \qquad \text{if } x\left(p_0^2, e\left(p_0^2, u_1\right)\right) \geq \bar{x} \tag{8}$$

were chosen.

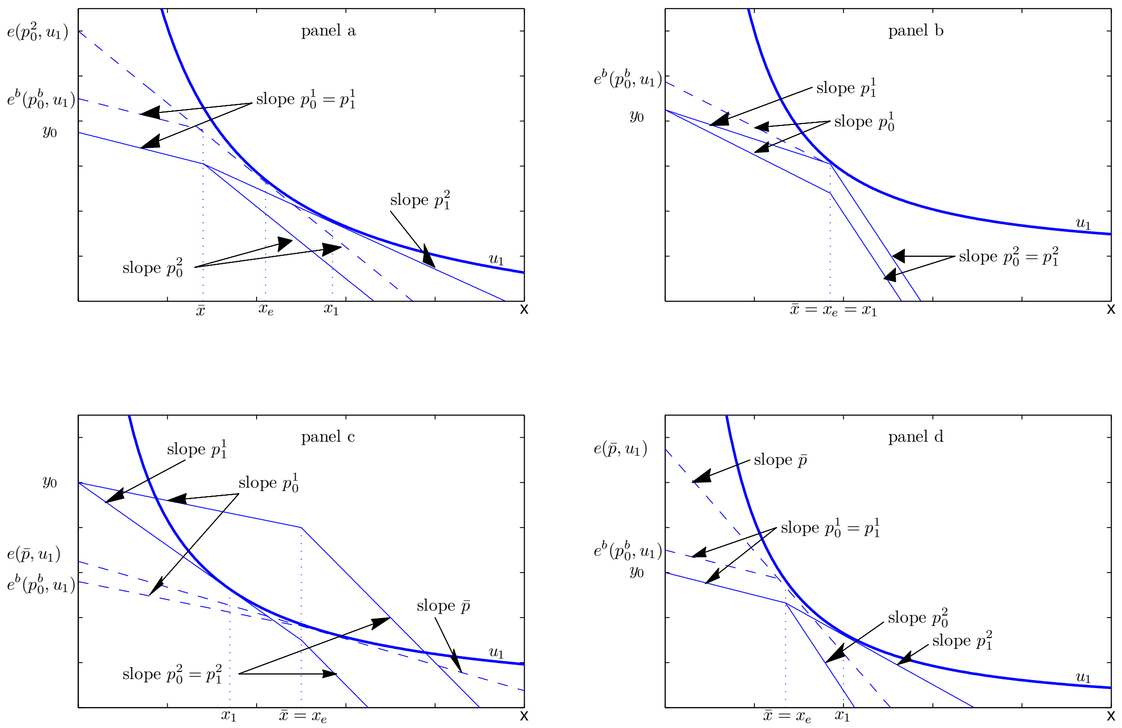

Figure 2: Schematic representation of EV in case of a kinked budget curve. Expenditures in case of a kinked budget curve if x_e and x_1 are at segment 2 of the budget curve (Panel a), x_e and x_1 are at the kink (Panel b), x_e is at the kink and x_1 at segment 1 of the budget curve (Panel c), and x_e is at the kink and x_1 at segment 2 of the budget curve (Panel d).

and in that case $EV\left(\boldsymbol{p_0^b},\boldsymbol{p_1^b},y_0\right) = e\left(p_0^2,u_1\right) - \left(p_0^2-p_0^1\right)\bar{x} - y_0$, see (6).[4] For this case $x_e = x\left(p_0^2, e\left(p_0^2,u_1\right)\right)$. Note that a change from a flat to a block pricing system or from a block to a flat price system is a special case of the method discussed above in which for the flat price system $p^1=p^2$.

Thirdly, if x_e is at the kink, $x_e=\bar{x}$, the situation is more complex (see Panel (b)-(d) in Figure 2). This situation happens if tangency with the indifference curve is at a point $x\left(p_0^1, e\left(p_0^1,u_1\right)\right) > \bar{x}$ for the budget line with slope p_0^1 and at a point $x\left(p_0^2, e\left(p_0^2,u_1\right)\right) < \bar{x}$ for the budget curve with slope p_0^2. The question is how to derive the price $\bar{p}$ and virtual income $\bar{y}=e(\bar{p},u_1)$ for which preferred demand would be $\bar{x}$. How $\bar{p}$ and $e\left(\bar{p},u_1\right)$ look like depends on whether the demand level after the price change, x_1, is at the kink or in one of the segments of the budget curve. If demand x_1 and x_e are at the kink, the method is simple (see Panel (b) of Figure 2). In that case, for demand for commodity 2, the numeraire, it has to hold that $\bar{x}'=y_0-p_1^1\bar{x}=e^b\left(\boldsymbol{p_0^b},u_1\right)-p_0^1\bar{x}$. It directly follows that $e^b\left(\boldsymbol{p_0^b},u_1\right)=y_0+\left(p_0^1-p_1^1\right)\bar{x}$ and that equivalent variation is

$$EV\left(\boldsymbol{p_0^b},\boldsymbol{p_1^b},y_0\right) \quad = \left(p_0^1-p_1^1\right)\bar{x} \tag{9}$$

If demand level x_1 is in block i and demand level x_e is at the kink (see Panel (c) and (d) in Figure 2), the method is more complex. In that case, the virtual equivalent income $\bar{y}=e(\bar{p},u_1)$ and price $\bar{p}$ for which demand would be $\bar{x}$ can be determined by using the demand functions $\bar{x}=\alpha\bar{p}+\beta\bar{y}+\boldsymbol{\gamma z'}$ and $x_1=\alpha p_1^i+\beta\tilde{y}_0^i+\boldsymbol{\gamma z'}$ and by the fact that it has to hold that $V\left(p_1^i,\tilde{y}_0^i\right)=V\left(\bar{p},\bar{y}\right)$, with $\tilde{y}_0^1=y_0$ if demand $x_1=x\left(p_1^1,y_0\right)$ is at segment 1 and $\tilde{y}_0^2=y_0+\left(p_1^2-p_1^1\right)\bar{x}$ if demand $x_1=x\left(p_1^2,y_0+\left(p_1^2-p_1^1\right)\bar{x}\right)$ is at segment 2. Using the indirect utility function (4) it follows that for the linear demand function

$$\begin{gathered}
\bar{p}=p_1^i+\tfrac{1}{\beta}\ln\left(\tfrac{\bar{x}+\frac{\alpha}{\beta}}{x_1+\frac{\alpha}{\beta}}\right)\\
e\left(\bar{p},u_1\right)=\bar{y}=\tfrac{1}{\beta}\left(\bar{x}-\alpha\bar{p}-\boldsymbol{\gamma z'}\right)=\tilde{y}_0^i+\tfrac{1}{\beta}\left(\bar{x}-x_1\right)-\tfrac{\alpha}{\beta^2}\ln\left(\tfrac{\bar{x}+\frac{\alpha}{\beta}}{x_1+\frac{\alpha}{\beta}}\right)\\
e^b\left(\boldsymbol{p_0^b},u_1\right)=e\left(\bar{p},u_1\right)-\left(\bar{p}-p_0^1\right)\bar{x}
\end{gathered} \tag{10}$$

This gives an equivalent variation of

$$EV\left(\boldsymbol{p_0^b},\boldsymbol{p_1^b},y_0\right)=\left(p_0^1-p_1^1\right)\bar{x}-\frac{1}{\beta}\left(\bar{x}+\frac{\alpha}{\beta}\right)\ln\left(\frac{\bar{x}+\frac{\alpha}{\beta}}{x_1+\frac{\alpha}{\beta}}\right)+\frac{1}{\beta}\left(\bar{x}-x_1\right) \tag{11}$$

Note that (9) and (11) are the same if $x_1=\bar{x}$.

In case of an n-tiered block price system, the methods discussed above slightly differ. Assume a situation with n block prices, $\boldsymbol{p^b}=(p^1,\ldots,p^n)$ with block frontiers equal to $\bar{\boldsymbol{x}}=\left(\bar{x}^0,\ldots,\bar{x}^n\right)$, so that for $\bar{x}^{i-1}<x<\bar{x}^i$ the price is equal to p^i. Note that $\bar{x}^0=0$ and $\bar{x}^n=\infty$. If demand is in block 1 , the usual definition of expenditures is used. If demand is in block $i>1$, equivalent variation for a change from $\boldsymbol{p_0^b}$ to $\boldsymbol{p_1^b}$ is defined as

$$EV\left(\boldsymbol{p_0^b},\boldsymbol{p_1^b},y_0\right)=\left[e\left(p_0^i,u_1\right)-\sum_{j=1}^{i-1}\left(p_0^{j+1}-p_0^j\right)\bar{x}^j\right]-y_0 \tag{12}$$

[4] Note that due to the implicit subsidy if demand is in block 2, the demand function $x=\alpha p^2+\beta\left(y+\left(p^2-p^1\right)\bar{x}\right)+\boldsymbol{\gamma z'}$ is equal to $x=(\alpha+\beta\bar{x})p^2+\beta(y-p^1\bar{x})+\boldsymbol{\gamma z'}$. As a result, the price elasticity of demand changes. As usually $\alpha<0$ and $\beta>0$, it is in theory possible that $\alpha+\beta\bar{x}>0$, meaning that, perversely, demand increases if the marginal price increases. In this case, the income effect of a move between two consumption blocks is larger than the price effect. In practice this is usually not a problem.

If x_1 is at kink or segment l and x_e is at kink i, $x_e = \bar{x}^i$, equivalent variation is

$$\begin{aligned} EV\left(\boldsymbol{p_0^b}, \boldsymbol{p_1^b}, y_0\right) &= \left[e\left(\bar{p}, u_1\right) - \left(\bar{p} - p_0^i\right) \bar{x}^i - \sum_{j=1}^{i-1} \left(p_0^{j+1} - p_0^j\right) \bar{x}^j \right] - y_0 \\ &= \left(p_0^i - p_1^l\right) \bar{x}^i - \sum_{j=1}^{i-1} \left(p_0^{j+1} - p_0^j\right) \bar{x}^j + \sum_{j=1}^{l-1} \left(p_1^{j+1} - p_1^j\right) \bar{x}^j \\ &\quad - \frac{1}{\beta} \left(\bar{x}^i + \frac{\alpha}{\beta}\right) \ln \left(\frac{\bar{x}^i + \frac{\alpha}{\beta}}{x_1 + \frac{\alpha}{\beta}} \right) + \frac{1}{\beta} \left(\bar{x}^i - x_1\right) \end{aligned} \tag{13}$$

The last term at the right-hand side of (12) and the last two terms at the right hand side of the first line of (13) are equal to the implicit subsidy the consumer receives. It is equal to the difference between what the consumer would pay if the only price were price p_0^i or $\bar{p}$ and the expenditures in the block price system. In the water demand and electricity literature, this term is usually defined as the difference variable and is first introduced by Nordin (1976).

The final element to be discussed deals with how to determine the segment at which optimal utility is obtained in case of a non-convex budget set. This method is taken from Hausman (1985). In case of a convex budget curve the method is as discussed above. For each segment i of the budget curve, it is determined what will be demand if the marginal price were block price p^i. Demand lies on segment i if $\bar{x}^{i-1} < x(p^i, \tilde{y}^i) \leq \bar{x}^i$. In case of a convex budget set and a quasi concave utility function, this procedure results in the unique utility optimizing demand level (Hausman, 1985). In the non-convex case, however, which applies for example in case of a (partly) regressive block price system, a unique optimum no longer necessarily exists as the indifference curves can be tangent to multiple segments of the budget curve. Information about the utility or indirect utility function has to be known to find the utility maximizing demand level. If this information is known, the non-convex budget set can be subdivided into a finite number of convex subsets, numbered $j = 1, \ldots, J$. So, the set of segments $I = \{1, \ldots, n\}$ can be subdivided into J subsets $I_j = \{i_{j-1} + 1, \ldots, i_j\}$, with $i_0 = 0$ and $i_J = n$. For each convex subset j and $i \epsilon I_j$, the optimal demand level $x_j(p^i, \tilde{y}^i)$, and corresponding price p^i and indirect utility level $V_j(p^i, \tilde{y}^i)$ can be derived by using the method described above, in which virtual income $\tilde{y}^i = y_0 + \sum_{j=1}^{i-1} \left(p^{j+1} - p^j\right) \bar{x}^j$. The overall optimal demand level can be determined by choosing the price p^i and demand $x(p^i, \tilde{y}^i)$ corresponding to the segment yielding the highest indirect utility: $V^* = max(V_1, \ldots, V_J)$. For the linear demand function, $V_j(p^i, \tilde{y}^i)$ is equal to (4).

For a given individual demand function, the measure of equivalent variation as discussed above gives the per capita welfare effects of price changes. For determining the overall impact, it is possible to follow a utilitarian social welfare approach and just aggregate the individual effects. However, in that case effects on the poor have the same weights as effects on the rich. An often applied measure that addresses the aggregation problem and takes into consideration inequality aversion is the Atkinson measure of social welfare. For given income levels y_k, $k = 1, ..., K$, for each individual, social welfare is written as (see e.g. Atkinson, 1970; Deaton, 1997; Slesnick, 1998)

$$W = \frac{1}{K} \sum_{k=1}^{K} \frac{y_k^{1-\rho}}{1-\rho} \tag{14}$$

with $\rho > 0$ an indicator controlling for the degree of inequality aversion in which $\rho = 0$ yields a utilitarian social welfare function and $\rho = \infty$ yields a Rawlsian maximin welfare function

(Slesnick, 1998). Usually for ρ a value between 0 and 2 is chosen.[5] Which value of ρ should be adopted is a political question, which is not further discussed here. In this paper, it will only be assessed to what extent a different value of ρ affects the price system that results in the highest level of social welfare.

To apply this measure for analyzing the social welfare effects of price changes, an income measure should be adopted that properly measures the income change that is equivalent to the welfare effect of a price change. For this, the measure of equivalent income is an appropriate measure.[6] Equivalent income is the income that an individual would need before the price change (at price $\boldsymbol{p_0^b}$) to have the post-change utility level ($u\left(\boldsymbol{p_1^b}, y_0\right)$), i.e. $y_e = e^b\left(\boldsymbol{p_0^b}, u_1\right)$ as defined in (7), (8) and (10). This gives the necessary ingredients to derive social welfare for a given value of inequality aversion ρ.

3 Water demand in the Metropolitan Region of São Paulo

The Brazilian Metropolitan Region of São Paulo (MRSP) is one of the most densely populated areas in the world, housing more than 15 million people. The MRSP houses 50% of the state's population whereas it only occupies 2.7% of its territory. The MRSP regularly suffers from water shortage. As a result, SABESP, the main energy, water resources and sanitation secretary of the MRSP, has to ration water distribution. SABESP applies a five-tiered, non-convex block price system in which between 1997 and 2002 the prices from block 2 to 5 were on average $p^2 = 0.41$, $p^3 = 1.43$, $p^4 = 2.04$ and $p^5 = 2.26$ Real/m^3 for consumption quantities ranging from 10-20, 20-30, 30-50 and higher than 50 m^3 per month per connection, respectively. In that period, the price of the first 10 m^3 was on average $p^1 = 2.56$ Real/m^3, which included the fixed costs. This system assures a safe minimum level of revenues for the water company, but may for the poorer population result in high average prices and relatively high expenses. Note that due to this price system, the budget constraint is non-convex. A connection contained on average 6.01 people. Comparable systems are applied in other Latin American cities (Walker et al., 2000).

In the past, much has been written on estimating water demand functions in a block price system (see e.g. Arbués et al. (2003) and Arbués and Villanúa (2006) for an overview). Even though using micro-level data is preferred for estimating water demand functions, only few papers actually use it due to the difficulty of obtaining these data (see e.g. Nieswiadomy and Molina (1989); Hewitt and Hanemann (1995); Arbués et al. (2004); Arbués and Villanúa (2006)). With micro-data, the discrete/continuous choice model as proposed by Hewitt and Hanemann (1995) could be applied, which specifically models the choice of consumption block, or a dynamic panel data method like in Arbués et al. (2004) and Arbués and Villanúa (2006). Similar to most papers focusing on water demand estimation, for the MRSP only aggregate data were available and, therefore, the estimates are based on these aggregate data. Besides a number of econometric estimation issues, demand functions can depend on average or on marginal prices, depending on how well consumers are informed about the block price system applied. According to Taylor (1975), price jumps caused by the movement to another block have an income effect due to which a demand function depending only on the marginal price is theoretically incorrect. For that reason, Nordin

[5] Note that for $\rho > 1$ social welfare levels W become negative which can be prevented by a simple linear transformation.

[6] Note that the measure of compensating income, as is used for determining CV ($y_c = e^b\left(\boldsymbol{p_1^b}, u_0\right)$), is not an appropriate mesaure as it gives the income necessary to stay at the same utility level as before a price change from $\boldsymbol{p_0^b}$ to $\boldsymbol{p_1^b}$. The problem is that compensating income y_c reduces if the price reduces whereas welfare increases in that case.

(1976) introduced a difference variable, accounting for the difference between the costs of water consumption if the marginal price were the only price and the true costs under the block price system. Its effect is hypothesized to be of the same magnitude as the income effect. It is, however, theoretically plausible and it has been empirically supported by different empirical studies (see e.g. Billings and Agthe, 1980; Chicoine and Ramamurthy, 1986) that the effect of a consumption related subsidy may be different from the income effect. This may be because consumers are not well informed or because the difference variable is small relative to income. A much cited comment on the use of marginal prices is that many people are not well informed and that therefore a demand model based on average prices is more realistic. To test for whether the marginal or average price model is superior, Opaluch (1982, 1984) proposed a model with a decomposed measure of average and marginal price. It is an empirical question which demand model is most appropriate.

For estimating a water demand function for the MRSP, aggregate data were used on monthly water consumption, number of connections, block prices and water rationing for the period July 1997 - December 2002 obtained from SABESP for the consumers from 39 municipalities covering almost the entire MRSP (data were available for a period of 64 months). Prices were deflated using the Brazilian price index IPCA/IBGE, which is available on a monthly basis. In the data set, average consumption per household (total residential consumption divided by the number of connections) was always in the third consumption block. Although individual households may be in different consumption blocks, depending on income and other household variables, because we only obtained aggregate consumption data, we interpret p^3 as the marginal price of household water consumption. Moreover, income data for the period 1996-2003 was obtained from the Brazilian Institute of Geography and Statistics (PNAD/IBGE) which were deflated using the Brazilian price index IPCA/IBGE, population data from the State Data Analysis System Foundation (SEADE) and monthly data on rainfall and temperature from the Institute of Atmosphere and Geography (IAG). For a more elaborate discussion of the data, see Ruijs et al. (2005).

Using these data, Ruijs et al. (2005) estimated the following marginal price, water demand function: $x_t = \alpha p_t + \beta y_t + \delta d_t + \boldsymbol{\gamma} \boldsymbol{z_t}' + \epsilon_t$, with p_t, y_t and d_t price in block 3 (p^3), income and difference variable and $\boldsymbol{z}_t$ a vector with rainfall, temperature, rationing, lagged consumption, lagged rainfall and the intercept and ϵ_t the error term. Using the approach of Opaluch (1982), it was estimated whether the marginal or average price model should be used, but based on the results neither of the methods could be rejected. Moreover, in this model, the coefficient δ of the difference variable was notably different from the income coefficient β, as observed in many other empirically estimated demand functions. In the current paper, a new function is estimated in which it is assumed that the income effect is equal to the effect of changes in the difference variable. Allowing for differences in these coefficients is theoretically debatable and would make the method discussed in Section 2 incorrect. After all, in that case it would have to be assumed that virtual income is not equal to income plus the difference variable, but smaller or larger, depending on the relation between β and δ. For that reason, the function estimated is

$$x_t = \alpha p_t + \beta(y_t + d_t^i) + \boldsymbol{\gamma} \boldsymbol{z_t'} + \epsilon_t \tag{15}$$

in which $d_t^i = \sum_{j=1}^{i-1}(p^{j+1} - p^j)\bar{x}^j$, see (12), if demand is in block i. Lagged consumption was included to correct for autocorrelation. The model was solved using OLS. As in the aggregate data all observations reflected consumption in the third consumption block, simultaneity which

Table 1: Regression estimates of per capita water demand (m^3/month/person)

	Descriptives		Water demand	
	Mean	Stand.Dev.	Coefficient	t-statistic
Intercept			2.2805	2.8114**
Price[1]	1.43	0.05	-0.5858	-1.7577*
Virtual Income[2]	744.23	25.74	0.0011	2.2590**
Time[3]			-0.0040	-3.3694**
Temperature[4]	19.55	2.57	0.0477	7.2488**
Rainfall[5]	118.30	90.94	-0.0004	-2.5994**
Rationing[6]	0.26	0.44	-0.0895	-3.1419**
Lagged consumption[7]			0.2928	3.3648**
Adjusted R^2	0.820		Durbin Watson test	1.666
F-statistic	42.015		Kolmogorov-Smirnov Z	0.815
Sample size	63			

Notes: * significant at 10% level, ** significant at 5% level, 1) Real/m^3, 2) Real/month/person, 3) month, 4) ^oC, 5) mm/month,6) no=0, yes=1, 7) m^3/month/person

is caused by the endogenous relation between price and consumption in a block price system, was not a problem and it was not necessary to use instrumental variable techniques (see e.g. Arbués and Villanúa, 2006). In the estimation, observations with studentized residuals exceeding ± 2.8 were removed, leaving 63 of the 64 observations. Finally, normality of residuals was tested using the Kolmogorov-Smirnov test. Results are presented in Table 1.

The coefficient signs are as expected. Higher prices, more rainfall and more rationing lead to a reduced demand, whereas higher income and higher temperatures result in an increase of demand. Higher temperatures or less precipitation will induce people to take more showers, do the laundry more often, water the garden more often and use the swimming pool more often. The price and income elasticities of demand, computed at the mean price and income values, are equal to -0.20 and 0.19, respectively. Water demand is inelastic and elasticities are rather low but within the ranges mentioned in many other studies reporting price elasticities of demand ranging between -0.05 and -0.75 and income elasticities ranging between 0.05 and 0.50 with a few studies reporting elasticities exceeding 1 or even 2 (Dalhuisen and Nijkamp, 2001; Arbués et al., 2003).

4 Scenario analysis

To illustrate the method discussed above, the distribution and welfare effects of changes in block pricing systems in the MRSP on different income groups will be analyzed, using the demand function estimated above. Demand changes, average prices, water bills, equivalent variation and social welfare will be determined for a number of price systems for five income groups in order to explore the effects of price changes. Extrapolating the demand function to other income groups may result in biased estimates of real demand and welfare effects, especially for the poorest and richest income groups, which could be prevented if the availability of micro data would allow for more detailed analysis. The analysis, however, will still give a good illustration of the method discussed above, which is the main objective of this paper, and give an indication of the income distribution effects of alternative price policies.

Using data on income distribution for the MRSP for the year 2000 (Minnesota Population Center, 2006), average income is determined for five income quintiles, which is used to calculate their demand and average price (see Table 2). The average expenses on water as percentage of income

Table 2: Yearly per capita income, per capita demand, water bill and average price per income quintile.

Income quintile[1]	Per capita income (Real/year)	Per capita demand (m^3/year)[2]	Water bill (Real/year)	Average price (Real/m^3)[3]	Water bill as % of income
1	1,257	42	63	1.48	4.98%
2	2,601	44	65	1.48	2.49%
3	4,361	46	68	1.48	1.55%
4	7,751	49	73	1.47	0.94%
5	28,753	68	105	1.54	0.37%
Average	8,945	50	75	1.49	0.83%

Notes: 1) Quintile 1 corresponds to the 20% of the population having the lowest income, quintile 5 corresponds to the 20% of the population having the highest income. Income shares are 2.81%, 5.82%, 9.75%, 17.33% and 64.29% for income quintile 1, 2, 3, 4 and 5, respectively. Income shares are for 2000, source: Minnesota Population Center (2006). 2) Consumers of quintile 1, 2, 3 and 4 have a monthly consumption per connection in block 3. Consumers of quintile 5 have a consumption in block 5. 3) Average price = water bill/demand.

are in line with data from the Brazilian Institute for Geography and Statistics (IBGE, 2003), which report for the MRSP water expenses as part of total expenses to be on average 0.77%. The differences between the poor and richer parts of the population, however, are considerable. Where the poorest 20% of the consumers spend on average almost 5% of their income on a consumption of 42 m^3 per year, the richest part of the population spends only about 0.4% of their income on a consumption of 68 m^3 per person per year. The richest consumers have a consumption in block 4, whereas the others have their consumption in block 3. The poorest population has a consumption in block 2 in some months. Average prices do not show a stepwise increase for the first four quintiles. So, although it is often claimed that a block price system is good for the poor, this can not be concluded for the current system in the MRSP which has a progressive price system only from the second till the fifth block and a very high price in the first block. Although average prices may show a slight progression, the water bill as a % of income for the poorest consumers is more than 14 times higher than for the richest consumers and still 5 times higher than for the consumers in the fourth income quintile.

In a scenario analysis, it is investigated for two types of scenarios what will be the distributional effects of introducing alternative pricing mechanisms (see Table 3 and 4). In the first scenario, a number of block price or block size changes are compared for which the welfare effects for the median consumer are negligible (i.e. for which EV = 0 for the consumers in block 3). In the second scenario, a number of block price changes are compared which are budget neutral for the water company, as results from the first scenario show that their revenues may change substantially. Remember that a partial equilibrium approach is adopted in which the indirect welfare effects of water suppliers' deficits or of changes in expenditures are not considered. An alternative and potentially interesting scenario would be the application of optimal nonlinear pricing (see e.g. Feldstein (1972); Renzetti (1992); Anderson (2004)). As cost data necessary for this are not available, this aspect is kept for future research.[7] The following scenarios are analyzed.

1. Block changes resulting in a zero welfare effect for the median consumer.

[7] It is recognized that many alternative scenarios of price change could be chosen. The scenarios chosen have as objective to explore whether the MRSP could adopt a price system that is more pro-poor without affecting to a too high extent total demand or total revenues for the water company.

(a) Decrease p^1 with 15%, increase p^2 and p^3 with 63.2% and do not change p^4 and p^5.

(b) Introduce a progressive block price system with $p^1 = 1$, $p^2 = 1.84$, $p^3 = 2.60$, $p^4 = 3$ and $p^5 = 4$ Real/m^3.

(c) Introduce a flat price system with $p^1 = p^2 = p^3 = p^4 = p^5$= 1.478 Real/m^3.

(d) Decrease p^1 with 15% only for the consumers of income quintile 1, 2 and 3, increase p^2 and p^3 with 63.2% for all consumers and do not change p^4 and p^5.

(e) Keep the prices at their base level but change the block structure into $\bar{x}^1$=5.25, $\bar{x}^2$=10, $\bar{x}^3$=25 and $\bar{x}^4$=50 m^3 per connection per month.

2. Block changes which are budget neutral for the water company.

(a) Decrease p^1 with 15%, increase p^2 and p^3 with 97.3% and do not change $p^4$and p^5.

(b) Introduce a progressive block price system with $p^1 = 1$, $p^2 = 2.27$, $p^3 = 2.60$, $p^4 = 3$ and $p^5 = 4$ Real/m^3.

(c) Introduce a flat price system with $p^1 = p^2 = p^3 = p^4 = p^5$= 1.480 Real/m^3.

(d) Decrease p^1 with 15% only for the consumers of income quintile 1, 2 and 3, increase p^2 and p^3 with 66.8% for all consumers and do not change p^4 and p^5.

The results of the scenario analysis shows some interesting patterns even though welfare effects are, as expected, small. The reader is reminded that a positive value for the equivalent variation represents a welfare increase whereas a negative value represents a welfare decrease. For all sub-scenarios of scenario 1, the effect of the policy change results in a zero welfare effect for the consumers in Quintile 3. The changes in demand, average price, water bill and compensating variation differ substantially between the different income groups. For example, if in Scenario 1a the price of the first block is reduced by 15% and the second and third block price increase by 63%, demand and water bills decrease substantially, especially for the poor. On average, welfare slightly decreases (-3.10 Real), but for the poor household welfare increases (+1.95 Real) whereas for the richest 40% of the population welfare decreases (-3.22 and -15.52 Real, respectively). A drawback is the reduction in revenues earned by the water company, which decreases by 4.5%. This reduction may, especially, cause problems in the quality of the water services provided. Moreover, in the results, equivalent variation increases, whereas demand decreases, which seems to be counter intuitive. The main reason for the increase of EV is a reduction of the average price due to which a higher equivalent income is needed to reach with the ex-ante price system the ex-post utility level. The reason why demand decreases, even though the average price falls, is that for this scenario the marginal price for the consumers increases (p^2 and p^3 increase) but that due to the reduction of p^1 the difference variable increases. The demand effect of an increase of the marginal price is much stronger than the income effect of an increase of the difference variable.

Next, if in Scenario 1b the price system is changed into a progressive block price system, the average welfare reduction is larger, especially so because of a larger negative welfare effect for the richest households. Moreover, welfare effects for the poorest are higher than in the other sub-scenarios. It is especially the larger reduction of the first block price which has a large effect on welfare for the poor as these fixed costs are such a large part of their water bill, especially compared to the situation for the richer groups. For this scenario, demand decreases as, like in Scenario 1a, the prices of the second till the fifth block increase. A positive effect is the large reduction of the water bill for the poorer consumers which is partly caused by a substantial reduction

Table 3: Effects of changing block price structures on demand, average price, water bill and equivalent variation for different income groups and effects on revenues collected by the water company for Scenario 1. Entries in bold are the percentage change of the revenues collected by the water company. Percentage changes are compared with the base results as presented in Table 2.

Income quintile	%change in water demand	Average water price (Real/m^3)	%change in water bill	Equivalent Variation (Real)
Scen.1a: p^1 -15%, p^2 and p^3 + 63.2% and p^4 and p^5 +0%				
1	-5.6%	1.42	-9.4%	1.95
2	-8.8%	1.42	-12.4%	1.29
3	-11.6%	1.43	-14.3%	0.00
4	-12.8%	1.49	-11.9%	-3.22
5	-0.03%	1.77	14.8%	-15.52
Average	-7.2%	1.54	**-4.5%**	-3.10
Scen.1b: p^1 = 1, p^2 = 1.84, p^3 = 2.6, p^4 = 3 and p^5 = 4 Real/m^3				
1	-7.9%	1.41	-12.4%	2.13
2	-9.3%	1.42	-13.1%	1.35
3	-12.6%	1.42	-16.0%	0.00
4	-16.3%	1.46	-17.0%	-3.79
5	-9.7%	1.85	8.4%	-25.58
Average	-11.2%	1.55	**-8.2%**	-5.18
Scen.1c: p^1 = p^2 =p^3 = p^4 = p^5 = 1.4784 Real/m^3				
1	-0.8%	1.48	-1.0%	0.16
2	-0.7%	1.48	-0.9%	0.09
3	-0.7%	1.48	-0.7%	0.00
4	-0.7%	1.48	-0.4%	-0.18
5	5.8%	1.48	1.7%	5.17
Average	1.1%	1.48	**0.06%**	1.05
Scen.1d: p^1 -15% for quintile 1, 2 and 3; p^2 and p^3 +63.2% and p^4 and p^5 +0% for all				
1	-5.6%	1.42	-9.4%	1.95
2	-8.8%	1.42	-12.4%	1.29
3	-11.6%	1.43	-14.3%	0.00
4	-12.8%	1.67	-1.4%	-10.88
5	-0.04%	1.88	22.0%	-23.19
Average	-7.2%	1.60	**-0.4%**	-6.16
Scen.1e: Block structure $\bar{x}^1 = 5.25, \bar{x}^2 = 10, \bar{x}^3 = 25, \bar{x}^4 = 50$				
1	0.0%	1.48	0.0%	0.00
2	0.0%	1.48	0.0%	0.00
3	0.0%	1.48	0.0%	0.00
4	-1.0%	1.48	-1.0%	0.14
5	-0.0%	1.63	5.8%	-6.10
Average	-0.2%	1.52	**1.4%**	-1.19

in demand. A negative effect is, however, a large reduction of the revenues collected by the water company. For this scenario, average prices increase stepwise with income.

In contrast, the flat price system presented in Scenario 1c does result on average in a welfare increase, but especially so for the richer households. Effects on welfare, demand and water bills for the poor are negligible. Welfare and demand effects are small as the average price only reduces marginally compared to the base situation. A positive effect is the negligible effect on revenues collected by the water company.

In Scenario 1d, in which the price of the first block only decreases for the consumers from quintile 1, 2 and 3, on average welfare decreases. The welfare increases for consumers from the poorest three quintiles are, of course, similar to those of Scenario 1a, but effects are worse for consumers from Quintile 4 and 5. For this scenario, average prices for the different income groups show a stepwise increase and especially the poorest benefit at the expense of welfare for the richest consumers. The richest consumers, in fact, compensate the water company for the subsidies given to the poor. This scenario is almost budget neutral for the water company. Such an income dependent price system is more favorable for the poor than for the rich, but one can wonder whether such a system is politically feasible and whether the administrative costs are not exceeding the equity gains. Note that an income dependent reduction of the fixed costs, closely corresponds to an income transfer to the poorer consumers.

Finally, a change in the block structure as proposed in Scenario 1e, does not result in any significant changes for the poor. In order to keep the median consumer at the same utility level, the change in block sizes should be such that a reduction in expenses due to the decrease of $\bar{x}^1$, is compensated by an increase of expenses due to an increase of the size of block 3 (i.e. by reducing $\bar{x}^2$), in which consumption is located. As consumers of Quintile 1 to 3 are all in consumption block 3, they are all affected in the same way. As a result also revenues by the water company will be unaffected. For consumers in Quintile 4 and 5, the welfare effect additionally depends on the change of the frontier of block 3 ($\bar{x}^4$). If $\bar{x}^4$ decreases by a large enough quantity, demand for both groups will be in block 4 and EV will decline as a larger part of consumption will be consumed at a higher price. If the block frontier increases, the reverse will happen.

Summarizing, these results show that specifically considering the welfare effects for different income groups gives more insight in the effects of price changes than just considering the average welfare effects. The average effect of a price change may be positive, and therefore appealing to decision makers, but its individual effects for particular groups may be the opposite. Moreover, a system that treats consumers more equally (e.g. a flat price system) will result in general in higher average welfare whereas the more pro-poor systems are detrimental for average welfare. The results, however, show that the reverse is true for welfare effects for the poor. It should be noted, however, that the welfare effects of the price changes proposed here are relatively small. The flat price system, which will result in the highest average welfare change, only has a marginal effect on welfare for the majority of the consumers compared to the benchmark, except for the rich. Note that a change from a progressive to a flat price system will have larger effects (the change from Scenario 1b to 1c will result in an average welfare increase of 6.23 Real, but a reduction of welfare for the first two quintiles of 1.97 and 1.26 Real, respectively; welfare of the richest group will increase with 30.75 Real). Moreover, a drawback of the pro-poor price systems, is that revenues collected by the water company may decrease, which might endanger the financial viability of the water services provision and therefore have important indirect welfare effects. This might be prevented by introducing an income dependent system, but at the expense of the rich.

Table 4: Effects of changing block price structures on demand, average price, water bill and equivalent variation for different income groups and effects on revenues collected by the water company for Scenario 2. Entries in bold are the percentage change of the revenues collected by the water company. Percentage changes are compared with the base results as presented in Table 2.

Income quintile	%change in water demand	Average water price (Real/m^3)	%change in water bill	Equivalent Variation (Real)
Scen.2a: p^1 -15%, p^2 and p^3 +97.3% and p^4 and p^5 +0%				
1	-5.6%	1.49	-5.0%	-0.83
2	-8.8%	1.49	-8.1%	-1.48
3	-12.7%	1.49	-11.9%	-2.82
4	-18.0%	1.51	-15.9 %	-6.83
5	-0.05%	1.95	26.7%	-28.04
Average	-8.4%	1.63	**0.0%**	-8.00
Scen.2b: p^1 = 1, p^2 = 2.27, p^3 = 2.6, p^4 = 3 and p^5 = 4 Real/m^3				
1	-13.8%	1.57	-8.5%	-5.48
2	-13.4%	1.60	-6.3%	-6.71
3	-14.2%	1.62	-5.9%	-8.41
4	-16.3%	1.67	-5.3%	-12.28
5	-9.8%	1.99	16.5%	-34.07
Average	-13.2%	1.72	**0.0%**	-13.39
Scen.2c: p^1 = p^2 =p^3 = p^4 = p^5 = 1.4795 Real/m^3				
1	-0.8%	1.48	-1.0%	0.11
2	-0.8%	1.48	-0.8%	0.04
3	-0.7%	1.48	-0.6%	-0.05
4	-0.7%	1.48	-0.4%	-0.23
5	5.7%	1.48	1.7%	5.09
Average	1.0%	1.48	**0.0%**	0.99
Scen.2d: p^1 -15% for quintile 1, 2 and 3; p^2 and p^3 +66.8% and p^4 and p^5 +10% for all				
1	-5.6%	1.43	-9.0%	1.65
2	-8.8%	1.43	-11.9%	0.99
3	-11.9%	1.44	-14.4%	-0.32
4	-13.5%	1.67	-2.0%	-11.33
5	-0.04%	1.90	23.3%	-24.53
Average	-7.4%	1.61	**0.0%**	-6.71

Next, Scenario 2 compares four different block price systems for which the effects on the revenues for the water company are negligible. Changing the block sizes without affecting the revenues is also possible, but will not be further considered here. Scenario 2a shows that a reduction of the first block price by 15% and an increase of the second and third block price by 97.3%, will result in a welfare reduction (-8.00 Real) which is negative for all consumers and which is largest for the richer consumers (-28.04 Real). Their water bill increases, whereas the bill for the poorer consumers decreases. Due to the larger increase of p^2 and p^3, average prices do increase for all consumption quintiles, due to which demand decreases more than the water bill. An interesting observation is that a revenue neutral price system does not exist if prices p^2 to p^5 all increase with the same percentage; increasing as well p^4 will result in a decrease of revenues for the water company due to a lower demand of consumption quintile 5. Note that compared to Scenario 1a, the prices p^2 and p^3 have to increase substantially more.

Scenario 2b shows that welfare effects are worse for (almost) all consumers if a progressive price system is introduced. Compared to Scenario 1b, in order to reach budget neutrality, p^2 has to be considerably higher (2.27 Real instead of 1.84 Real) which has a considerable effect on water demand and individual welfare for all consumers. It is an interesting observation that combining the objective of having a pro-poor price system with the objective of revenue neutrality for the water company is difficult even though the progressive price system is said to be pro-poor. In order to reach revenue neutrality p^2 and p^3 have to increase to such an extent that the positive welfare effects of decreasing p^1 are nullified.

The results of Scenario 2c are comparable to those of Scenario 1c, but are presented because of the importance of the flat price system. Note that only for the flat and for the income dependent price system (Scenario 2c and 2d), a budget neutral price change results in a positive welfare effect for the poor. A flat price system is moderately positive for the rich (+5.10 Real), negligible for the poor (+0.11 Real) and on average moderately positive for welfare (+1.00 Real). The income dependent price system has a negative average welfare effect (-6.71 Real) and a negative effect on welfare for the rich (-24.53 Real). The poor benefit (+1.65 Real) as their fixed fees (price p^1) are reduced.

In summary, these results show that there is a trade off between a more equitable price system that is welfare increasing for the poor and revenues collected by the water company. Reaching both objectives with changes in the price system is not feasible and alternative policies will be needed which can either be subsidizing the water company or financially supporting the poorer households via other price or income measures. Note that the results only give the partial equilibrium effects of price changes. A decrease in financial viability of the water company will negatively affect a welfare increase of individual consumers and a subsidy to either the water company or the poorer consumers has to be financed in one way or the other. Finally, changing the current price system into a flat price system which leaves the revenues of the water company unaffected would for most consumers result in only a small effect on average prices, demand, water bill and welfare. The average welfare change is small for most households and moderately positive for the rich. So, like in Scenario 1, albeit the flat price system is welfare improving it is at the expense of the poor.

Finally, social welfare levels for the different scenarios are discussed. The Atkinson social welfare measure as discussed in (14) gives an aggregate welfare measure which takes into account inequality aversion. The higher inequality aversion, the more emphasis will be put on the welfare effects for the lower income groups. The results in Table 5 show, as can be expected, that the

Table 5: Percentage changes in social welfare for the different price scenarios for different levels of inequality aversion. Percentage changes are compared to the base level of social welfare. Figures in bold give the subscenarios yielding the highest level of social welfare.

Scenario	$\rho = 0$	$\rho = 0.5$	$\rho = 1$	$\rho = 1.5$	$\rho = 2$
Base Scen.	8945	164	8.52	-0.032	-0.00031
Scen.1a	-0.035%	-0.006%	**0.0026%**	0.028%	0.086%
Scen.1b	-0.058%	-0.013%	0.0019%	**0.029%**	**0.092%**
Scen.1c	**0.012%**	**0.004%**	0.0008%	0.003%	0.008%
Scen.1d	-0.069%	-0.022%	-0.0004%	0.020%	**0.077%**
Scen.1e	-0.013%	-0.004%	-0.0005%	-0.0006%	-0.0003%
Scen.2a	-0.089%	-0.041%	-0.0088%	-0.034%	-0.066%
Scen.2b	-0.150%	-0.092%	-0.0273%	-0.142%	-0.328%
Scen.2c	**0.011%**	**0.004%**	**0.0006%**	0.002%	0.005%
Scen.2d	-0.075%	-0.026%	-0.0016%	**0.014%**	**0.061%**

difference in social welfare between the different scenarios are small. Water expenses are on average about 0.83% of total income (see Table 2) and as a consequence, a small change in water prices only result in a small change in equivalent income. If no account is given to inequality (for $\rho = 0$), a flat price (Scenario 1c and 2c) gives the highest level of social welfare. This scenario is also the only scenario considered that results in a positive average equivalent variation. If more account is given to inequality, Scenario 1a, 1b and 2d, become slightly better for social welfare. Even though average equivalent variation is negative and even though equivalent variation for the higher income groups does decrease, social welfare increases more than in the other scenarios. If no account is given to budget neutrality, the negative effects of an income dependent system (Scenario 1d) on the rich make that a smaller fixed fee (Scenario 1a) or a progressive price system (Scenario 1b) score better. If budget neutrality is considered, jointly with a reduction of the fixed fee, an income dependent system can compensate the water company for the reduced revenues obtained from the poor. Due to the skewed income distribution in the MRSP, already for low levels of ρ, the more pro-poor price systems give a higher level of social welfare than the flat price system. The social welfare indicator confirms the results already given above that there is a trade off between income distribution and welfare. The more account is given to inequality, the more pro-poor pricing schemes should be. Furthermore, the lower social welfare levels for most subscenarios of Scenario 2 compared to those in Scenario 1 also confirm the trade off between revenue neutrality and income distribution. Due to the very small differences in social welfare between the different scenarios, however, a final choice on the optimal price system needs a more in depth analysis of the transaction costs of the different systems and of the indirect welfare effects of cross subsidization through pricing systems.

5 Conclusions

In this paper, the welfare and distribution effects of changes in block price systems are evaluated. A methodology is discussed with which equivalent variation can be determined in case of a block price system with a linear demand function. This paper shows that determining the exact welfare effects of changes in block price systems with equivalent variation is possible on the basis of the Marshallian demand function and that it is not much more difficult than determining the less exact measure of consumer surplus.

The methodology has been applied to evaluate welfare and distribution effects of residential water demand in the Metropolitan Region of São Paulo. Currently, the main water company in the MRSP applies a five-tiered block price system in which the prices in the second till the fifth blocks increase stepwise and in which the price in the first consumption block is higher than the price in the fifth block. Using aggregate, monthly data on consumption, prices, income, rainfall, temperature, rationing and population for the period July 1997 to December 2002, a linear demand function has been estimated. Price and income elasticities are -0.20 and 0.19, respectively. The inelasticity shows that it is difficult to reach a substantial reduction of demand, especially for the richer consumers, by using only pricing policies. Additional policies will be needed to make people more aware of the water scarcity problems in urban areas.

Using the demand function, the effects of a number of scenarios of alternative price systems are evaluated for five income groups. The results show that although the average water price for the richer households is higher than for the poorer, water bills for the poor are a substantial part of their income whereas they are very small for the rich. The scenario analysis shows that, as can be expected, a flat price system is better for the rich and a progressive block price system is in general better for the poor. Moreover, if no account is given to inequality, social welfare is highest in a flat price system. If inequality aversion increases, pro-poor systems and income dependent systems, result in higher social welfare. The individual welfare effects, however, are only marginal. As a result no major income distribution changes can be reached in the MRSP if the water pricing system would be turned into a more pro-poor system. Furthermore, one can question whether the transaction costs of the administrative system necessary for an income dependent or pro-poor price system do not outweigh the welfare gains. An additional analysis of these transaction costs would be required for answering this question. Finally, there is a trade off between the financial situation of the water company and a more equitable price system that is welfare increasing for the poor. Compared to the current price system, a progressive block price system that does not affect the revenues collected by the water company, results in a welfare loss for all.

Although price systems that consider income distribution may not be as good for average welfare as flat price systems, their direct effects on poverty and social welfare should not be neglected and are worthwhile to look at. As for the MRSP these effects turned out to be small, it can be questioned whether it would not be better and cheaper to use other instruments than water price changes to reach a situation in which consumption by the rich is treated differently than consumption by the poor.

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A Appendix: Derivation of utility level u_1.

The definition of indirect utility shows that in case of a flat price p and budget y, utility is equal to $u = V(p, y)$, see (4). In case of a kinked budget curve, the exact definition depends on the segment on which demand $x_1$is located, see also Figure 1, 2 and 3, and see also the discussion on $e^b(\boldsymbol{p^b}, u_1)$. From this it follows that:

- if $x_1 = x\left(p_1^1, y_0\right) < \bar{x}$, then $u_1 = V\left(p_1^1, y_0\right)$
- if $x_1 = x\left(p_1^2, y_0 + \left(p_1^2 - p_1^1\right)\bar{x}\right) > \bar{x}$, then $u_1 = V\left(p_1^2, y_0 + \left(p_1^2 - p_1^1\right)\bar{x}\right)$

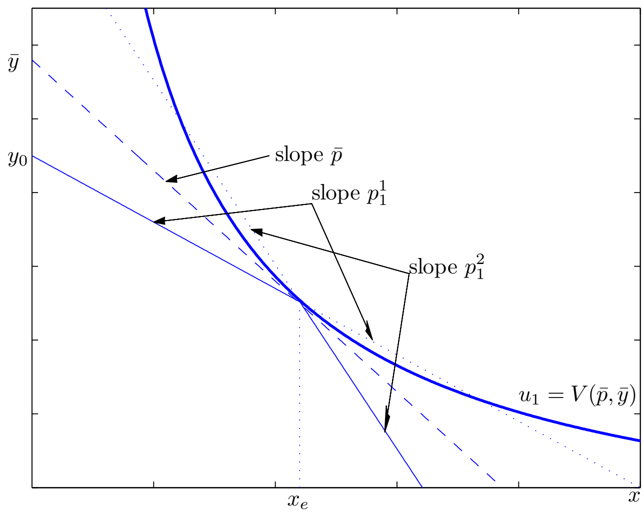

Figure 3: Schematic representation of utility if demand x_1 is at the kink of the budget curve.

- else x_1 is at the kink and it can easily be seen that in case of a convex budget curve $u_1 < V\left(p_1^1, y_0\right)$ and $u_1 < V\left(p_1^2, y_0 + \left(p_1^2 - p_1^1\right)\bar{x}\right)$. It can easily be seen from Figure 3 that $u_1 = min_{\bar{p}}\left\{V\left(\bar{p}, y_0 + \left(\bar{p} - p_1^1\right)\bar{x}\right) \middle| p_1^1 \leq \bar{p} \leq p_1^2\right\}$. From (2) follows that $\frac{\partial^2 V}{\partial \bar{p}^2} > 0$ and $\frac{\partial V}{\partial \bar{p}} = 0$ for $\bar{p} = \left[\bar{x} - \beta y_0 - \boldsymbol{\gamma z} + \beta p_1^1 \bar{x}\right] / \left(\beta \bar{x} + \alpha\right)$. As $y_0 - p_1^1 \bar{x} = \bar{y} - \bar{p}\bar{x}$, it follows that $\bar{y} = y_0 + \left(\bar{p} - p_1^1\right)\bar{x}$, which gives all ingredients to derive $u_1 = V\left(\bar{p}, \bar{y}\right)$.

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