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Demand and Equity Effects of Water Pricing Policies

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Demand and Equity Effects of Water Pricing Policies

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Abstract

Worldwide, water scarcity threatens delivery of water to urban centres. Water pricing is often recommended to reduce demand. In this paper, demand and equity effects of water pricing policies are examined in a block pricing model that is applied to the Metropolitan Region of São Paulo. Water demand functions are estimated using marginal and average price models based on monthly data for the period 1997-2002. Price elasticities of water demand range between -0.46 and -0.50 and income elasticities between 0.39 and 0.41. For the current combined regressive-progressive block price system, the poor spend almost 6% of their income on water. The rich only pay 0.6% of their income whereas they consume three times as much. A progressive block price system will result in a more equalized income distribution. However, for the system considered here, it will result as well in higher water demand and lower revenues for the water company.

1. Introduction

For an increasing number of countries, water scarcity has become a major problem. Supply fails to meet demand causing pressure between different water users, uses or regions. Regional differences are large, as within a country, some regions may have excess water availability whereas other regions face seasonal shortages. For the fast growing mega-cities in the world, keeping pace with urbanization is difficult for local authorities and water companies and the expansion over several river basins makes river basin management challenging (Lundqvist et al., 2005). For example, the Brazilian Metropolitan Region of São Paulo (MRSP) suffers from water shortages almost yearly, due to which SABESP (the main Energy, Water Resources and Sanitation Secretary of the MRSP) has to ration water distribution. Water supplies in the MRSP come for about 40% from the Alto Tietê Basin, located almost entirely within the MRSP, and for 60% from neighbouring basins. The MRSP houses almost 50% of the state's population whereas it only occupies 2.7% of its territory. From the Alto Tietê Basin, 80% of water withdrawals are for urban water use, whereas the basin is also used to drain off industrial effluents and as domestic sewer, has some protected areas within urbanized areas, and is affected by disordered urbanization in the spring areas. In Brazil, water resources are considered a public good for which the State holds management, cleaning and maintenance responsibility. River basin committees, consisting not only of representatives of the State and the cities and municipalities in the basins but also of participants from civil society, decide on issues like prices, expenses and allocation of water use rights (Jacobi, 2004; Lundqvist et al., 2005). Currently, SABESP applies a combined regressive-progressive block pricing system, with water prices for the second till the fifth consumption block increasing stepwise. The charge for the first 10 m^3 is fixed, regardless of whether it is consumed, with a converted price per cubic meter which is considerably higher than for the other blocks. This system assures a safe minimum level of revenues for the water company. Many Latin American cities have a comparable price system, but with a first block of 15 m^3 (Walker et al., 2000). The water tariffs in the different blocks are different for residential, commercial, industrial or agricultural use.

As the economic importance of the MRSP for Brazil is substantial and the water supply problems will have clear impacts on social stability and economic productivity, solutions for dealing with the water shortages are necessary. For that reason, the main aim of this paper is to study the demand and equity effects of water price policies for different income groups. Moreover, it will be assessed to what extent price policies will in the medium to long term be cancelled out by demographic and climatic changes. For this purpose, a water demand function will be estimated for the MRSP on the basis of data on monthly water consumption, prices, income, population size, rainfall, temperature and water rationing. The main, extensively debated theoretical and estimation issues, dealing with choosing the appropriate price variables, simultaneity and auto-correlation, are carefully taken into account. As more urbanized metropolitan regions suffer from the same problems, results from this analysis have a broader scope than just the metropolitan region of São Paulo.

A novel element of this study is its special focus on the equity effects of water pricing policies. Although, the last decades, many empirical studies estimated price and income elasticities of water demand (see e.g. Espey et al, 1997; Arbués et al., 2003 and Dalhuisen et al., 2003 for an overview), and many authors emphasize the importance of water pricing for water conservation (Azevedo and Baltar, 2005; Garcia, 2005), equity effects of pricing policies are still a largely underexposed element in literature. Estimates of price elasticities usually range between -0.05 and -0.75 whereas income elasticities are in most cases in the range of 0.05 and 0.5. Moreover, other variables reported to be significant include climatic variables, age distribution and household size (see e.g. Lyman, 1992; Hewitt and Hanemann, 1995; Renwick and Green, 2000). Price responsiveness is reported to be dependent on a number of factors, making the design of appropriate demand management policies complex (Renwick and Green, 2000; Rietveld et al., 2000; and Krause et al., 2003). On the basis of the studies focussing on the equity effects of pricing policies, no general conclusions can be drawn. A large study in 17 Central American cities demonstrated large differences in prices paid, water demanded and price responsiveness between households connected and those not connected to tap water (Strand and Walker, 2005). The authors observe little income-related differentiation in consumption, an almost equal distribution of price subsidies between income quintiles and a low to zero progressivity in the subsidy system, in the sense that the poor are not favoured more than the rich (Walker et al., 2000). Price increases affect the poor harder than the more wealthy, except when many poor households are still not connected. In such situations, water infrastructural investments using revenues collected from price increases will substantially help the poor. Rietveld et al. (2000) for Indonesia and Hajispyrou et al. (2002) for Cyprus point at the negative welfare effects of block price systems compared to a flat price system. A flat price system removes prices distortions but at the expense of some groups of consumers, which usually are the low income groups or the larger households. For Western countries, empirical evidence shows that equity effects of block pricing schemes are ambiguous (Hajispyrou et al. 2002).

The paper proceeds as follows. The second section presents a brief review of the water demand literature and the main discussion points to be considered when estimating a water demand function. The third and fourth sections describe the data, methodology, estimation results and analysis, respectively. In these sections, the main question of the study will be answered: Are price policies effective to decrease residential water demand in MRSP; how will these policies affect equity and will population and climate change increase the need for such policies? The paper ends by drawing some conclusions on the effects of the policies analysed.

2. Estimating Water Demand: a review of methodological issues

In the last decades much has been written on problems encountered when estimating water demand functions in a block price system (see e.g. Arbués et al. (2003) for an overview). While using micro-level data is optimal to account for inter-household differences in price-levels, this study as well as most other studies rely on aggregate data because disaggregate data are not available (Hewitt and Hanemann, 1995; Pint, 1999). For the same reason, panel data methods remain under-explored (Pint, 1999; Arbués et al.,2000; Martínez-Espiñeira and Nauges, 2001), whereas the use of random coefficient models or dynamic specifications could shed more light on the seasonal effects of water demand policies and the seasonal trends in water demand. Given the type of data available, two important issues remain: (1) whether to use marginal or average price in the estimation; and (2) the simultaneity problem between price and quantity.

In a block price system, average and marginal prices differ. It depends on the way consumers are informed whether they respond to average or marginal prices or to lagged prices. In much of the earlier work, marginal price is the only price related variable included in water demand functions (Arbués et al., 2003). Taylor (1975) is one of the first commenting on this, stating that the use of average or marginal price does not represent reality. He indicates that there is also an income effect due to the change of price when consumption moves to another consumption block. Nordin (1976) complements Taylor's comments suggesting the use of marginal price and a difference variable which represents the income effect. This variable represents the difference between the consumer's actual water bill and the expenditures in case the entire consumption were charged at the marginal price. Its effect on water demand is hypothesized to be of the same magnitude of the income effect but with opposite sign. This, however, is not confirmed by much of the empirical literature in which difference variables are not significant or do not have the proper magnitude (Billings and Agthe, 1980; Jones and Morris, 1984) or are of incorrect sign and not highly significant (Howe, 1982; Foster and Beattie, 1979, 1981; Chicoine and Ramamurthy, 1986). Reasons reported are that consumers are poorly informed, that difference variables are only a very small fraction of household income (Nieswiadomy and Molina, 1989), or that estimates are biased (Schefter and David, 1985). Moreover, due to lags in payments of water bills, lagged average prices instead of marginal prices and difference variables should be used (Charney and Woodward, 1984). An important comment on Taylor and Nordin's approaches is that marginal price would only result in superior statistical estimates if consumers are well informed about the pricing system (Billings and Agthe, 1980; Foster and Beattie, 1981, Griffin and Martin, 1981). Well-informed consumers will react to marginal price changes and Nordin's difference variable. However, due to information costs, most consumers will not spend much effort on keeping informed about (intra)marginal price changes and just respond to average price (Billings and Agthe, 1980; Bachrach and Vaughan, 1994). For that reason, Opaluch (1982, 1984) proposes a model with a decomposed measure of average and marginal price in order to detect whether consumers respond to average or marginal prices. Chicoine and Ramamurthy (1986) conclude from testing Opaluch's model that the appropriate behavioural model is an empirical question that must be addressed on a case-by-case basis.

Next to the problem of adopting the appropriate price variable, a simultaneity problem arises because in a block rate system marginal and average prices are endogenously determined by quantity demanded. Therefore, the explanatory variables and error term may be correlated, in which case parameter estimation using OLS will be biased and inconsistent and instrumental variable (IV) techniques, such as 2SLS and 3SLS are to be preferred. Some studies, however, show that OLS and IV techniques give similar results for water demand elasticities and, therefore, a simpler OLS may be appropriate even in the presence of simultaneity (Jones and Morris, 1984; Chicoine and Ramamurthy, 1986; Saleth and Dinar, 2000). However, other studies do find biased OLS results due to simultaneity (Nieswiadomy and Molina, 1988). Testing for simultaneity by using a Hausman test (Billings and Agthe, 1980) easily shows whether simultaneity is present and whether IV techniques should be used.

3. Data and model

The model used in this study is based upon the neoclassical theory of consumer demand, which specifies four determinants of quantity demanded: price, prices of related goods, income, and preferences. As water has no close substitutes, we assume all cross-price elasticities to be negligible. Below, we discuss the data used to specify the remaining three factors and the econometric model used to estimate water demand.

Data for monthly water consumption for the period 1996 – 2004 are obtained from SABESP, which provides its services to 39 municipalities which almost cover the entire MRSP. The data cover total consumption, total residential consumption, the number of connections, and the occurrence of rationing. For converting residential consumption to per capita consumption, we interpolate yearly population data obtained from SEADE, the State Data Analysis System Foundation, to monthly data. Residential consumption corresponds approximately to 80% of total consumption and per capita consumption follows a similar pattern as total residential consumption. There is no clear trend in any of the consumption variables (see Figure 1).

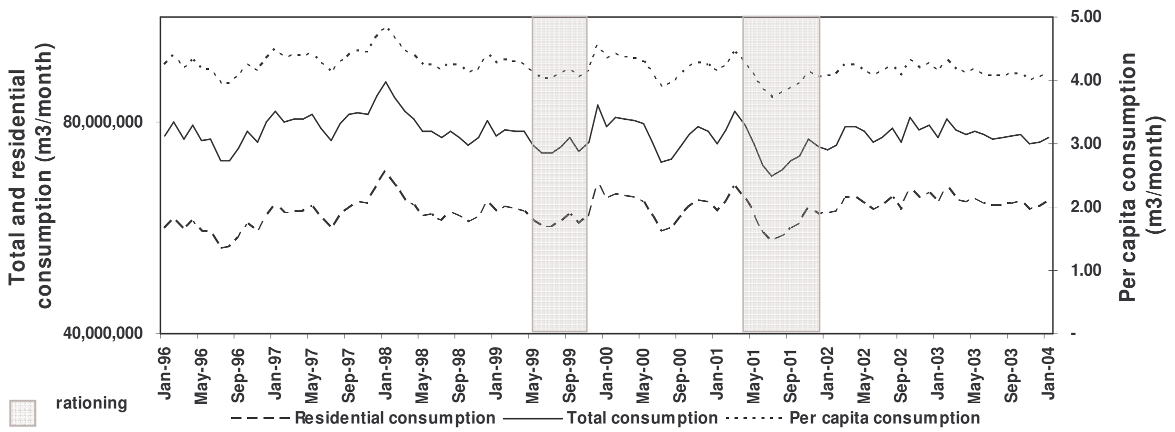

Figure 1. Total, residential and per capita water consumption in the MRSP for the period 1996-2004 (in m^3/month).
Source: data obtained from SABESP and SEADE

Data on water prices for the five consumption blocks are available from SABESP for the period July 97-December 2004. Prices are deflated using the Brazilian price index IPCA/IBGE, which is available on a monthly basis. Therefore, the resulting time series covers prices that change monthly (see Figure 2). The first block price, p_1, is the highest and applies to the first $10m^3$ of water consumed in a year. For the other blocks, prices increase stepwise with the price in block 5 still lower than that in block 1. Block prices p_2, p_3, p_4, and p_5 (in Real/m^3)[1] are charged for quantities consumed per connection in the ranges of 11-20 m^3/year, 21-30 m^3/year, 31-50 m^3/year, and 50 m^3/year onwards, respectively. In the data set, average consumption per household (total residential water consumption divided by number of connections) is always in the third block. Although we are aware that individual households may be in different consumption blocks each with its own marginal price, because our data are aggregated for all households, we interpret p_3 as the marginal price of household water consumption.

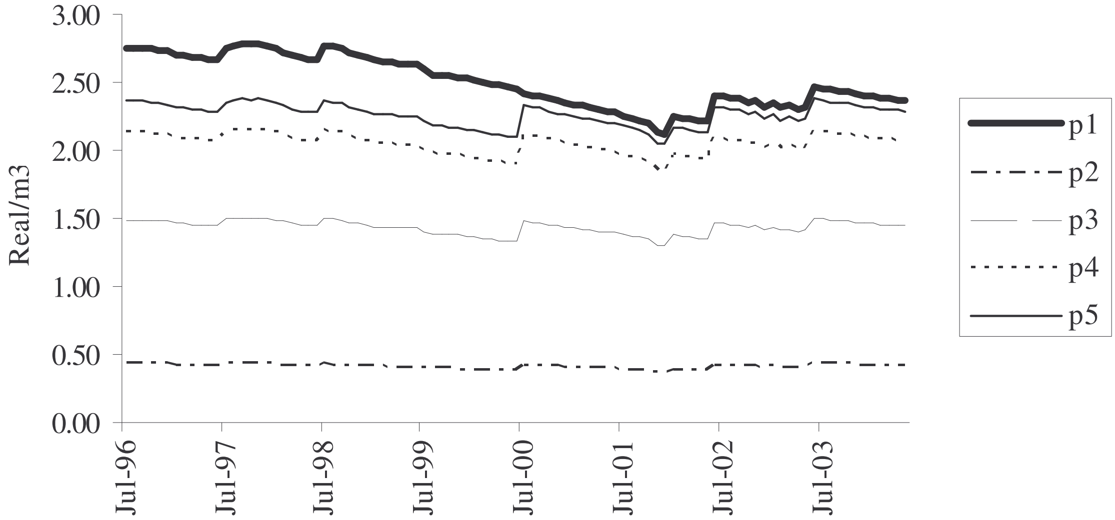

Figure 2. Block prices for water in the MRSP for the period 1997-2002 (in Real/m^3, base year 1997). Source: data obtained from SABESP

Income is expected to be an important determinant of residential water demand. The water company suggests that the income effect in water consumption is more important than the price effect. Yearly income data at the MRSP level for the period 1996-2003 are obtained from the Brazilian Institute of Geography and Statistics (PNAD/IBGE). Income is deflated using the IPCA/IBGE price index (see Figure 3). The main reasons of the peculiar form of income development are most likely the differences in economic growth between 2001 and 2002 and the elections in 2002.

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[1] 1 Real = € 0.37.

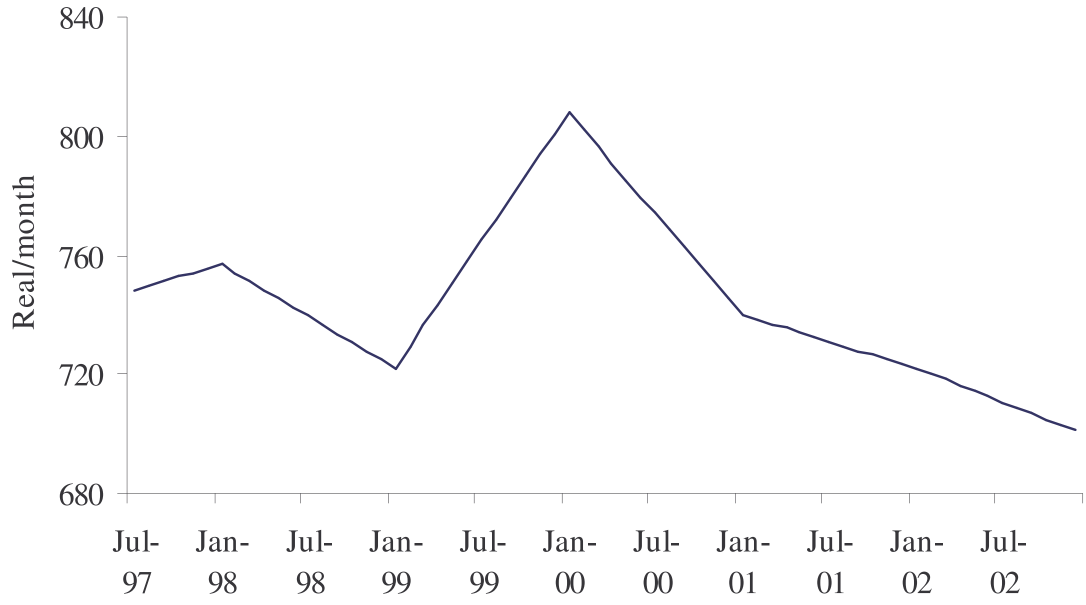

Figure 3. Real monthly per capita income in the MRSP for the period 1996 – 2003 (in Real/month, base year 1997).

Source: IBGE

At the aggregate level, water preferences are best measured by including monthly data on rainfall and temperature, which is provided by the Institute of Atmosphere and Geography (IAG). For example, demand for garden watering will be highest in the dry season, whereas demand for water will increase when temperatures are high, because of high evaporation and high demand for water for swimming pools, laundry and washing.

Using the data discussed above, monthly water demand functions are estimated. Because of the lack of consensus on the most appropriate price specification to be used, we first use Opaluch's (1982) approach to show whether an average or a marginal price model should be adopted. For our data, the null hypotheses of Opaluch's model to test to which prices consumers respond are both not rejected, showing that it can not be concluded whether consumers respond to average or marginal prices. For that reason, we estimate two models – one based on average price and one on marginal price – and compare the results.

The average price model for month τ is specified as follows:

$$q_\tau = \alpha_0 + \alpha_1 ap_\tau + \alpha_2 y_\tau + \alpha_3 t_\tau + \alpha_4 r_\tau + \alpha_5 ra_\tau + \alpha_6 time_\tau + \varepsilon_{1\tau},$$

in which q_τ is per capita consumption of water (m^3/month), ap_τ is the average price (Real/m^3), y_τ is per capita income (Real/month), t_τ is average temperature in month τ (degrees Celcius), r_τ is rainfall (mm/month), ra_τ is a dummy for whether rationing occurred in month τ and $time_\tau$ is a time trend.

For the marginal-price model, we followed the specification of Nordin (1976):

$$q_\tau = \beta_0 + \beta_1 mp_\tau + \beta_2 d_\tau + \beta_3 y_\tau + \beta_4 t_\tau + \beta_5 r_\tau + \beta_6 ra_\tau + \beta_7 time_\tau + \varepsilon_{2\tau},$$

in which mp_τ is the marginal price (Real/m^3) and d_t the difference variable (Real/month), *i.e.*, what consumers actually pay minus what they would pay if the only price were the marginal price. For example, if consumption is in block 3, then $mp_\tau = p_3$ and $d_\tau = (p_1q_1 + p_2(q_2\text{-}q_1) + p_3(q_\tau\text{-}q_2)) - p_3q_\tau$ in which q_1 and q_2 are the maximum consumption levels in block 1 and 2, respectively.

We test for endogeneity in both equations, using block prices as instruments. As the marginal price is very highly correlated with some of the block prices, instrumentation makes no sense, and we use OLS for the marginal price model. For the average price model, exogeneity is rejected at the 5% level, and we use 2SLS estimation. Moreover, Breusch Godfrey tests for autocorrelation indicate that autocorrelation is present in both models, which is corrected by including lagged consumption and lagged rainfall. Finally, we use Chow tests to assess potential differences in coefficients between periods with and without rationing. As we can not reject equality of coefficients, we pool all data in single regressions and include only a dummy for rationing, as specified in the mathematical representation of the models above.

4. Results and analysis

Estimation results

The results for the average and marginal price models are very similar (see Table 1). All coefficients are significant at the 5% level, and the signs of the coefficients are as expected. The price variables are negatively correlated with consumption in all the models, as expected from demand theory. The same holds for rainfall and the rationing dummy. The more it rains (in the current and in the previous month), the less water will be consumed, because less garden watering will be necessary and there will be less swimming-pool activities. When there is water rationing, water use logically decreases. The time trend coefficient also has a negative sign, which shows that per capita water consumption has decreased over time.

Table 1: Regressions estimates per capita water demand for alternative price specifications.

	Descriptives		Average price model (2SLS estimation[a])		Marginal price model (OLS estimation)	
Variables	mean	s.d.	Coefficient	t statistic	Coefficient	t statistic
Average price	1.47	0.09	-1.43779	-3.47		
Marginal price	1.43	0.06			-1.34114	-3.11
Difference	1.06	1.37			-0.06629	-3.15
Income	745.20	26.43	0.00220	3.93	0.00232	3.80
Temperature	19.61	2.59	0.05165	7.58	0.05239	7.53
Rainfall	118.61	90.27	-0.00035	-2.21	-0.00036	-2.23
Rationing dummy	0.26	0.44	-0.08628	-3.21	-0.08634	-3.15
Time trend			-0.00859	-4.43	-0.00886	-4.33
Lagged consumption			0.25804	3.15	0.27596	3.22
Lagged rainfall			-0.00039	-2.54	-0.00040	-2.50
constant			2.99163	4.07	2.69738	3.24
Adjusted R^2			0.84		0.83	
F statistic			41.90		35.91	
Sample size			65		65	

Notes: a) Instrumented ap_τ; instruments: p_1, p_2, p_3, p_5 and exogenous model variables. All coefficients are significant at the 5% level.

Temperature, income and lagged water consumption affect current water consumption positively. Warm weather will induce people to take more showers, do their laundry more frequently, water their garden frequently, and use swimming pools, and therefore the use of water will increase. The higher income, the higher water consumption will be. As income increases, the water bill will correspond to a smaller part of the total expenditure. In lower income families, the water bill corresponds to a more significant part of the income, and they will be more concerned in saving water. Lagged water consumption also affects current consumption positively, because this variable includes some of the individual preferences and habits driving demand and as it takes time for habits to adjust.

According to Nordin's specification, the difference variable coefficient should have the same magnitude of the income coefficient, but with opposite sign. Like in most previous studies, this hypothesis is strongly rejected. The literature gives several explanations for this deviation of empirics from theory. Schefter and David (1985) argue the use of aggregate date results in incorrect specification of the model, which leads to biased results. On the other hand, Nieswiadomy and Molina (1989) reason that the observed deviation may reflect the real situation, since consumers often lack information about the tariff structure and that the difference variable amounts to only a small fraction of total household income.

To assess the impact of changes in price and income on water demand, we use the regression results to compute elasticities (see Table 2). The elasticities resulting from the two models are very similar. Water demand is shown to be price inelastic, but still reactive to prices: a one percent increase in prices results in a 0.5 percent decrease in water demand. Income is also an important factor in water consumption. A one percent increase in real income results in a 0.4% increase in water demand.

Table 2. Price and income elasticities of water demand

	Average price model	Marginal price model
Average price	-0.50	
Marginal price		-0.46
Income	0.39	0.41

Note: All elasticities are computed at mean values of demand and price or income.

Scenario analysis

The demand function estimates show that income and price have a clear influence on water demand. Price increases will reduce demand, which may in the future be cancelled out by demand increases due to economic or population growth. In order to assess the effects of alternative price policies, we analyse to what extent price changes will affect demand for the different income quintiles. Moreover, we will carefully look at the equity effects of policy changes. For this purpose, in the marginal price model as estimated above, the variables price and income and the difference variable will be adjusted according to the policy introduced and the income group considered. We are aware that extrapolating the results from our analysis may result in biased estimates of real demand, especially for the low and high income groups, but argue that the analysis still gives a good indication of the income distribution effects of price policies.

Table 3 shows the share of national income and the average income levels for people in each of the five income quintiles. Data on income distribution for São Paulo are not available and therefore we used data for the whole of Brazil. Even though income distribution might be somewhat different in São Paulo, as it is one of the economic centres of the country, the data clearly show the effect of the current price system on the poorer parts of the population. The poorest 20% of the population spends about 5.8% of their income on water. On the other hand, the richest 20% of the population only spends 0.6% of their income on water, even though they consume more than three times as much. The average costs of water of 1.0% of the average annual income are in line with micro data from the Brazilian Institute for Geography and Statistics (IBGE), which report for the MRSP water expenses as part of total expenses to be on average 0.77%. The analysis clearly shows that under the current water pricing system, the unequal income distribution in Brazil induces the poorest part of the population to spend a considerable part of their income on water. Moreover, due to the combined regressive-progressive block system, the average water price for the poorest part of the population is higher than for the other income groups. This implicitly means that the poor subsidize water demand for the more wealthy inhabitants.

Table 3. Income, demand and water bill per income quintile.

Income quintile[1]	Income share[2]	Average annual per capita income (Real)	Household demand (m^3)[3]	Water bill (Real)	Average price (Real/m^3)[4]	Water bill as % of household income
1	2.16%	966	194.1	337.4	1.74	5.8%
2	5.41%	2419	214.4	345.7	1.61	2.4%
3	10.06%	4499	242.7	362.4	1.49	1.3%
4	18.31%	8188	293.7	433.0	1.47	0.9%
5	64.06%	28647	638.3	1104.2	1.73	0.6%
average		8944	316.6	516.5	1.63	1.0%

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; 2) incomes shares for 1998, source: World Bank (2003); 3) average number of consumers per connection in São Paulo is 6.01, number of connections and population data obtained from SABESP and SEADE, www.seade.gov.br; 4) average price = water bill / household demand.

Effects of changes in block prices are presented in Table 4 for seven scenarios of price changes. We analyse the following scenarios (for average values of current monthly prices, see Table A1 in the appendix):

a) Increase all prices with 10%
b) Decrease p_1 with 25% and keep the other prices at their original level
c) Decrease p_1 with 40%, increase p_2 and p_3 with 10% and increase p_4 and p_5 with 25%
d) For income quintile 1, 2 and 3, decrease p_1 with 40%, increase p_2 and p_3 with 10% and increase p_4 and p_5 with 25% and for income quintile 4 and 5, keep p_1 at its current level, increase p_2 and p_3 with 10% and increase p_4 and p_5 with 25%
e) Set all prices at 1 Real/m^3
f) Set all prices at 1.5 Real/m^3
g) Set all prices at 2 Real/m^3

In Scenario a, in which all block prices increase with the same percentage, the poorer part of the population is most affected. For them, demand and average price change the most, and the water bill becomes even a larger percentage of their income. Price increases are, however, an effective instrument to reduce water demand. An overall price increase of 10% results in a reduction of total water demand of 4.1%, even though it is especially at the expense of water demand for the poorest inhabitants. On the other hand in Scenario b, in which the price of the first block decreases, especially the poor population benefits. For them, a reduction of p1 with 25% results in an increase of demand with almost 16% and a considerable reduction of the average price and the water bill. For this scenario, the entire population benefits even though the richer population will be less affected. For the water company, however, revenues collected will decrease. For a reduction of p1 with 25%, their revenues decrease with almost 8%. Such a reduction might endanger their financial situation and therefore the quality of the water distribution system.

Table 4. Effects of changes in the price system on demand, average price and water bill for different income groups and on revenues collected by the water company. Percentage changes are compared with the current situation as presented in Table 3.

Scenario	Income quintile					Average
	1	2	3	4	5	
a) Increase all prices with 10%						
% Change in demand	-7.3%	-6.6%	-5.6%	-4.9%	-1.3%	-4.1%
Average price (Real)	2.03	1.87	1.68	1.62	1.90	1.83
% Change in water bill	8.1%	8.2%	6.3%	4.8%	8.1%	7.3%[1]
b) Decrease p1 with 25%						
% Change in demand	15.8%	13.9%	12.4%	10.4%	4.8%	9.6%
Average price (Real)	1.22	1.18	1.20	1.23	1.64	1.37
% Change in water bill	-19.1%	-16.9%	-9.9%	-7.6%	-0.7%	-7.7%[1]
c) Decrease p1 with 40%, increase p2 and p3 with 10%, and increase p4 and p5 with 25%						
% Change in demand	23.9%	21.3%	19.1%	16.0%	11.2%	16.2%
Average price (Real)	1.01	1.04	1.09	1.16	1.90	1.40
% Change in water bill	-28.1%	-22.0%	-13.0%	-8.4%	22.2%	-0.3%[1]
d) Quintile 1-3: -40%, +10%, +10%, +25%, +25%; Quintile 4-5: +0%, +10%, +10%, +25%, +25%						
% Change in demand	11.6%	10.3%	9.1%	-0.7%	3.6%	5.5%
Average price (Real)	1.33	1.27	1.28	1.52	2.02	1.62
% Change in water bill	-14.3%	-13.2%	-6.6%	2.1%	20.9%	4.7%[1]
e) All prices equal to 1 Real/m^3						
% Change in demand	11.1%	10.0%	9.1%	7.7%	-5.7%	3.2%
% Change in water bill	-20.1%	-14.7%	-8.6%	-8.7%	-31.9%	-20.9%[1]
f) All prices equal to 1.5 Real/m^3						
% Change in demand	-1.42	-1.3%	-0.9%	-0.6%	-9.5%	-4.4%
% Change in water bill	-14.9%	-8.2%	-0.4%	1.2%	-21.5%	-12.1%[1]
g) All prices equal to 2 Real/m^3						
% Change in demand	-26.4%	-23.9%	-20.8%	-17.0%	-17.1%	-19.7%
% Change in water bill	-15.3%	-5.6%	6.1%	12.6%	-4.2%	-1.6%[1]

Notes: 1) represents the change in revenues collected by the water company SABESP.

As Scenario c shows, however, a reduction of p1 combined with an increase of the other block prices can result in a system which is budget neutral for the water company and in which the poor do not have to bear the largest burdens. A drawback of such an equalized pricing system is, however, a considerable increase of water demand. Table 4 shows that for this scenario demand may increase with 16%. Considering the current water scarcities in the Metropolitan Region of São Paulo, this may cause additional problems in the security of water deliveries and an increased number of water cuts. Scenario d shows that a price differentiation based on income might partly solve this. A reduction of p1 only for the first three income groups combined with a price increase for the other blocks will result in a total increase of water demand of only 5%, a slightly increased financial situation of the water company and a considerable reduction of the water bill for the poorer income groups. The increase of the water bill of 20% for the richest groups still corresponds to a water bill of only 0.8% of annual income, whereas the reduction of 14% for the poorest people corresponds to a water bill of 5.0% of annual income. The increased demand for the highest income group is most likely caused by extrapolation biases due to which the difference variable, which is negative for the price levels adopted, has a stronger effect than the price effect. If demand would decrease, which is more likely if a more precise demand function were available for this income group, total demand increase would be smaller than 5%.

The results of Scenario e, f and g show that introducing a flat price system will not improve much the water situation of the MRSP (see Table 4 and Figure 4). For high enough price levels (Scenario g), water demand will considerably decrease. However, demand for the poorer parts of the population will decrease the most. The water bill of the poorest income groups reduces most. However, this reduction is less than the reduction of their demand. Changes in the water bill are affected both by water demand and price levels. For all income groups, the percentage change of the water bill shows a quadratic path, but it depends on the income group at what price level the percentage change of the water bill starts to decrease again (see Figure 4). In the increasing parts of the graphs in Figure 4, the price increases have a larger effect than demand reductions. In the second part, the reverse happens. For reasonable price levels, the water company will experience a reduction in the revenues collected. Only for a price level of 2.25 Real/m^3 their revenues remain stable (an increase of 0.2%). A further increase of water prices, however, again leads to a reduction of revenues collected due to the large reductions of water demand.

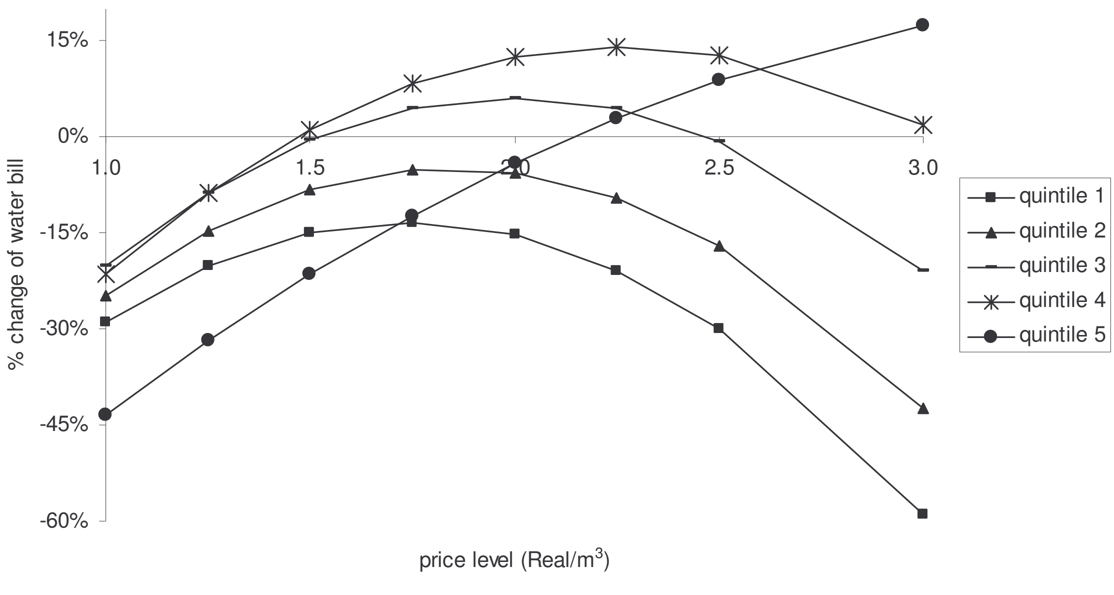

Figure 4: Effects of a flat price system on the water bill for different income quintiles.
Note: % change in water bill compared to the current water bill; see Tables 3 and 4.

Summarizing, this analysis shows that designing a water pricing system that both considers equity and reduces demand is difficult. A system that applies for the entire population is either good for equity or reduces demand. Only price differentiation based on income levels could result in a possible reduction of water demand which does not disproportionally affect the poorer income groups. However, the administrative costs of such a system may be inhibitive and one can wonder whether such a price system is politically feasible.

Demand changes due to changing pricing systems may be cancelled out by a number of structural changes. Income growth and population growth will already in the short run result in demand increases. In the state of São Paulo, for the next 5 years, a population growth is expected of 1.4% per year (SEADE)[2]. As a result, even if SABESP succeeds in reducing individual water demand by 5%, total demand will exceed current demand already in four years. As urban population growth is expected to be somewhat higher than total growth in the state of São Paulo, this point might even be reached at an earlier stage. For that reason, although pricing policies remain necessary to give consumers the correct signal on the value of the water they are consuming, much attention should be paid to alternative water saving policies. Such policies should focus on more conscious water demand habits and the promotion of water saving devices. Moreover, income growth will also lead to an increased demand of water. However, as average GDP per capita has decreased during the last 5 years according to the 2005 World Development Indicators (World Bank, 2005), no forecasts can be made of the rate of increase of demand due to income growth.

Finally, precipitation and temperature changes due to climate change are likely to have an effect on water demand. Climate scenarios for the next 15 and 45 years as presented by IPCC[3] (Nakicenovic and Swart, 2000) predict a temperature increase of on average 3% in the year 2050 and an increase of average annual rainfall of 0.3%. Monthly changes, however, may be larger. The largest increase in temperature is reported to be in the period March-April with an average increase of 4.6% and an increase of precipitation of 1.9% in the months October-November and a reduction in precipitation of about 1% in the months January–March. Although effects of these envisaged climate changes may be important for agriculture, our demand models indicate that they are small for domestic water demand. The changes in precipitation have a negligible effect on water demand. The increase of temperature has an effect exceeding 1% only in the warm months march and April. Income and population growth most likely have a much larger effect than climate change.

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[2] See www.seade.gov.br.

[3] See also the Climate Scenarios' Data Visualization at the IPCC Data Distribution Centre, http://ipcc-ddc.cru.uea.ac.uk/.

5. Conclusions

In this paper, water demand is estimated for the Metropolitan Region of São Paulo. This region is one of the most developed parts of the country, with a significant share of the population of Brazil. Due to recent developments with regard to water pricing policies and due to the increasing problems of water scarcity in urban areas in Brazil as well as in many other parts of the world, the results of this study are useful for other cities as well. In this study two water demand models are estimated. The first estimates a water demand function as a function of the average water price. The second follows Nordin's specification in which the marginal price and a difference variable account for the effect of price on water demand. The results of the analyses and the resulting demand and income elasticities are very similar for both models and do not deviate much from results reported in other studies. Price and income elasticities of water demand are shown to be inelastic, -0.46 and -0.50 for the price elasticities and 0.39 and 0.41 for the income elasticities.

The marginal price model is used to assess the effects of alternative price policies on water demand for five income quintiles in the MRSP. Even though this analysis could be refined if household data on water demand and income levels were available, the analysis shows interesting results on the effects of price changes on water demand. The current price system has a combined regressive-progressive block system, in which the water price in the first block is the most expensive. The main reason for this is to assure the financial viability of the water company. A result of this price system is, however, that water is an expensive commodity for the poorest part of the population. Average prices are higher for the lowest than for the richer parts of the population and expenses on water as percentage of the total income are almost 10 times as high for the poorest 20% of the population than for the richest 20%. A drawback of the current system is that the poor subsidize water for the rich. Changing the water pricing system in such a way that equity is improved, demand is reduced and the financial situation of the water company does not deteriorate is, however, difficult. A more equitable price system will either result in an increased demand or a deteriorated financial situation of the water company. An income dependent price system, in which the richer income groups pay higher prices for all or the first few consumption blocks, may partly solve the problem, even though administrative costs of such a system may be inhibitive. Population and income growth may cancel out water savings achieved by changes in the price system already in the short run. Forecasted temperature and precipitation changes due to climate change, however, hardly have an influence on residential water demand. In order to regulate water demand changes resulting from these structural effects, water pricing policies can probably not reach the intended goals. Pricing policies should be combined with alternative policies dealing with water consciousness and promoting water saving devices. Future research should be carried out to assess the short and long term effects of such policies. Nevertheless, in order to continuously give consumers the incentive to use water in a conscious way, pricing policies will remain necessary. One can wonder whether the current combined regressive-progressive price policy in the MRSP gives the right signal to these consumers.

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Appendix

Table A1: Average monthly prices for the period 1997-2002 for the five blocks (in Real/month).

	p_1	p_2	p_3	p_4	p_5
January	2.59	0.41	1.44	2.05	2.27
February	2.58	0.41	1.43	2.04	2.26
March	2.57	0.41	1.42	2.03	2.24
April	2.55	0.40	1.42	2.02	2.23
May	2.55	0.40	1.41	2.01	2.23
June	2.54	0.40	1.41	2.01	2.22
July	2.56	0.41	1.45	2.07	2.29
August	2.58	0.41	1.45	2.07	2.29
September	2.57	0.41	1.45	2.07	2.29
October	2.56	0.41	1.44	2.06	2.27
November	2.54	0.41	1.43	2.04	2.25
December	2.53	0.41	1.42	2.03	2.24

Source: Data obtained from SABESP.