DOCUMENT DE TRAVAIL DT/2006-10

Water Tariff Increase In Manaus (Brazil): An Evaluation Of The Impact On Households

Anne OLIVIER

DIAL • 4, rue d'Enghien • 75010 Paris • Téléphone (33) 01 53 24 14 50 • Fax (33) 01 53 24 14 51
E-mail : dial@dial.prd.fr • Site : www.dial.prd.fr

WATER TARIFF INCREASE IN MANAUS (BRAZIL):

AN EVALUATION OF THE IMPACT ON HOUSEHOLDS

Anne Olivier
EHESS, DIAL, Paris
olivier@dial.prd.fr

Document de travail DIAL
June 2006

ABSTRACT

Increasing block tariffs seek a cross-subsidy mechanism between the water network users, based on the common assumption of a low water price elasticity. In Manaus, the capital city of the Brazilian state of Amazonas where most of the 1.6 million dwellers are supplied through the municipal water network, a substantial consumption drop followed the tariff increase of 2004. This drop questions the cross-subsidy capacity of the current structure. We see this 31.51% tariff increase as a natural experiment applied to the whole network user population of Manaus and this allows us to measure the impact on monthly consumption of metered households, using month-on-month differences between years 2003 and 2004.

Key Words: Water Demand, Tariff, Price-elasticity, Impact Evaluation, Natural Experiment, Brazil

RESUME

Les structures tarifaires progressives par tranche de consommation en eau cherchent à établir des péréquations entre les usagers du réseau d'approvisionnement, ceci sous l'hypothèse d'élasticités faibles au prix de l'eau. A Manaus, capitale de l'Etat d'Amazonas au Brésil où résident 1,6 million de personnes majoritairement approvisionnées par le réseau municipal, la dernière hausse du prix de l'eau, appliquée uniformément à chaque tranche de consommation en janvier 2004, a conduit à une baisse significative des consommations, remettant en cause la capacité de subventions croisées de la structure tarifaire. L'exploitation de cette hausse de 31,51 % du tarif, comme un choc naturel subi par l'ensemble des usagers du réseau d'approvisionnement de Manaus, permet d'en mesurer l'impact sur les consommations mensuelles en eau des ménages équipés de compteurs par différence mois à mois entre les années 2004 et 2003.

Mots-clés : Demande en Eau, Tarif, Élasticité-Prix, Evaluation d'impact, Expérience naturelle, Brésil

JEL Code : D12, Q21, Q25

Contents

List of Tables

List of Figures

1 INTRODUCTION: ACCESS TO WATER AND TARIFF STRUCTURE ISSUES

Non-linear tariffs for water supply services are widespread, especially increasing block tariffs which main objectives are to favour resource conservation (by charging more for higher consumption), and to introduce cross subsidies from high to low water consumers (by creating an initial consumption block that is heavily subsidised). Assessing the impact of price variations on demand for water within such tariffs frameworks is complex, given the endogeneity of consumer price. Many works on price elasticity estimation have thus been biased[1].

1.1 Setting water tariffs

Setting water tariffs remains a controversial issue due to the multiple and often conflicting objectives concerned. For public authorities, in charge of providing their population with access to water, affordability and equity objectives remain the prime concerns, however these are increasingly accompanied by a drive for economic efficiency due to resource scarcity (whether for environmental reasons, or competition in uses between agricultural and domestic needs) and, more recently, the objective of full cost recovery within the framework of water sector reforms.

- The impact of access to water on health and development, in both urban[2] and rural[3] areas, makes water a special good to which access must be ensured regardless of the population living standards. In many developing countries, this affordability target has led to the introduction of a highly subsidised or even free first consumption block (in South Africa and Flanders), or of social tariffs targeting specific consumer categories (as in Santiago, Chile).
- Equity, in its true sense, means that similar consumers receive similar treatment and that those who place an additional load on the system should be charged more. In practice its meaning is often extended to cover equitable pricing that accounts for the living standard of consumers and is thus in line with affordability and fairness targets.
- Economic efficiency requires a tariff structure that sends a signal to consumers (indicating financial as well as environmental costs of water use), so as to maximise the aggregated benefits for a given cost of supply.
- Finally, for the water operator, whether public or private, cost recovery is necessary to ensure financial independence, both for investments for network maintenance and for its expansion[4].

Over and above the conflicting aspects of these objectives, there is little consensus on the effectiveness of water tariff settings towards these objectives.

- Fixed charge tariffs are still used in industrialised countries where water resources are abundant (Canada, Norway, United Kingdom), but also in developing countries, given meter installation and reading costs. There is, therefore, no incentive to limit consumption. Within this context, it is possible to allocate a fixed consumption level based on the type of dwelling and to differentiate between households by income level. However, in the event of a tariff increase, households have no opportunity to alter their consumption in order to reduce their bill.

[1] See the review of the literature on residential water demand in Chapter II, in particular Blundell and Nauges (2002) [5] , Arbues et al. (2002) [2] and Dalhuisen et al. (2003) [8]

[2] Galiani, Gertler & Schargrodsky (2005) [14] have shown that the expansion of water supply networks in Argentina municipalities between 1990 and 1999 reduced infant mortality

[3] Jalan and Ravallion (2001) [18] have shown a reduction in morbidity (in terms of both incidence and severity of diarrhoea cases) as a result of provision of water supply in rural India

[4] Water sector reforms, under impetus from the World Bank, have brought this objective to the top of the agenda to improve existing supply systems and expand water coverage.

Table 1: Basic types of water tariff structures (from PPIAF 2002 [25]):

1. Single-part tariffs:
(a) Fixed charge : monthly water bill is independent of the volume consumed
(b) Water use charge
i. Uniform volumetric tariff
ii. Block tariff: unit charge is constant over a specified range of water use and then shifts as the use increase
- Increasing blocks
- Decreasing blocks
iii. Increasing linear tariff : unit charge increases linearly as the water use increases
2. Two-part tariffs (fixed charge + water use charge)

- Volumetric tariffs based on actual consumption may be uniform, as in Australia, Europe and the United States. They then indicate the short-run marginal cost of using water.

- Increasing blocks tariffs (IBT) are widespread in developing countries, as well as in Japan, Spain and the United States. Depending on the context, they might be introduced to achieve three objectives: affordability, with a highly subsidised first block (known as the *subsistence block* or *lifeline rate*), resource conservation (high consumption is more highly charged), and economic efficiency when the upper block corresponds to the short-run marginal cost of using water. The first objective remains rather controversial, given that all users have access to the subsidised block and large families or households sharing connections are disadvantaged as their consumption reaches higher blocks than that of others. Moreover, these tariffs are often inappropriately designed, with the first block extending well beyond *subsistence* level, meaning that few consumers are covered by a tariff that reflects marginal cost. As such, they are subject to much criticism (Boland & Whittington, 2000 [7]), but it remains politically difficult to raise questions about such tariff structures which are seen as favouring the poorest. In Jakarta (Indonesia), under municipal authorities pressure, the so-called social tariffs were exempt from tariff increases[5], generating a perverse effect in that they strongly dissuaded the water operator from providing service to poor households whose consumption was highly subsidised. The actual regressivity of such structures is, however, largely due to the exclusion of the poorest from supply networks, and therefore their exclusion from consumption subsidies. When water service coverage is high enough, limiting the size of the first block can improve the progressiveness of the tariff, as long as consumption levels rise with living standard (Foster et al, 2006) [13].

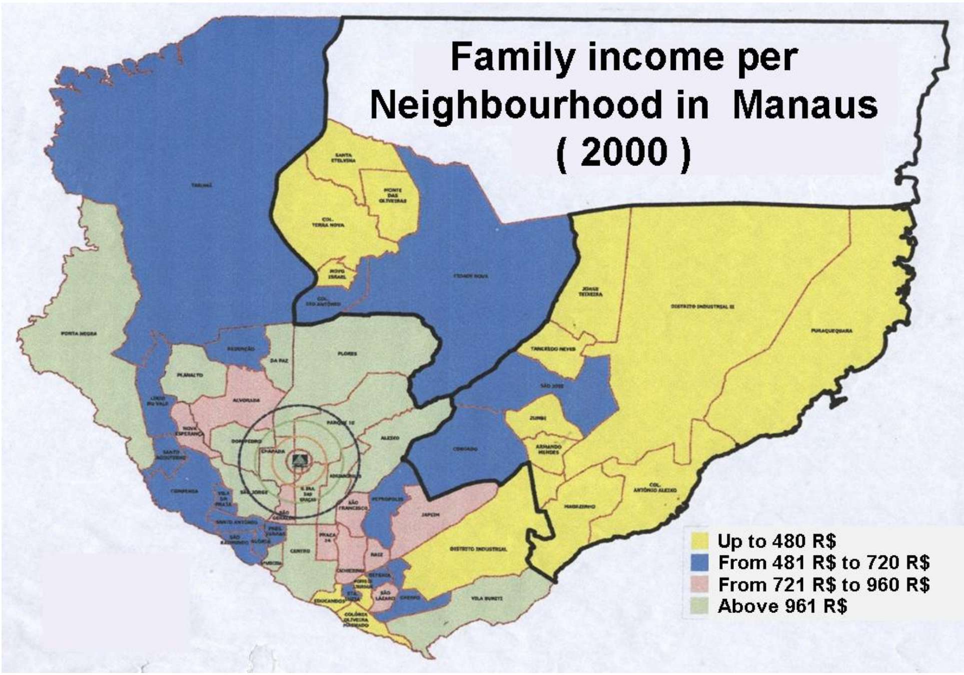
- Two-part tariffs, widely promoted by the World Bank, aim at recovering costs (the fixed part usually corresponding to the fixed costs of production and administration) and achieving economic efficiency (the proportional part being adjusted to marginal cost). In the case of water scarcity context, the fixed part might become negative (rebate) to maintain a strong signal by means of the proportional part without generating excess revenue. Subsidies targeting categories of low-income consumers can be introduced in parallel. They have the advantage of transparency compared to volume-based subsidies, but lead to substantial exclusions regardless of the targeting mechanisms.

[5]This failure of the tariff structure was corrected in January 2005.

1.2 Water supply in Manaus

Manaus, the capital of the Amazonas state of Brazil, is characterised by a high population growth since 1970, date of the free trade zone creation, as well as a continuous geographical expansion of the city with the appearance of new neighbourhoods, known as *invasions*. These new neighbourhoods have been progressively integrated into the city by providing urban infrastructure such as roads, electricity and water. In October 2004, the city's population reached 1.6 million, 31 per cent of whom were living below the poverty line[6]. Income inequalities are very high in the city, as they are throughout Brazil[7]. High-income households are concentrated in the historic central parts and in a western residential area. The poorer households have settled either in the peripheral neighbourhoods (sometimes as a result of specific municipal programmes) or in illegal settlements along the water courses (Igarapés) that run through Manaus (figure 1).

Figure 1: Breakdown of residential areas of Manaus by average family income



Source: Aguas do Amazonas, based on IBGE (2000).

Since 2000, water and sanitation services have been managed by a private operator[8]. Water coverage of the population - 80 per cent at the end of 2004, a low level for a Brazilian municipality - is to become universal in 2006 (with a minimum of 95 per cent of the population)[9] thus accompanying the city's geographical expansion. The poorest neighbourhoods remain severely under-equipped and the level of poverty reaches 45 per cent among unconnected households ; These households mainly live (but not exclusively) in unsupplied neighbourhoods and get their water from wells, public standpipes or from illegal networks. However, 20 per cent of unconnected households belong to the wealthiest quintiles, such as villas owners in the peripheral areas or housing condominiums, equipped with their own wells or boreholes (figure 2).

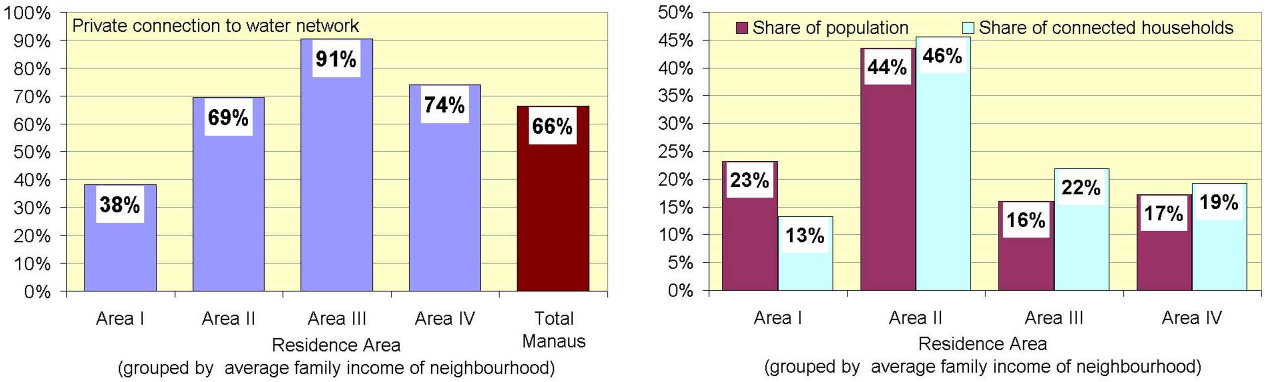
[6]The poverty line used by IBGE in 2000 was half the minimum wage per capita, i.e. Réais 75.5 /cap./month. This threshold updated to Réais 2004 is Réais 105/cap./month (the minimum wage was readjusted to 260 Réais per month in October 2004, i.e. around $US 90, bringing the poverty level to 42 per cent based on the new threshold).

[7]The 2000 Gini index was 0.64 for the Manaus metropolitan area, equal to the average level of income inequality for Brazil (IBGE, 2000).

[8]In June 2000, Aguas do Amazonas, a subsidiary of Suez Environnement, signed a 30-year concession contract for water and sanitation services with the Manaus municipal authorities.

[9]The network should cover 95 per cent of the population, although households should be able to maintain their alternative supply source (wells in particular). Network availability is taken into account rather than effective coverage of households

Figure 2: Access to residential water services and distribution of the population by neighbourhoods' living standard in 2000



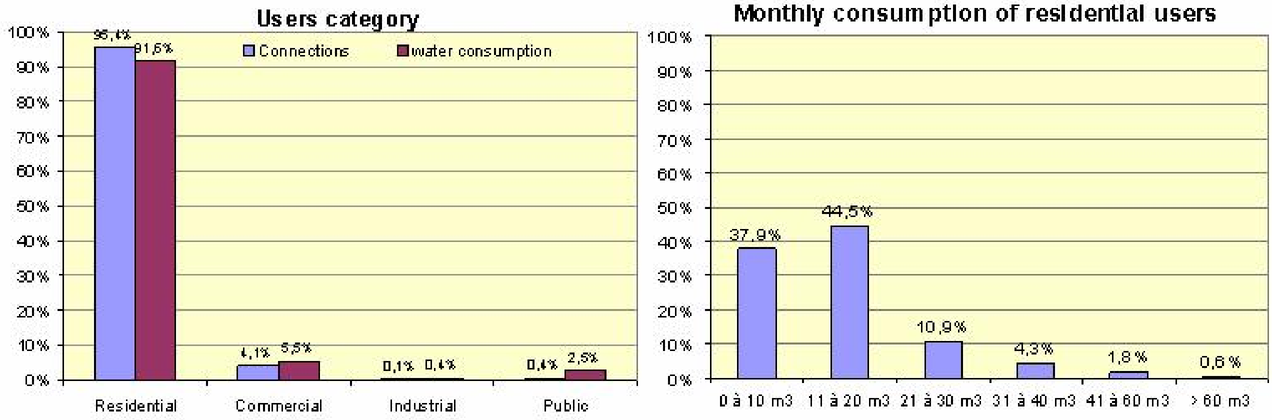
Calculation based on IBGE 2000 data[10]

The sanitation network remains severely limited and covers only 7 per cent of households, mainly in the historical centre. Uncollected effluents are treated by individual systems (septic tanks) for well-off households or discharge directly into the water courses (Igarapés), via the storm water drainage system, without any form of treatment.

1.2.1 Water tariffs

The tariff applying in Manaus is a specific tariff per customer category (residential, commercial and industrial or public) and increases per consumption block, similar to tariff structures current elsewhere in Brazil. For residential users, there are six consumption blocks, with a minimum bill corresponding to 10 m^3/month (figure 3).

Figure 3: Distribution of user categories and consumption



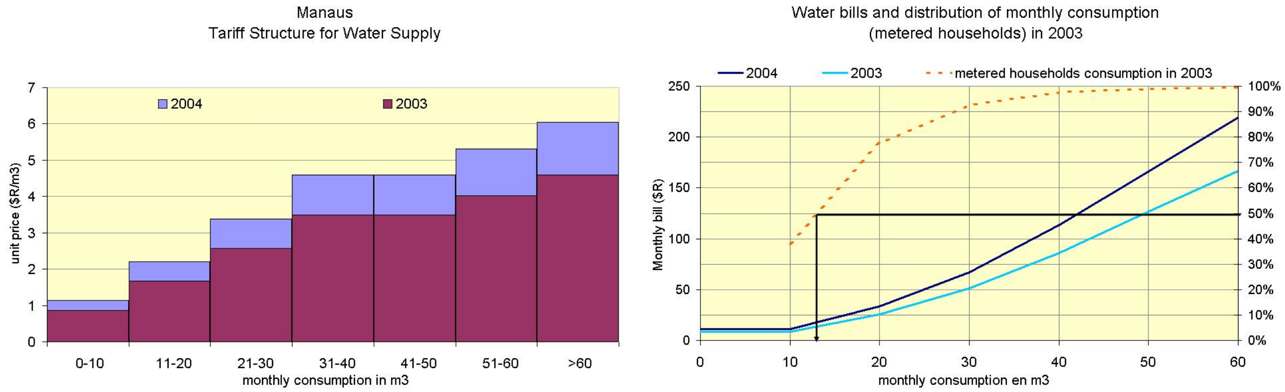
Source : Suez Environnement

The principle of cross-subsidy, inherent to this type of tariff structure (from industry towards households as well as from high consumers towards low consumers) is weakly implemented: 92 per cent of the water charged is consumed by households, of which 83 per cent consume in the first two tariff blocks (see figure). The second block tariff is calculated to be close to average price, whereas the first block represents about half of this. Yearly re-evaluations of tariffs to account for inflation (around 10 per cent), as well as two exceptional, additional, increases since 2000 - the last of which, in January 2004, reached 31.5 per cent - are applied uniformly and affect each consumption block equally (see Appendix A.1 for details of successive tariffs applied between 2000

[10] Aggregated data from the IBGE for neighbourhoods, on the basis of the October 2000 census, enables grouping of households by residence area, based on the average income for the residential area (Area 1: average household income less than $R480 in 2000; Area 2: between $R481 and $R720; Area 3: between $R721 and $R 960; Area 4: above $R960).

and 2004). The median water bill amounts around 3 per cent of households' monthly income in September 2004[11].

Figure 4: Water tariffs and billing



The average water price for households therefore depends on their monthly consumption, with a fixed minimum of 10m^3/month. For households not equipped with meters - i.e. about half of Manaus' residential users - a fixed level of consumption is set on the basis of the number of water outlets in the dwelling. The minimum consumption is fixed at 12m^3/month.

1.2.2 Preliminary criticism of the tariff structure :

At first view, several criticisms can be levelled at this tariff structure :
The impossibility of providing the cross-subsidies expected from this structure, owing to the absence of high consumers within the supply network (industries, as well as high residential consumers, have their own water resources) leads the operator to increase tariffs in a uniform manner, regularly. In addition to the burden imposed on all users, these tariff increases have the perverse effect of keeping high consumers out of the network without ad hoc regulation on the underground resource use. The tariff blocks do not appear to be well designed here, with a first block too wide to correspond to *subsistence* consumption (10 m^3/month is equivalent to 82 litres per person per day for a family of four). This block is heavily subsidised and benefits the entire population, as the median effective consumption of metered households (11.6 m^3/month in 2003) is not far from the 1st threshold. Furthermore, the existence of a minimum billing rate of 10m^3/month applying to the entire first block is heavily penalising to small consumers (mainly poor and small size households[12]), whose actual consumption stands below that level (supply characteristics per quintile are given in appendix, in table 12).
In parallel with this increasing block structure, 40 per cent of network users are billed at fixed rate. Here again, the billing threshold of 12m^3/month is high for a small size household. Even though fixed bills, which therefore ensure regular and predictable amounts, protect vulnerable households from excessive bills (especially in the case of leaks), these households do not have the opportunity to adjust their bill via their consumption in case of a substantial increase in tariff.

[11]See socio-economic study by A. Waichman, Ufam [29], in 2004

[12]Couples (retired) or people alone (young or widowed) represent 15 per cent, i.e. a substantial proportion of low-income households in Manaus, based on a previous survey with Ufam in 2002 (Morel à l'Huissier and Olivier, 2003) [20]

2 IMPACT EVALUATION OF A WATER TARIFF INCREASE

2.1 Review of the literature on residential water demand

Most of the literature on residential demand for water services focuses on estimation of the price elasticity of the demand for water. Tariff issues relating to conditions of access, equity or the well-being of users are rarely addressed in this literature, mainly developed from empirical data in industrialised countries, where the issue of price as a policy instrument for water resource management remains predominant. The meta-analyses by Espey et al. (1997)[10] then Dalhuisen et al. (2003)[8] on the numerous empirical studies made since the 1960s conclude that water demand has low price elasticity (respectively -0.51 and -0.41 on average) but that the estimated value depends very much on the choice of price variable, data type and model specification. Dalhuisen et al., in particular, show that studies based on increasing block tariffs lead to higher price elasticity, as do works using sophisticated price variables (*difference* or *price* perception variable) and those using the Hewitt and Hanemann (1995) [17] discrete-continuous choice model based on labour supply works (price elasticities reach -1.6 in this case). However, the non-linear nature of most water tariff structures raises issues of identification and econometric specification making somewhat irrelevant comparisons of approaches that account unequally for these questions and of which the results may be biased[13]:

- the choice of the price variable - marginal price or average price paid by the household- is not the subject of a full consensus among authors. Nordin (1976)[22] after works undertaken on electricity demand, modified the price specification by including, in addition to the marginal price, a so-called *difference* variable (corresponding to the difference between the bill actually paid by the user and what the bill would have been if the marginal price was applied to all of the consumption) so as to introduce an income effect generated by the block tariff structure. This specification was subsequently used by most authors. It implies, however, that the user has a refined understanding of the tariff structure and this question led Shin (1985) [27] to introduce a new *price perception* parameter. The choice of average price, marginal price or even of perceived price as explanatory variable requires empirical tests to select the most appropriate variable, as a function of the size of blocks, the existence and amplitude of a fixed part, the transparency of the tariff and the advantage for the user of knowing it in detail in accordance, for example, with the budgetary coefficient of water expenditure[14] .

- Many analyses have been performed using aggregated municipal data, while Schefter and David (1985) [26] have shown that averages for price variables (marginal price or difference variable) must then be weighted by user distributions in each consumption category, information that is missing in a number of studies using aggregated data.

- Finally, in such non-linear structures, as the price depends on consumption (both marginal and average prices), estimates obtained by ordinary least squares techniques are biased and inconsistent and two-stage models (McFadden, 1977) or instrumental variables (Billings, 1982 and Billings and Aghte, 1980) lead to better estimates once the endogeneity issue has been addressed. A bias persists because of discontinuities in the tariff structure. For this reason, Hewitt and Hanemann, (1995) and Blundell and Nauges (2003) [5] have used maximum likelihood (ML) methods based on discrete choice modelling applied to the analysis of labour supply where the budget constraint is piecewise-linear. This modelling provides a correct approach to consumer behaviour and the price elasticities estimated in these latter studies by ML are significantly higher than those estimated with least squares regression or in two stages models. However, Blundell and Nauges, after testing, rejected the assumption of normality of error terms required by the ML method, thus invalidating the results obtained. They propose an alternative non-parametric method of choice modelling (series) and estimate lower average price elasticity (-0.36

[13] The implications of the choice of variables, of types of data used and specification of models, as well as the main related econometric problems, are detailed in the review of the *state of the art* by F. Arbuès et al. (2003)[2].

[14] The tests carried out by Nieswiadomy and Molina (2001) [21] on water demand with increasing and decreasing block tariffs are not really conclusive given the variance of the price perception parameter.

instead of -0.68 by ML). They also show an inverse gradation of elasticity with income level (price elasticity is lower for well-off households than for poor households which are more sensitive to price[15]).

Main implications of non-linear tariffs for the demand function and for econometric specifications are developed below.

2.1.1 Implications of non-linear tariffs on the demand function

Non-linear tariffs raise issues of specification of the demand function similar to those encountered in the literature on labour supply, when incomes are taxed progressively with threshold (see Burtless and Hausman, 1978 and Moffitt, 1990 [23]).

In the simplified context of an increasing tariff with two blocks with prices p_1 and p_2 (l_1 is the limit of block 1), where q is the water consumption and z the consumption of a composite good bringing together the other goods with unit cost normalised to 1, the budget constraint of a household that maximises a strictly concave utility function is written as:

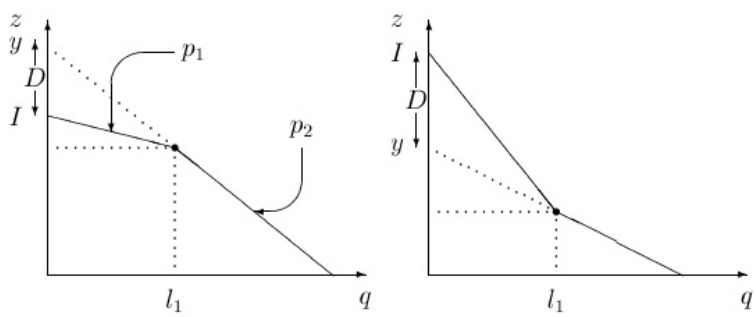
$$I = \begin{cases} p_1 q + z & q \leq l_1 \\ p_1 l_1 + p_2(q - l_1) + z & q > l_1 \end{cases}$$

and might be written as:

$$\begin{aligned} I &= p_1 q + z \qquad && q \leq l_1 \\ I + (p_2 - p_1) l_1 &= p_2 q + z \qquad && q > l_1 \end{aligned}$$

The term $I + (p_2 - p_1) \cdot l_1$ is the *virtual income* whereas $D = (p_2 - p_1) \cdot l_1$ is called the *difference variable*. This quantity corresponds to the difference between what the bill would be if all consumption was charged at marginal rate and the actual bill. It is positive and can be interpreted as an implicit subsidy in the context of increasing tariffs.
These variables (*virtual income* or *difference* variable) were introduced after the works on electricity demand by Taylor (1975) [28] then Nordin (1976) [22] to account for transfers implied by block rates.
The budget constraint is then *piece-wise linear*: see Figure 5.

Figure 5: *Budget sets for two blocks rate tariffs with increasing and decreasing blocks*



Increasing tariffs Decreasing tariffs

Source : Blundell and Nauges, 2002.

[15]The price elasticity estimated by Blundell and Nauges for the first income quartile is -0.46, against an average of -0.36 for the total population of Cyprus

2.1.2 Implications of non-linear tariffs on econometric specification of the model and approaches for parameters estimation

The main problems in specifying a water demand model are the co-determination of price and consumption (simultaneity) as well as the existence of possible discontinuities and jumps in demand at the limits of the blocks. The estimation techniques used to overcome simultaneity of consumption and marginal price and *difference* are mainly instrumental variables (Billings (1982) [4] uses as instruments the marginal prices and *difference* variables calculated from tariff structures applied) and two stage least squares (McFadden (1977) uses the average price estimated from predicted consumption with the amount billed). These two methods, although they address the problem of endogeneity of the consumer price variable, imply linearisation of the tariff structure. By way of simplification, the estimated functions are usually linear functions or more often log-linear, implicitly assuming that price elasticity remains constant with price[16].
These functions imply direct modelling of consumption without, however, modelling the choice of block. Accounting for discontinuities requires modelling of demand conditionally to the choice of consumption block.

In a two-block setting, where p_1 and p_2 are the prices and y_1 et y_2 are the *virtual incomes* in blocks 1 and 2, and where the budget constraint is convex, the conditional demand is:

$$q = \begin{cases} q^*(p_1, y_1) & if\ q < l_1 \\ l_1 & if\ q = l_1 \\ q^*(p_2, y_2) & if\ q > l_1 \end{cases}$$

and the unconditional demand, corresponding to the combination of the discrete choice (choice of consumption block) and continuous choices is therefore:

$$q = \begin{cases} q^*(p_1, y_1) & if\ q^*(p_1, y_1) < l_1 \\ l_1 & if\ q^*(p_2, y_2) \leq l_1 \leq q^*(p_1, y_1) \\ q^*(p_2, y_2) & if\ q^*(p_2, y_2) > l_1 \end{cases}$$

The corresponding stochastic model brings in two types of errors, after the work of Burtless and Haussman (1978) and Moffitt (1986):

- ε corresponds to the heterogeneity in household preferences, which escape analysis (unobservables, specification errors, etc.)
- η corresponds to an optimisation error by households (due to the difference between desired and actual consumption)

$$q = \begin{cases} q^*(p_1, y_1) + \varepsilon + \eta & if\ \varepsilon < l_1 - q^*(p_1, y_1) \\ l_1 + \eta & if\ l_1 - q^*(p_2, y_2) \leq \varepsilon \leq l_1 - q^*(p_1, y_1) \\ q^*(p_2, y_2) + \varepsilon + \eta & if\ \varepsilon > l_1 - q^*(p_2, y_2) \end{cases}$$

The likelihood for one observation can be estimated assuming the normality and homoskedasticity of error terms. The results of estimation are, however, sensitive to these hypotheses and non-parametric methods make it possible to overcome this[17].

[16] Recent works (Gaudin et al, 2001 [15] and Martinez-Espineira and Nauges, 2004 [19]) model a function of the *Stone Geary* form to show the existence of a threshold below which water demand is not sensitive to price. They show in two industrialised countries contexts (Texas and Seville) that about half of average consumption constitutes a threshold for insensitivity to price (3m^3/cap.month in the case of Seville, where average consumption is 6,3m^3/cap.month).

[17] See Blundell and Nauges, 2002

2.2 Impact evaluation in a *natural experiment* context.

Natural experiment methods often known as *Difference in Difference* methods, have been developed to measure the impact of a shock or a policy, generally covered by the term *treatment*, using data from before and after the *treatment* studied. The central issue for such approach is the absence of a *counterfactual* scenario (i.e. the situation of individuals or households without the *treatment*).

The impact measured is the average treatment effect on the individuals or households *treated* (*average treatment effect on the treated*): $E(Y_1 - Y_0/X, D = 1)$
$E(Y_1/X, D = 1)$, the parameter of interest for the individuals or households is observable.
$E(Y_0/X, D = 1)$, the parameter of interest for these same individuals or households in the absence of treatment (counterfactual) is approached by $E(Y_0/X, D = 0)$, observable for individuals or households not affected by the treatment.

- The *simple difference* (or *before/after*) estimator uses the outcome variables measured before *treatment* to approximate the counterfactual situation:

  For *treatment* implemented on date k ($t > k > t'$), $Y_{0,t'}$ is the outcome variable before treatment and for each individual or household $Y_{1,t} - Y_{0,t} = (Y_{1,t} - Y_{0,t'}) + (Y_{0,t'} - Y_{0,t})$
  $(Y_{0,t} - Y_{0,t'})$ is the selection bias. If the average can be considered to be zero, then $(\overline{Y}_{1,t} - \overline{Y}_{0,t'}/D = 1)$ is the effect due to treatment for the treated individuals or households (average measured after and before treatment).

- The *Difference in Difference* (DD) estimator :

  If the average selection bias cannot be assumed to be zero (the outcome variable cannot be considered as identical in the absence of treatment) a control group must be identified that is not affected by the treatment (or *not treated*) and a *Difference in Difference* method applied, assuming that the effects over time are common to both groups. This rules out the effects of unobservables for households as well as *macro* effects affecting all households. The choice of a control group in line with this assumption, crucial for the evaluation, is the main difficulty in applying this method (Heckman et al, 1999 [16]). The implicit assumption is that in the absence of a programme, the outcome variable is the same in the *treated* group as in the *untreated* group, i.e. :
  $E(Y_{0,t} - Y_{0,t'}/D = 1) = E(Y_{0,t} - Y_{0,t'}/D = 0)$
  The *DD* estimator $(\overline{Y}_{1,t} - \overline{Y}_{0,t'}/D = 1) - (\overline{Y}_{0,t} - \overline{Y}_{0,t'}/D = 0)$ for $t > k > t'$ is an estimator of the effects of the *treatment on the treated* $E(Y_{1,t} - Y_{0,t}/D = 1)$

  - The effect can be considered as homogeneous within the treated households (simple case). For *treatment* at date k :

    $$\begin{aligned} Y_{i,t} &= \beta X_{i,t} + \alpha d_i + U_{i,t} && if\ t > k \\ Y_{i,t} &= \beta X_{i,t} + U_{i,t} && if\ t \leq k \end{aligned}$$

    α measures the homogeneous effect of *treatment* for the treated group (for whom d_i, the binary variable for participation in *treatment*, is equal to 1), Y the explained variable, X all of the exogenous variables and $U_{i,t}$ the error term of mean zero, which is assumed to be uncorrelated with X.

  - It is also possible to consider that the effect is not homogeneous for all individuals:

    $$\begin{aligned} Y_{i,t} = \beta X_{i,t} + \alpha_i d_i + U_{i,t} & & if\ t > k \\ with & & \alpha_i = \overline{\alpha} + \epsilon_i \\ and & & \alpha_T = \overline{\alpha} + E(\epsilon_i | d_i = 1) \end{aligned}$$

where $E(\epsilon_i|d_i = 1)$ is the mean deviation of the impact among treated individuals.

$$Y_{i,t} = \beta X_{i,t} + \overline{\alpha}.d_i + [U_{i,t} + d_i\epsilon_i] = \beta X_{i,t} + \overline{\alpha}.d_i + [U_{i,t} + d_i(\alpha_i - \overline{\alpha})] \qquad if\ t > k$$

The average effect $\overline{\alpha}$ cannot be identified if the fact of belonging to the *treated* group is not independent of household characteristics as $E(\epsilon_i|d_i = 1)$ is not necessarily zero. Only the effect of *treatment on the treated*$\alpha_T = \overline{\alpha} + E(\epsilon_i|d_i = 1)$ can then be identified without further assumptions (Blundell, 2000 [6])

A tariff increase or an income tax rise (Piketty, 1999 [24]) can be considered as an exogenous shock and analysed using a *Difference in Difference* approach. This can be done by before/after estimation assuming constant consumption in the absence of the tariff increase (controlling for observable effects determining the consumption level) or by a *Difference in Difference* method with identification of a consumer group not affected by the increase.

2.3 Impact of a water price increase in Manaus

For the 2003-2004 period, a drop in monthly water consumption of about 4.5 per cent was observed for metered households. This is the result of several factors, which need to be distinguished: extension of the network to low-income neighbourhoods with lower water consumption levels; metering programmes (replacing fixed consumption billing); and an actual drop in water consumption under the impact of the tariff increase. In parallel with the consumption drop, bill recovery dropped over the period and the number of disconnections increased significantly. To measure the specific impact of the tariff increase, the analysis was carried out on all connected households in Manaus, based on monthly consumption data, status of connections and delays in bill payment between January 2003 and December 2004.

2.3.1 Dataset description

Description of Aguas do Amazonas residential customer *database 2003/2004:*

The initial database consisted of monthly data recorded by the operator over the January 2003-December 2004 period (i.e. 24 consecutive months) for all *strictly residential*[18] users of the Manaus water supply network, identified by a connection that may be shared by several households. It thus covers 78 per cent of Manaus' population, estimated at 368 000 households at the end of 2004[19].

	Connections over the period	Connections in Oct. 2004	Shared meters	Connected Households in oct.2004	Pop. share Manaus
Initial data base	242 724	235 082	12,9 %	288 305	78 %
data base analysed	226 009	221 181	13,3 %	272 132	74 %

The dataset was restricted to two main types of connections: *Water* or *Water and Sanitation*, and for which the water connection was active at least once over the 24 month period (6.9 per cent of connections in the database remained inactive during the study period; they were not retained in the dataset). Data were monitored monthly in terms of connection status (active or not); type of connection (*meter* or *fixed bill*, and water only or water and sanitation (sanitation giving rise to billing for an additional amount equal to 80 per cent of the price of water); whether or not the connection was shared by several households (each household then being

[18]The dataset does not include households having a commercial activity or sharing their connection with a commercial activity.

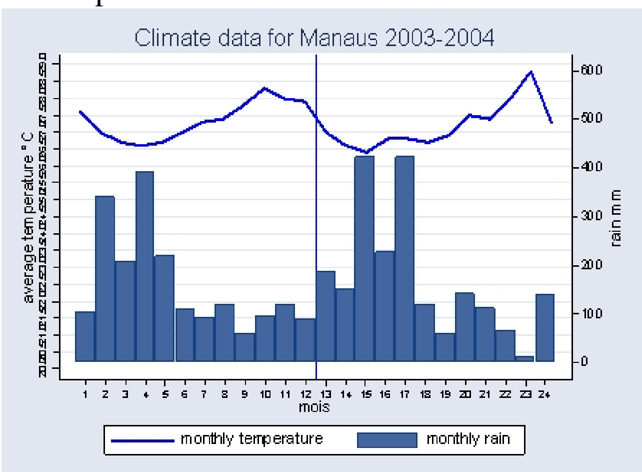
[19]From the projection based on the IBGE census in 2001, (Ufam, 2004) in October 2004.

billed individually); and monthly consumption (whether metered or allocated for households without meters). The measured consumption was divided by the number of households sharing the connections, so as to be expressed as monthly consumption per household. Aberrant values for measured consumption (resulting from meters) were replaced by the consumption actually billed for when this was above the billing threshold. As the price of water depends on the consumption block, a *reference* category variable was created to break down the households by level of consumption: this corresponds, for each household, to the average consumption category in 2003. Payment recovery within 10 days, available as an amount paid, was converted into a binary variable corresponding to payment or default within 10 days after invoice.

Comment: in case of zero consumption
Cases of zero consumption represent a significant proportion of the consumptions recorded for metered connections considered to be active. They are billed at the minimum threshold of 10 m^3 but can cover a variety of situations: empty dwellings (of the 4 231 connections with consumption always zero over the period, 53 per cent of them nevertheless pay their bills on time); meter reading errors (these are corrected by readers the following month); or by-passing of meters concealing actual but un-measurable consumption. Several types of processing were applied to eliminate the *noise* that these connections could generate[20].

Monthly average rainfall and temperature data complete the analysis, given the seasonal nature of consumption. Although annual temperature and rainfall were similar for 2003 and 2004, amplitude variation was higher in 2004. Rainfall was particularly high in March and May of 2004, leading to exceptionally high water levels in the Rio Negro. These monthly variables allow for climatic variations between 2003 and 2004 (figure 6).

Figure 6: Temperature and rainfall in Manaus in 2003 and 2004



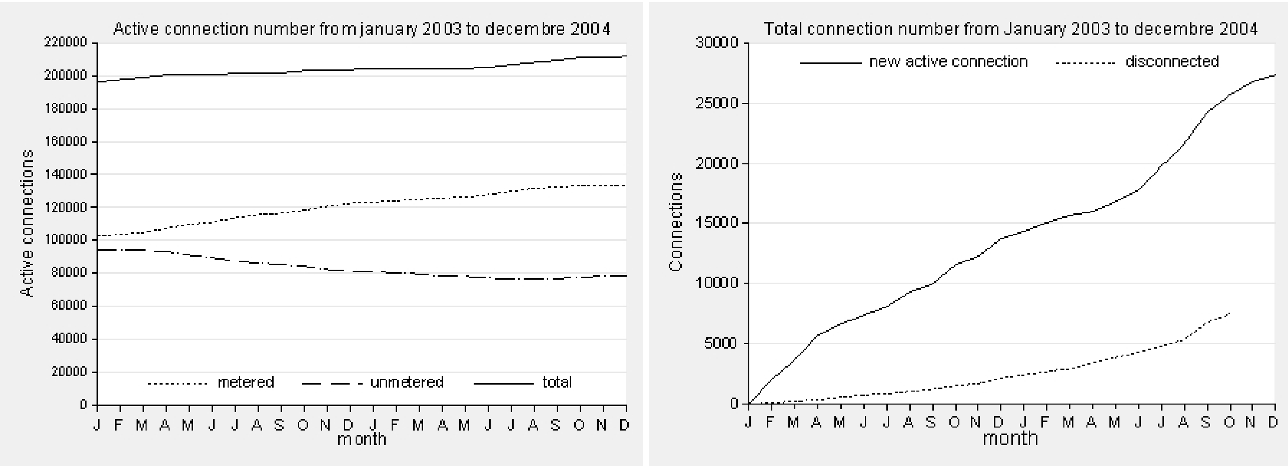
Source : Inmet (Brazilian National Institute of Meteorology, GrEC-USP (Climate Study Group of Sao Paulo University)

[20]Cases of zero consumptions preceding initial non-zero consumption were eliminated (these generally corresponded to new connections not yet in use). Connections for which consumption becomes zero were identified as such and the corresponding consumption eliminated as they may be connections that have become inactive or that have been by-passed. Occasional zero consumptions were smoothed by taking the average with the following month.

Main variations during study period (January 2003 to December 2004):

Expansion of the water supply network compensated the urban population growth, estimated at 3.2%/yr, the number of active connections having increased by 7.9 per cent in 2 years. This increase is partially explained by actual new connections (18 029, 84 % of which were equipped with meters) but also by activation of existing connections (9 320 in all). 80 % of the new connections were made in low-income neighbourhoods which are also the majority of new neighbourhoods. In parallel with the supply network extension, some connections became *permanently inactive*[21] between January 2003 and October 2004 (7 459, of which 64 % were unmetered connections). The proportion of meters increased as a result of the new connections, most of which are metered (whereas most disconnections were of unmetered connections), but also as a result of metering programmes on existing connections. The proportion went from 52.2 per cent of connections, active in January 2003, to 63.1 per cent in December 2004. The level of connections to the sanitation system went from 9.4 per cent to 10.7 per cent of active residential connections (see Figure 7).

Figure 7: Variations in number of connections in 2003 and 2004



Descriptive analysis of consumption variations :

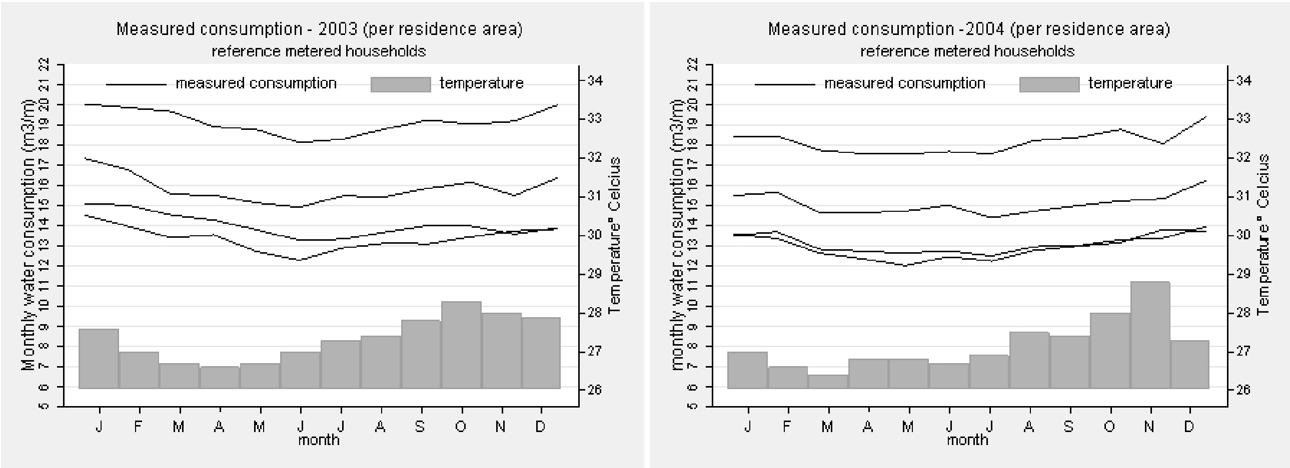
In order to analyse variations in consumption, apart from changes in the sample structure, descriptive analysis was performed on a cylindered sample: this is restricted to households equipped with a meter maintaining an active connection throughout the study period, i.e. 97 533 connections (74 per cent of all metered connections active in December 2004).

Residence Area (per average income)	Meter distribution (2003)	Average consumption (m^3/month) 2003	2004
Area 1	8.7%	13.36	12.92
Area 2	49%	14.02	13.10
Area 3	15.3%	15.82	15.09
Area 4	26.9%	19.16	18.16
All		15.62	14.74

The graphs of monthly consumption figures over time, grouped by residence area, show two main trends (See Figure 8):

[21]In this context, *permanently inactive* means inactive for at least three consecutive months. Connections inactive for only the last two months are not taken into account, as this may be a temporary condition.

Figure 8: Monthly Water consumptions of all metered households, grouped by residence area in 2003 and 2004



- Seasonal variations, with lower consumption during wet season increasing again when the weather is hot and dry (consumption billed on a given date corresponds to the water consumed the previous month).
- Positive correlation between income level, proxied here by residence area[22], and water consumption level. This income-level indicator is nevertheless flawed as it represents the income level per neighbourhood, whereas the consumption is restricted to connected and metered households. In the case of Area 1, the water coverage is low (38 per cent in 2000) and only 30 per cent of connected households have meters. Unconnected households in these neighbourhoods have few private boreholes and are mainly dependent on the municipal standpipes or illicit networks. It is therefore very likely that the water consumption recorded for Area 1 corresponds to consumption by the better-off households only and these are not necessarily poorer, on average, than those of Area II where the majority of households are connected and metered. Conversely, the missing households in Area IV (74 per cent connected in 2000) are well-off households with their own boreholes.

Taking only households billed in 2003 above the 10 m^3/month consumption threshold[23] (and therefore able to adjust their bill depending on the price), the drop in consumption from January 2004 appears clearly, and for each residence area (see Figure 9):

Residence Area	Consumptions (m^3/month) 2003	2004	Average variation
Area 1	18.80	17.24	- 8.33%
Area 2	19.12	16.89	-11.64%
Area 3	20.77	19.08	- 8.15%
Area 4	24.27	22.24	- 8.38%
All	20.92	18.88	- 9.75%

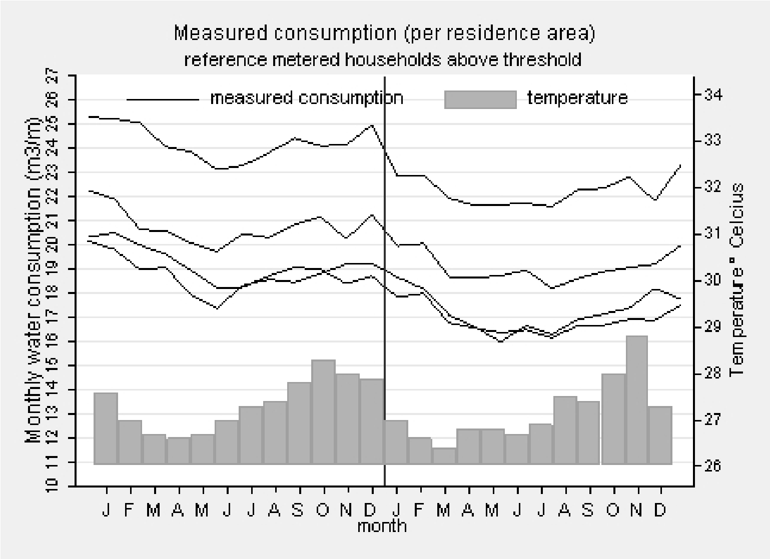
Beyond the billing threshold, the reduction in water consumption by metered households is, on average, -10 per cent between the two years. The greatest drop is seen in the neighbourhoods with monthly income below 1000 Réais[24] (-11 per cent on average). However, two non-independent effects may infer: income effect and

[22]Here the residence areas group Manaus neighbourhoods on the basis of household income measured by the IBGE census in 2000 (updated to 2004 Réais so as to compare with the minimum wage of $R260/month).

[23]Households consuming above the billing threshold represent 63 per cent of all previous connections (and only 60 per cent of metered connections living in Areas I and II, the others consuming below the minimum billing threshold)

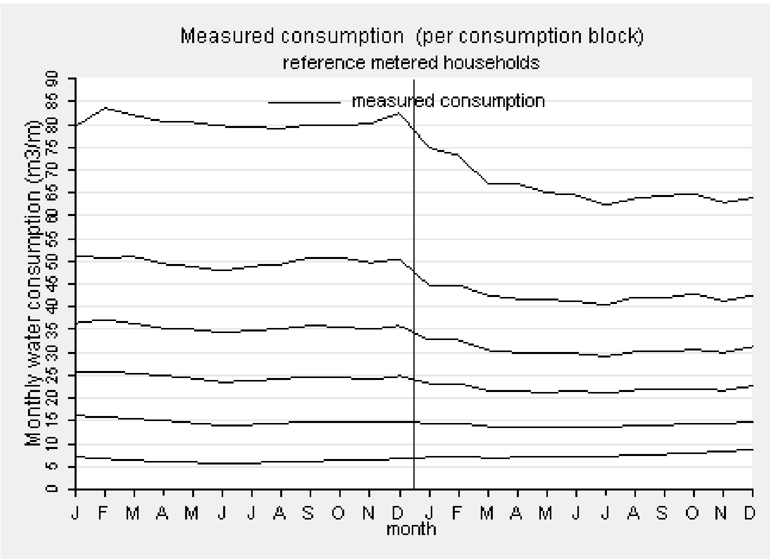
[24]Réais updated to 2004 value

Figure 9: Monthly water consumption by metered households consuming above the billing threshold, grouped by residence area, from January 2003 to December 2004



initial consumption level effect. Breaking down the data into consumption block enables to isolate, partially, these two effects (see Figure 10):

Figure 10: Variations in monthly water consumption by metered households, grouped by consumption block, from January 2003 to December 2004



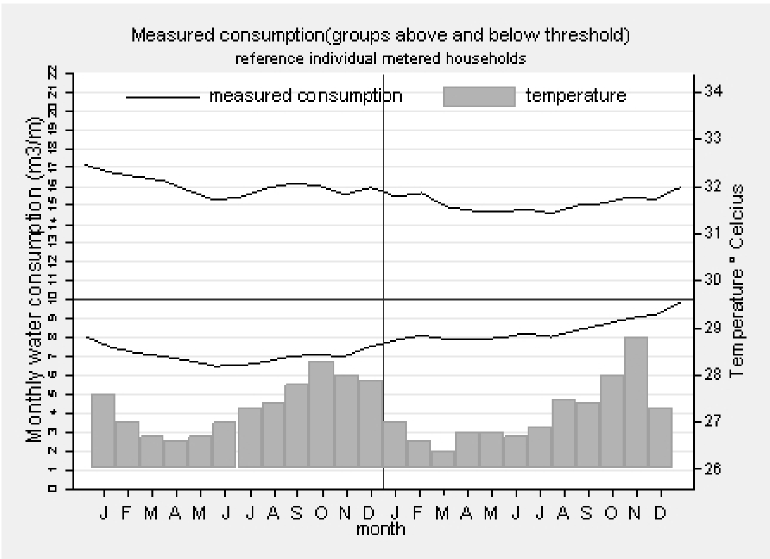
The variation in consumption between 2004 and 2003 is limited to -5.5 per cent on average for users in the 11-20m^3/month block and reaches -18 per cent on average for users in the block above 60m^3/month in 2003. These variations are to be compared with those of households in Block 1[25], i.e. consuming below the 10m^3/month billing threshold, for which average consumption rose by 9 per cent over the same period, their actual billed consumption, however, remaining the same.

[25]Here, the users taken into account are those whose average annual consumption is more than 5 m^3/month, to avoid consumption levels that are abnormally low including by-passed meters or dwellings occupied irregularly.

Consumption blocks	Monthly Consumption (m^3/month) 2003	2004	Variation
Block 1	8.14	8.85	8.7%
Block 2	14.87	14.05	-5.5%
Block 3	24.64	21.93	-17.7%
Block 4	35.58	30.59	-14%
Block 5	49.9	42.3	-15.2%
Block 6	80.52	66.15	-17.8%
All	17.51	16.13	-7.9%

Comparison of consumption variation between groups consuming above and below the threshold:
As users consuming below the billing threshold cannot adjust their bills by modifying their consumption, they could serve as a control group, on the assumption that the price increase does not affect their consumption and that the consumption trend in the absence of increase (i.e. the counterfactual situation in relation to households billed for consumption) is the trend actually observed for this group. This *natural* trend, in the absence of price rise, seems to be towards a gradual increase in consumption (+9 per cent observed). Detailed graphic analysis of metered households consumption shows opposing trends on either side of the billing threshold, without however correcting for variations arising in the period (see figure 11 and also figure 14 in appendix showing the evolution of consumption broken down by 1m3 blocks for low consumers).

Figure 11: Monthly water consumption for the group consuming below the billing threshold and households consuming just above the threshold in 2003



It thus appears that the low consumer group has a specific trend tending to approach its monthly billing threshold. This trend, after econometric analysis correcting for temperature variations, should be *detrended* prior to be used as control group.

Delaying payment of bills :
Delaying payment of bills is also a way for a household to adjust to the price rise. Here it is approximated by the binary information according to which the household paid (or did not pay) its bill by the due date (i.e. within 10 days). Average variations in the payment rate within 10 days between 2004 and 2003 are significant, especially for unmetered households and in the low-income areas, characterised by payment rates below aver-

age even before the price rise (figure 12 and table 2).

Figure 12: level of bill recovery within 10 days per user category (metered and unmetered households)

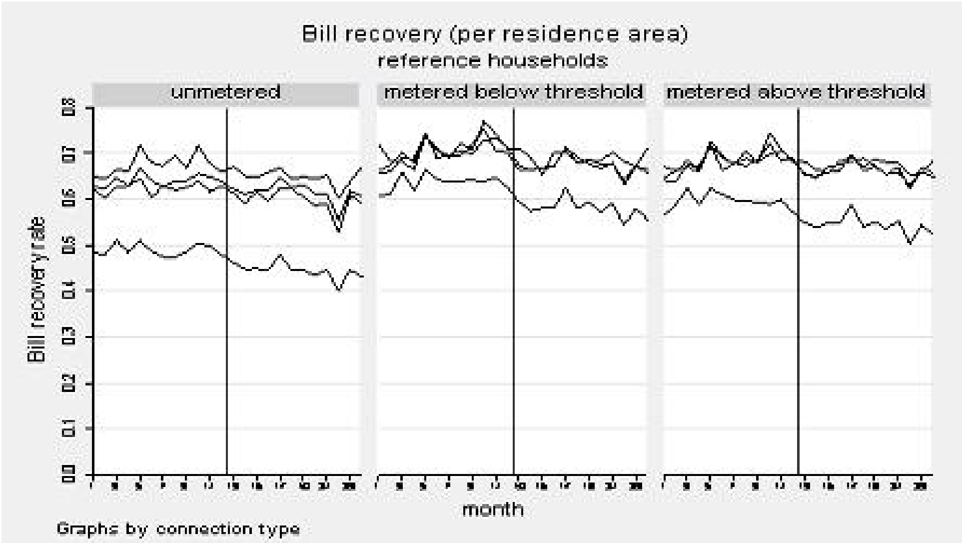


Table 2: Annual variations in recovery rates within 10 days by connection type and residence area:

	Area 1	Area 2	Area 3	Area 4	All
unmetered	-9,0%	-3,9%	-4,2%	-3,8%	-5,4%
meters below threshold	-8,6%	-4,1%	-4,1%	-3,1%	-4,4%
meters above threshold	-8,8%	-3,5%	-2,1%	-2,3%	-3,3%

The recovery rate within 10 days dropped between 2003 and 2004 by 4 per cent (in the better-off areas) to 9 per cent (in the poorest neighbourhoods) for unmetered connections. It should be noted that in these low-income areas, drop in the payment rate is of the same order for households billed for actual consumption. Although delay in payment is not an indicator as to actual eventual payment (the average level of recovery by the operator improves significantly at three months, reaching 76 per cent for the entire concession area in 2003[26]), its relative value (year-on-year variation) provides a control for these households' behaviour in terms of payment of bills.

Disconnections:
Because of disconnections, a certain number of households that may have chosen to stop consuming water from the network as a result of the tariff rise are removed from the analysis sample. Ascribing zero consumption to these households would, however, not distinguish them from households not consuming while maintaining their active connection for a variety of reasons (temporary absence, etc.) and therefore still being invoiced at the minimum level. Furthermore, closure might be at the operator request (after repeated failure to pay) but also at the user's request. Disconnections were limited in Area 1 whereas payment, already low, suffered the highest decrease. Sixty-four per cent of 2004 disconnections were of unmetered connections, these closures totalling 10 per cent of unmetered connections in Areas 3 and 4 with modest or high incomes (where the bills are also the highest). Cases of prolonged failure to pay do not seem to be dealt with equally by the operator, but it may also be a user decision with regard to the type of supply, and therefore linked to the available alternatives.

[26]Information from Aguas do Amazonas Sales Department.

The preliminary analysis of households with meters remaining active over the entire 24 months, therefore of the cylindered sample, indicated an average drop in consumption between the two years independently from the attrition of the sample (attrition, moreover, remaining slight for this category of user, only 2 687 meters were permanently inactive in 2004, and will be considered as negligible for the rest of the analysis).

2.3.2 Impact evaluation of the tariff increase

The tariff increase of January 2004 is considered as an exogenous shock applied between year a and year $a+1$. For each household i, the difference in consumption (as ln) between the month m of the year $a+1$ and the month m of the year a is:

$$\Delta lnC_{(m,i)} = lnC_{(m(a+1),i)} - lnC_{(m(a),i)}$$

The difference no longer includes characteristics of households that have not changed between years $a+1$ and a (i.e. fixed household effects - this assumes no change in characteristics influencing demand such as the size and income of the household) as well as the fixed month effects. Only variables having varied between years $a+1$ and a, considered month by month, are now determining factors, i.e.: the monthly rainfall, P, average monthly temperature,T, characteristics of household connections, X_i (number of households sharing the bill, possible connection to sanitation system); and the tariff, whose effect will be measured in the constant linked to year a, this remaining constant within each year.

$$\Delta lnC_{(m,i)} = \Delta A + \alpha.\Delta lnP_{(m)} + \beta.\Delta lnT_{(m)} + \gamma.\Delta X_{(m,i)} + \Delta U_{(m,i)}$$

As the entire population connected to the water network was subject to the tariff rise simultaneously, there is no natural control group and the critical question of the counterfactual scenario arises. The aggregated monthly consumptions communicated by the operator do not allow approximation of a possible consumption trend over several years, given the important changes in the structure of the customers set (extension into poor neighbourhoods, conversion of numerous unmetered connections to metering, separating of connections - *deco-habitations*) but also because of the low or zero consumptions recorded by the operator as the billing threshold. Estimation of this possible annual trend would have required individual data for an additional year before the tariff increase, i.e. for all of 2002.

- An initial assumption, according to which there is no specific annual trend in the absence of the tariff rise, allows simple difference analysis of consumption month on month for households consuming above the billing threshold. Because of the lag between the month of consumption and the month of billing, the corresponding climatic data used is the average for the two months prior to billing. The residual variation measured between the two years will then be attributed to the price increase (+31.51 per cent between 2003 and 2004 for each consumption block) without former information on any possible shocks during this period.

- A second assumption, according to which households consuming below the billing threshold have a specific gradual linear tendency to approach the threshold at which they are billed, allows, once this specific trend has been eliminated, to retain this group as the control group and to thus eliminate unobserved shocks (supply or other problems) that have affected the entire population. Under this assumption, and assuming that these households are affected by these shocks in the same way as the others, variation measured using the *Difference in Difference* method for consumers above the billing threshold can be attributed to the price rise between 2003 and 2004.

2.3.3 Econometric analysis of consumption variation by month-on-month difference :

The data used for the econometric analysis are those for all of the metered households for which the connection was active at least once during the study period, after elimination, however, of : households having modified their type of connection (by ceasing to share or change in number of households), as the effects of these changes would be different depending on the initial consumption level[27]; households that change the status of their connection (*Water* or *Water and Sanitation)*, as these modification can be in both directions; and households for which the average monthly consumption was not more than $5m^3$/month[28].

Simple difference analysis for consumers above the billing threshold :

Table 3 presents the results of the regression of the difference in water consumption over the full year, showing monthly variations in relation to the annual mean and controlling for variations in the recovery rates. The complete regression results are presented in appendix, in Table 13.

Table 3: Monthly variations in water consumption reduction between 2003 and 2004 for all metered households (OLS regression):

	Est. Coefficients	
Consumption difference (as ln)	-0.1446	**
January	0.0404	**
February	0.0344	**
March	-0.0162	**
April	-0.0205	**
May	-0.0130	**
June	0.0181	**
July	-0.0115	**
August	-0.0172	**
September	-0.0281	**
October	-0.0119	**
November	-0.0003	
December	0.0256	**
control variables		
recovery rate variation		
* significant at 5%; ** significant à 1%		
the sum of the monthly coefficients is constrained to 0		

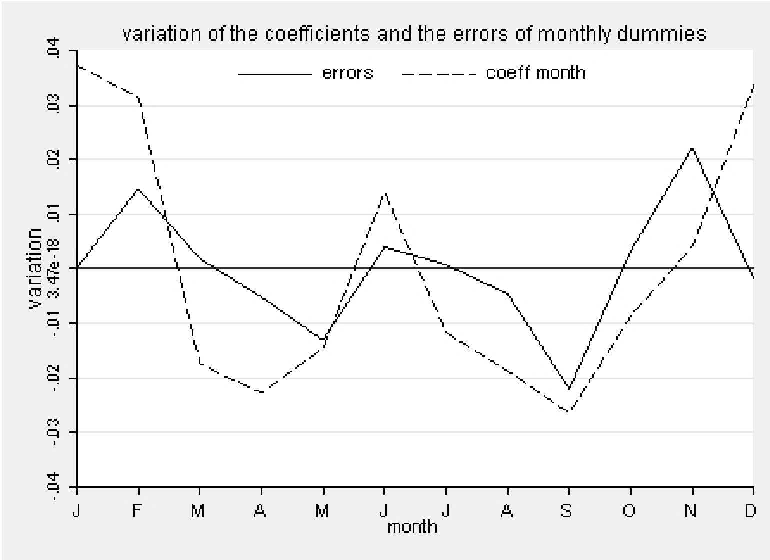
As time variations are partly due to climatic variations (monthly temperature and rainfall are not stable from one year to another), it is necessary to analyse these consumption variations once controlled for climatic variations, by regressing the monthly dummy coefficients estimated from previous regression on the corresponding temperature and rainfall data so as to extract the error terms (figure 13, the corresponding regression is shown in appendix, in Table 13):

Once the effect of climatic variations is allowed for, there is no visible time-related trend for monthly variations in the water consumption reduction. In particular, the lower reductions observed at the start and end of the period (January and December) are corrected. Residual variations, unexplained by the variables available for analysis (of $\pm 2\%$), may be due to events affecting the entire city, as water supply incidents, or to variations in the interval between two meter readings (interval which can vary from 29 to 32 days).

[27] A household initially consuming below the threshold and separating into two households will double its bill whereas a household consuming in the higher blocks will reduce its unit price while separating in two connections

[28] The users taken into account are those whose average annual consumption is more than $5m^3$/month, to avoid abnormally low consumptions including by-passed meters or dwelling used irregularly.

Figure 13: Monthly Dummies' coefficients and error terms of the regression of these coefficients on temperature and rainfall variation for each month.



The rest of the analysis is therefore carried out for all year, controlling for temperature and rainfall variations. As expected, the increase in temperature, and reduction in rainfall lead to increased water consumption. Finally, the factor of improvement in paying bills on time (to avoid cut off) also leads to a reduction in water consumption. Once controlling for these variations, the average reduction in consumption between 2003 and 2004 was -13.19 per cent (-0.1415 as logarithm difference), see tables 4 and 14 in appendix.

Table 4: Average variation in water consumption (as ln)

Consumption difference (as ln)	-0.1415	[-0.1425	-0.1405]
control variables			
rain variation (as ln)	-0.0162	[-0.0187	-0.0137]
temperature variation (as ln)	1.5325	[1.4252	1.6398]
recovery rate variation	-0.0159	[-0.0176	-0.0142]

95% confidence interval in brackets

Using the residence area as a proxy for living standard, we show that the households in areas 1 and 2, the poorest areas, reduced their water consumption (-13 to -15%) more than those on the better-off areas 3 and 4 (-11%), see tables 5 and 15 in appendix.

This greater price elasticity in the low-income neighbourhoods is, however, only slightly apparent because of the effect of the initial consumption level. For similar income levels, the higher the initial consumption level (average 2003 consumption), the greater the reduction in consumption in 2004, for all areas, reaching an amplitude of -25 per cent for consumption blocks above 40m^3/month. Consumption level is, however, a complex variable in that it stands as a proxy for income, but involves other aspects of water consumption such as the existence of a consumption threshold that is only slightly compressible and *luxury* consumption above that threshold that is more sensitive to price (Table 6).

[29]The rates of variation are calculated directly from the mean differences of the logarithms of consumption, with the assumption that impact is homogeneous. The effects of heterogeneity of impact are presented in Appendix A.3.3

Table 5: Variation in water consumption (as ln), by residence area

Residence Area	Consumption Difference between 2004 and 2003	
	as difference of ln	as variation rate[29]
Area 1	-0,1433 [-0,1495 - 0,1372]	-13.4 %
Area 2	-0,1625 [-0,1652 - 0,1597]	-15.0 %
Area 3	-0,1203 [-0,1246 - 0,1160]	-11.3 %
Area 4	-0,1196 [-0,1230 - 0,1162]	-11.3 %

95% confidence interval in brackets

Table 6: Variation in water consumption (as ln) by consumption block

Monthly consumption block	Consumption Difference between 2004 and 2003			
	Area 1	Area 2	Area 3	Area4
Block 2	- 0,1065	- 0,1252	- 0,0786	- 0,0771
Block 3	- 0,2127	- 0,2286	- 0,1605	- 0,1277
Block 4	- 0,2600	- 0,2698	- 0,2183	- 0,1827
Block 5	- 0,2846	- 0,2473	- 0,2564	- 0,2164
Block 6	ns	- 0,3133	- 0,3563	- 0,2868

High consumers were therefore those who moderated their consumption the most, although this reduction is less pronounced in well-off neighbourhoods[30]. Using average income per neighbourhood (IBGE data 2000) to refine the effect of living standard on consumption variation, this effect appears significant and positive, i.e. income effectively moderates reduction in water consumption, and does so in spite of the effect of consumption level: the more the residential area is well-off the less households reduced their consumption in 2004 (see Table 16 in appendix, presenting the results of regression and including the average income of the neighbourhood instead of residence area variable).

Impact of tariff increase depending on household living standard :

The distributive impact of the tariff increase was then assessed using the households sample of the socio-economic survey conducted by the Federal University of Amazonas (Ufam) in September 2004[31]. These households, taken from a representative sample of the city of Manaus (see the description of sample in Appendix A.2), were grouped by quintile based on monthly family income, expressed per adult equivalent[32] (table 7)
Amongst the households connected to the water network, 70 per cent of the poorest receive fixed bills, either unmetered or under the billing threshold. They were therefore subject to a 31.5 per cent bill increase without the opportunity of adjusting their consumption. Conversely, 63 per cent of the wealthiest households, billed on the basis of their actual consumption, could adjust their bill. The actual households consumption is only known for those metered, i.e. around 60 per cent of the connected population. Average and median individual consumption levels are respectively 4.1 m^3/cap.month and 3,4 m^3/cap.month. Regression analysis of consumption difference was carried out, with the same control variables. Over this sample, reduced to households consuming above

[30]Households consuming in block 2 represent 60 per cent of the sample used for elasticity, whereas blocks 5 and 6 represent only 4 per cent.

[31]3 012 households representative of Manaus' population were interviewed by field researchers from Ufam in September 2004. Amongst these, 2 122 households out of 2 282 connected to the water network were identified in the database of the operator Aguas do Amazonas.

[32]The size of household in the denominator is raised to the power 0.7 to allow for scale efficiency.

Table 7: Breakdown of households connected to the water network, by income quintile

	Unmetered Connection	Metered Connection	
		Block 1	Above Block 1
quintile 1	56.7%	15.3%	28.0%
quintile 2	47.0%	16.9%	36.1%
quintile 3	45.9%	14.9%	39.2%
quintile 4	35.0%	16.8%	48.2%
quintile 5	22.2%	15.0%	62.8%

the consumption threshold and for which socio-economic data are available (849 households), temperature difference is no longer significant, and only the rainfall difference is kept as climatic variable (see Table 8 and table 17 in appendix).

Table 8: Households connected to the water network and consuming above the billing threshold

	Households distribution	Consumption Difference between 2004 and 2003	
		as ln	as variation rate
quintile 1	9,8%	-0,2386	-21,23%
quintile 2	16,4%	-0,1421	-13,25%
quintile 3	15,5%	-0,1069	-10,14%
quintile 4	24,3%	-0,0810	- 7,78%
quintile 5	34,1%	-0,1044	- 9,91%

The regression results confirm the trend approached by the preceding analysis based on the residence area, i.e. that the poorest households (including those that had the opportunity to control their bill as, initially, consuming above the billing threshold) reduced their consumption more than the others following the tariff increase. Andrade and Araùjo Lobão (1996) [1] in Brazil and Blundell and Nauges (2002) [5] in Cyprus had also shown greater price elasticity for water in the poorest households. The households in the first quintile (i.e. those among the 20 per cent of Manaus' poorest) reduced their consumption by 21 per cent between 2004 and 2003. The wealthiest households also reduced their consumption but in a lower proportion (-10%). As a consequence of this reduction, the bills of households able to adjust their consumption increased by a median value of 16.5 per cent, while that of the other households (70 per cent of the poorest households connected to the water network, i.e. the major part of them) increased by 31.5 per cent.

Difference in Difference *analysis using households consuming between 6 and 8 m3/month on average in 2003 (i.e. below the billing threshold but with significant consumption) as the control group:*

Once controlling for variations in climatic conditions month by month between 2004 and 2003, a time-trend towards increased consumption remains in the control group (group consuming below the billing threshold). Graph 15, in appendix, shows, for the control group, the coefficients for monthly dummies of the regression of the difference in water consumption without controlling for climatic variations, and the regression error terms after controlling for climatic variations and for a uniform linear monthly trend.

Two hypotheses are applied here to absorb the macroeconomic shocks to which all users were subject, but unobserved with the available data:

- Low hypothesis: the consumption increase trend is specific to the category of user consuming below the billing threshold, users attempting to approach the billed threshold. By eliminating this uniform trend, the monthly variation, once the climatic variation data have been equalised, becomes slightly negative. The implicit assumption becomes the following: without price increase, the trend over time for all users, left unexplained by the available variables, is towards a slight reduction in consumption.
- High hypothesis: the progressive increase in consumption observed for the control group is the counterfactual trend for all users.

With the *Difference in Difference* method, the consumption variation between 2003 and 2004 for users consuming above the threshold is therefore lower than that measured by simple difference with the low hypothesis (-12 per cent against -13.2 per cent), and is more pronounced with the high hypothesis (-17.7 per cent): see regression in Table 9 and 18 in appendix, and levels of variation accounting for heterogeneity of impact, in Appendix A.3.3. These two hypotheses encompass the estimate of corresponding average price elasticity, by attributing the entire residual variation to the 31.5 per cent tariff increase, determining a bracket from -0.38 to -0.56, according to the prior trend assumption.

Table 9: Variation in consumption using a *Difference in Difference* Method

Initial Consumption Block	Consumption Difference between 2003 and 2004 (as ln)	
	low hypothesis	high hypothesis
All (except block 1)	- 0,1275	- 0,1955
Block 2	- 0,0907	- 0,1587
Block 3	- 0,1694	- 0,2374
Block 4	- 0,2072	- 0,2752
Block 5	- 0,2183	- 0,2863
Block 6	- 0,2832	- 0,3512
Control Group (block 1)	-0,0140	+ 0,0540

3 CONCLUSION

Water price increase in Manaus, although applied uniformly to all users, has differing effects for different categories of residents:

Only the poorest households, consuming below the billing threshold of 10 m^3/month or on the basis of a pre-established fixed monthly amount, experienced an effective increase in their water bills of 31.5 per cent, i.e. of the same range as the unit price increase. In this category, late payments have increased more than in others. Better-off households, having the opportunity to alter their consumption, as they are billed on their actual consumption, reduced the impact of this price increase on their monthly bill, evidencing price elasticity of water consumption of -0.4 to -0.6 on average, according to the prior trend assumed and rising with initial consumption level. Assuming equal consumption blocks (and it should be borne in mind that most of the households billed beyond the threshold consume in the second block), the poorest households reduced their consumption the most (price elasticity of first quintile households is estimated at -0.7 in the absence of prior consumption trend).

The uniform price increase, by leading to reduction of highest consumptions, has introduced a further imbalance into the cross-subsidy mechanism which was already hardly satisfactory, by penalising the poorest households as the majority of whom are billed on a fixed basis.

Since then, a tariff reform project has been proposed by the operator in coordination with the services regulator, on the basis of a uniform tariff offset by a requirement to ensure a *social tariff* in the form of a rebate for eligible low-income households.

References

[1] Andrade T.A. et W.J. de Araùjo Lobão (1996), *Tarifação Social no Consumo Residencial de Agua*, Texto para discussão n° 438, IPEA, Brazil.

[2] Arbues F. et al. (2003), *Estimation of residential water demand: a state-of-the-art review*, Journal of Socio-Economics 32, 81-102.

[3] Bertrand M., Duflo E. and Mullainhatan S.(2003), *How Much Should we Trust Differences-in-Differences Estimates?*, Quarterly Journal of Economics, MIT Press, vol. 119(1), pages 249-275, February.

[4] Billings R. and Agthe (1980), *Price Elasticities for Water: A Case of Increasing Block Rates*, Land Economics 56(1), 73-84

[5] Blundell R. and C. Nauges (2002), *Estimating Residential Water Demand under Block Rate Pricing: A Non parametric Approach*, Working Paper 02.21.096 LEERNA-INRA, Toulouse and University College London

[6] Blundell R. and M. Costa Dias (2000), *Evaluation Methods for Non-experimental Data*, Fiscal Studies, Vol 21, N°4, pp 427-468.

[7] Boland J. and D. Whittington (2000), *The Political Economy of Water Tariff Design in Developing Countries*, in Ariel Dinar (ed) The Political economy of Water Pricing Reforms, Oxford University Press: Oxford, 215 -235.

[8] Dalhuisen J. et al. (2003), *Price and Income Elasticities of Residential Water Demand: A Meta-Analysis*, Land Economics 79 (2), 292-308.

[9] Duflo E.(2002), *Empirical Methods* , mimeo MIT

[10] Espey J.,Espey M. and Shaw W.(1997), *Price Elasticity of Residential Demand for Water: A Meta-Analysis*, Water Resources Research, 33(6): 1369-1374.

[11] Ferreira F. Lanjow P. and Neri M. (2000), *A new Poverty profile for Brazil using PPV*, PNAD and Census Data.

[12] FGV, GV Consult (2004), *Estudo de Novo Regime Tarifario, Survey for Aguas do Amazonas, coord. Roberto Perosa, FGV*, Report for Aguas do Amazonas.

[13] Foster V. et al. (2006) *The Distributional Incidence of Residential Water and Electricity Subsidies* World Bank Policy Research Working Paper 3878.

[14] Galiani S., Gertler P. and Schargrodsky E.(2005), *Water for Life : The Impact of the Privatization of Water Services on Child Mortality*, Journal of Political Economy, vol 113, 83-120

[15] Gaudin S. Griffin R.. and Sickles R. (2001), *Demand Specification for Municipal Water Management : Evaluation of the Stone-Geary Form*, Land Economics 77 (3), 399-422.

[16] Heckman J., Lalonde R. and J. Smith (1999), *The Economics and Econometrics of Active Labor Market Programs*, in Handbook of Labor Economics, Volume 3, Elsevier Sciences, 1865-2097.

[17] Hewitt J. and Hanemann W. (1995), *A Discrete/Continuous Choice Approach to Residential Water Demand under Block Rate Pricing*, Land Economics 71 (May), 173-192.

[18] Jalan J. et M. Ravallion (2001), *Does Piped Water Reduce Diarrhea for Children in Rural India?* World Bank Policy Research Working Paper 2664.

[19] Martinez-Espineira R. and Nauges C. (2004), *Is all Domestic Water Consumption Sensitive to Price Control?* , Applied Economics 36, 1697-1703.

[20] Morel à l'Huissier A. et A. Olivier (2003), *Willingness to Pay Survey for Water and Sanitation Services in Manaus*, Report for Suez Environnement.

[21] Nieswiadomy M. and Molina D. (2001), *A Note on Price Perception on Water Demand Models*, Land Economics 67 (3), 352-359

[22] Nordin, J. (1976), *A Proposed Modification of Taylor's Demand Analysis : Comment*, The Bell Journal of Economics, 7, 719-721.

[23] Moffitt R. (1986), *The Econometrics of Piece-wise Linear Budget Constraints*, Journal of Business and Econometric Statistics, 4(3), 317-328.

[24] Piketty T. (1999), *Les hauts revenus face aux modifications des taux marginaux supérieurs de l'impôt sur le revenu en France, 1970-1996*, Economie et Prévision 138-139 , 25-60

[25] PPIAF (2002), *Water and Subsidies in South Asia: Understanding the Basics*, Prepared by Whittington D., Boland J. and Foster V.

[26] Schefter J. and David E. (1985), *Estimating Residential Water Demand under Multi-Part Tariffs, using aggregate Data*, Land Economics 61 (3), 272-280.

[27] Shin J. (1985), *Perception of Price when Price Information is Costly: Evidence from Residential Electricity Demand*, Revue d'Economie et Statistiques, 67(4), 591-598.

[28] Taylor L. (1975), *The Demand for Electricity : A Survey*, The Bell Journal of Economics, 6, 74-110.

[29] Universidade Federal do Amazonas (2004), *Pesquisa Socioeconomica : Subsidios para a definiçao de novo regime tarifario*, Survey for Aguas do Amazonas, coordinated by Dra. Andrea Waichman.

A APPENDIX

A.1 Tariffs applied from 2000 to 2004.

Tariff increases applied until 2004 are uniform, without modification of the block structure:

Table 10: Tariffs applied in Manaus from 2000 to 2004

Category and consumption block	Tariffs (R/m^3)				
	(1)	(2)	(3)	(4)	(5)
Residential					
0 to 10 m^3	0,6240	0,6929	0,7955	0,8670	1,1402
11 to 20 m^3	1,210	1,344	1,5425	1,6800	2,2094
21 to 30 m^3	1,848	2,052	2,3558	2,5650	3,3733
31 to 40 m^3	2,517	2,795	3,2086	3,4940	4,5951
41 to 60 m^3	2,904	3,225	3,7019	4,0310	5,3013
> 60 m^3	3,311	3,677	4,2207	4,5960	6,0444
Industrial					
0 to 40 m^3	2,891	3,210	3,6853	4,0120	5,2763
> 40 m^3	3,964	4,402	5,0532	5,5020	7,2359
Public					
0 to 12 m^3	2,891	3,210	3,6853	4,0120	5,2763
> 12 m^3	3,964	4,402	5,0532	5,5020	7,2359
Commercial					
0 to 12 m^3	2,215	2,460	2,8236	3,0750	4,0441
> 12 m^3	3,085	3,426	3,9326	4,2820	5,6314
Mixed					
0 to 40 m^3	1,6057	1,7830	2,0468	2,2285	2,9308
> 40 m^3	3,3107	3,6763	4,2204	4,5951	6,0432

Source: FGV, 2004 [12]
(1) July 2000
(2) Annual adjustment + 11,0421% - January 2001.
(3) Exceptional tariff increase + 14,8% approved on 06/03/02.
(4) Annual adjustment + 8,8778% approved on 27/06/02.
(5) Exceptional tariff increase + 31,5141%, applied in January 2004.

A.2 Description of the data base *Ufam Household survey* - September 2004

Household data have been collected from 3012 households between August and September 2004, representative from the whole city of Manaus (56 neighbourhoods). They include socio-economic characteristics of the households (size, education, occupation, monthly expenses and income) and the housing conditions (housing type, energy, water, sewage, main equipment). Among these households, 2282 have a municipal water network connection, active during the survey period, i.e. 76% of the sample, and 5% a sewage connection. 2122 households have been identified within the operator database using their customer number, i.e. 93% of the households identified as active customers of the water network. Cross section socioeconomic data as well as monthly water consumption data from January 2003 to 2004 have been collected for these households.

	Total Households	water network users	share of water network users	Share of households identified among the water network users
Initial data base	3012	2282	76%	
data base analysed	2122	2122	100%	93 %

Main characteristics of the sub-sample of network water users compared to all residential users in October 2004:

- 18,5% share their connection (vs. 29% of all residential customers).
- 59.9% have a meter (vs. 62% of all residential customers)
- 6.6% have a sewage connection (vs. 9.6% of all residential customers)

Distribution of the households per income quintile (income per adult equivalent) in the sub-samples:

Table 11: Water network users per income quintile

	households connected and active		identified households from the HH survey		
Income Quintiles	Freq.	Percentage.	Freq.	Percent.	Share of users
1	389	17.05 %	360	16.97 %	92.5%
2	399	17.48 %	370	17.44 %	92.7%
3	472	20.68 %	436	20.55 %	92.4%
4	502	22.00 %	469	22.10 %	93.4%
5	520	22.79 %	487	22.95 %	93.7%
Total	2,282	100.00 %	2,122	100.00 %	93 %

Except for the under-representation of households sharing their connection, the socio-economic pattern of the sub-sample of identified households allows us to use it for the analysis of the connected households.

Table 12: Description of the water supply characteristics per income quintile

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	All
active connection in October 2004	64.6%	66.3%	78.4%	83.3%	86.4%	75.8%
Connected						
meters	43,33%	52,97 %	54,12 %	65,03%	77,82%	59,94%
consumption 2004 (m^3/m)	13,54	14,09	14,56	16,32	17,72	15,42
water exp. ratio	6,7%	4,4 %	3,6 %	3,3%	1,7%	3,8%
Meters						
1^{st} block	35,3%	31,9%	27,6%	25,9%	19,3%	26,3%
consumption 2004 (m^3/m)	12,03	13,15	13,85	15,71	17,20	14,97
water exp. ratio	6,5%	4,8 %	3,7 %	3,4%	0,8%	3,6%

A.3 Regression results

A.3.1 Simple Difference Analysis

Table 13: Monthly variation of the consumption drop (MCO)

	(1) Consumption Difference (as ln)		(2) monthly coefficients errors	
Constant	-0.1446	[0.0009]**	0.0034	[0.0045]
January	0.0404	[0.0031]**		
February	0.0344	[0.0031]**		
March	-0.0162	[0.0030]**		
April	-0.0205	[0.0030]**		
May	-0.0130	[0.0029]**		
June	0.0181	[0.0029]**		
July	-0.0115	[0.0028]**		
August	-0.0172	[0.0028]**		
September	-0.0281	[0.0028]**		
October	-0.0119	[0.0028]**		
November	-0.0003	[0.0028]		
December	0.0256	[0.0028]**		
control variable				
recovery rate variation	-0.0158	[0.0017]**		
temperature variation (as ln)			1.5545	[0.4511]**
rainfall variation (as ln)			-0.0171	[0.0107]
Observations	825562		12	
R^2	/		0.75	
F test	58.82		3.21	
Root MSE	0.79		0.01	
Standard errors in brackets * significant at 5%; ** significant at 1%				
regression (1) is constrained : the sum of monthly dummies' coefficients is 0				

Table 14: Consumption variations (MCO)

	(Model with compilation)		(Fixed effect model)
	(1)	(2)	(3)
Consumption difference (as ln)			
Constant	-0.1410 [0.0010]**	-0.1415 [0.0010]**	-0.1423 [0.0008]**
control variables			
rainfall variation	-0.0132 [0.0025]**	-0.0162 [0.0025]**	-0.0203 [0.0020]**
temperature variation	1.6183 [0.1073]**	1.5325 [0.1073]**	1.4389 [0.0870]**
recovery rate variation	-0.0188 [0.0017]**	-0.0159 [0.0017]**	-0.0136 [0.0016]**
HH number per connection variation	-0.4774 [0.0062]**		
Observations	842555	825562	825562
R^2	0.008	0.001	0.408
F test	1598.37	178.43	259.91
Root MSE	0.802	0.792	

Standard errors in brackets
* significant at 5%; ** significant at 1%
regression (1) keeps the connections that modified their sharing characteristics (74 451 connections)
regressions (2) et (3) use 74 292 connections

Table 15: Consumption variations per area (MCO)

	(1)		(2)	
consumption difference (as ln)				
Constant	-0.1433	[0.0031]**	-0.1065	[0.0037]**
area 2	-0.0191	[0.0033] *		
area 3	0.0230	[0.0038] **		
area 4	0.0237	[0.0035]**		
z1cl3			-0.1062	[0.0074] **
z1cl4			-0.1535	[0.0132] **
z1cl5			-0.1781	[0.0244] **
z1cl6			-0.1095	[0.0519] *
z2cl2			-0.0187	[0.0040] **
z2cl3			-0.1221	[0.0045] **
z2cl4			-0.1633	[0.0063] **
z2cl5			-0.1408	[0.0105] **
z2cl6			-0.2068	[0.0257] **
z3cl2			0.0279	[0.0046] **
z3cl3			-0.0540	[0.0055] **
z3cl4			-0.1118	[0.0079] **
z3cl5			-0.1499	[0.0125] **
z3cl6			-0.2498	[0.0304] **
z4cl2			0.0294	[0.0044] **
z4cl3			-0.0212	[0.0048] **
z4cl4			-0.0762	[0.0057] **
z4cl5			-0.1099	[0.0072] **
z4cl6			-0.1803	[0.0138] **
control variables				
rainfall variation (as ln)	-0.0163	[0.0025]**	-0.0162	[0.0024]**
temperature variation (as ln)	1.5245	[0.1073]**	1.5330	[0.1070]**
recovery rate variation	-0.0162	[0.0017]**	-0.0151	[0.0017]**
Observations	825562		825562	
R^2	0.001		0.006	
F test	180.96		222.45	
Root MSE	0.791		0.790	
Standard errors in brackets				
* significant at 5%; ** significant at 1%				

Table 16: Consumption variation per area, using the average monthly income of the neighbourhood (MCO)

	(1)	(2)
consumption difference (as ln)		
Constant	-0.1415	-0.4026
	[0.0010]**	[0.0118]**
control variables		
rainfall variation	-0.0162	-0.0160
	[0.0025]**	[0.0025]**
temperature variation	1.5325	1.5280
	[0.1073]**	[0.1073]**
recovery rate variation	-0.0159	-0.0163
	[0.0017]**	[0.0017]**
average monthly income of the neighbourhood (ln)		0.0385
		[0.0017]**
Observations	825562	825562
R^2	0.001	0.001
F test	178.43	256.53
Root MSE	0.792	0.791
Standard errors in brackets		
* significant at 5%; ** significant at 1%		

Table 17: Consumption variations per quintiles (MCO)

	(1)	(2)
consumption difference (as ln)		
Constant (quintile 1)	-0.2386	-0.2408
	[0.0269]**	[0.0264]**
quintile 2	0.0965	0.0970
	[0.0352]**	[0.0351]**
quintile 3	0.1317	0.1321
	[0.0324]**	[0.0324]**
quintile 4	0.1576	0.1575
	[0.0311]**	[0.0311]**
quintile 5	0.1342	0.1341
	[0.0296]**	[0.0296]**
control variables		
rainfall variation	-0.0280	-0.0335
	[0.0230]	[0.0199]
temperature variation		0.5086
		[1.0011]
recovery rate variation		-0.0167
		[0.0168]
Observations	8135	8135
F test	4.62	6.22
Root MSE	0.73	0.73
Standard errors in brackets		
* significant at 5%; ** significant at 1%		

A.3.2 Difference in Difference Analysis

Figure 14: Monthly consumption of the low consumers group, per block of 1 m3

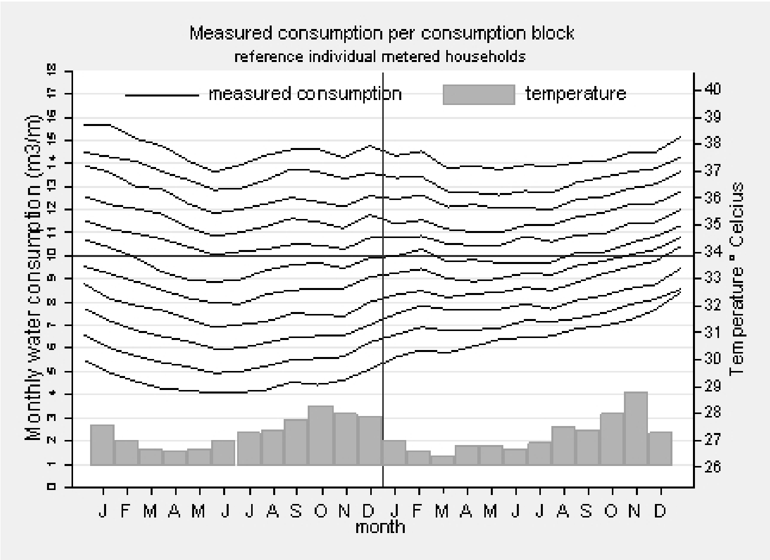


Figure 15: Monthly consumption variation of the control group :

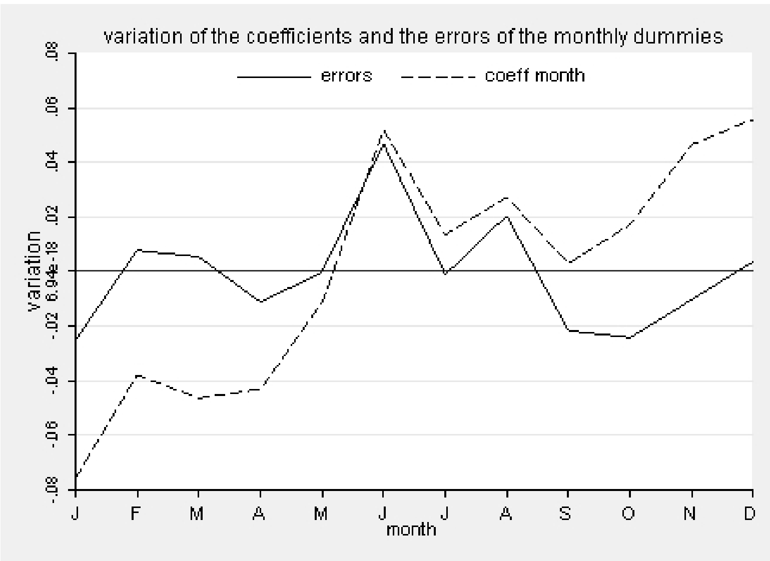


Table 18: Difference in Difference Analysis of the monthly variations (MCO)

	(1)	(2)	(3)	(4)
Consumption Difference (as ln)				
target group (all blocks)	-0.1955	-0.1275		
	[0.0033]**	[0.0061]**		
block2			-0.1587	-0.0907
			[0.0034]**	[0.0061]**
block3			-0.2374	-0.1694
			[0.0036]**	[0.0063]**
block4			-0.2752	-0.2072
			[0.0043]**	[0.0067]**
block5			-0.2863	-0.2183
			[0.0058]**	[0.0077]**
block6			-0.3512	-0.2832
			[0.0114]**	[0.0125]**
control variables for the target group				
temperature variation - target group	1.0285	0.6642	1.0384	0.6742
	[0.3375]**	[0.3386]*	[0.3370]**	[0.3381]*
rainfall variation - target group	-0.0376	-0.0323	-0.0377	-0.0323
	[0.0078]**	[0.0078]**	[0.0078]**	[0.0078]**
recovery rate variation - target group	-0.0011	-0.0037	0.0000	-0.0025
	[0.0054]	[0.0054]	[0.0054]	[0.0054]
Constant (control)	0.0540	-0.0140	0.0540	-0.0140
	[0.0031]**	[0.0060]*	[0.0031]**	[0.0060]*
monthly trend of the control group		0.0103		0.0103
		[0.0008]**		[0.0008]**
control variables of the control group				
rainfall variation	0.0214	0.0160	0.0214	0.0160
	[0.0074]**	[0.0074]*	[0.0074]**	[0.0074]*
temperature variation	0.5041	0.8683	0.5041	0.8683
	[0.3193]	[0.3205]**	[0.3188]	[0.3199]**
recovery rate variation	-0.0148	-0.0122	-0.0148	-0.0122
	[0.0051]**	[0.0051]*	[0.0051]**	[0.0051]*
Observations	920343	920343	920343	920343
R^2	0.006	0.006	0.009	0.009
F test	788.49	711.96	768.60	719.33
Root MSE	0.807	0.807	0.805	0.805
Standard errors in brackets				
* significant at 5%; ** significant at 1%				

A.3.3 Impact Heterogeneity based on initial consumption level

While breaking down the results into consumption blocks, the answer shows a positive gradient with the initial consumption level:

Reminder : Difference in Difference consumption variation

Initial consumption block	prop.	consumption difference between 2003 and 2004 (as ln)	
		low hypothesis	high hypothesis
All (except block 1)	100%	- 0,1275	- 0,1955
Block 2	60.68%	- 0,0907	- 0,1587
Block 3	26.27%	- 0,1694	- 0,2374
Block 4	9.01%	- 0,2072	- 0,2752
Block 5	3.38%	- 0,2183	- 0,2863
Block 6	0.66%	- 0,2832	- 0,3512

The impact measured using the regressions between year a and year $a+1$ have been expressed as logarithm difference of the monthly consumptions:

$$lnC_{a+1} = lnC_a + A$$
$$A = dlnC = lnC_{a+1} - lnC_a = ln(\frac{C_{a+1}}{C_a})$$

the consumption variation rate is δ : $\delta = \frac{C_{a+1}-C_a}{C_a}$ thus the relation between the variation rate and the logarithm difference is $\delta = exp(A) - 1$

Under the assumption of an heterogeneous impact, the average variation rates, calculated using the consumption difference in log, must be corrected using the distribution of the consumptions:

$$\delta(C) = exp(A(C)) - 1 \qquad and \qquad \overline{\delta} = \int_C [exp(A(C) - 1].dc$$

The distribution per consumption blocks will be used as a proxy for a continuous distribution : the average variation rate is thus slightly corrected (-11.87 % and -17.66% instead of -11.97% and -17.76%) when these rates are calculated based on the average differences.

Initial	prop.	low hypothesis		high hypothesis	
Consumption Block		Difference as ln	variation rate	Difference as ln	variation rate
Block 2	60.68%	- 0,0907	-8.67%	- 0,1587	-14.67%
Block 3	26.27%	- 0,1694	-15.58%	- 0,2374	-21.13%
Block 4	9.01%	- 0,2072	- 18.71%	- 0,2752	-24.06%
Block 5	3.38%	- 0,2183	-19.61%	- 0,2863	-24.9%
Block 6	0.66%	- 0,2832	-24.66%	- 0,3512	-29.62%
Average Variations		- 0,1275	-11.87%	- 0,1955	-17.66%