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Consumer Demand and Welfare under Increasing Block Pricing

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Abstract

This paper argues that an increasing block pricing structure needs to be supplemented by allowances for household size and composition to be equitable. Household behaviour is modelled as the outcome of a two-stage budgeting resulting in an integrable water demand model. The welfare effects of block pricing are studied using the concept of relative equivalence scale, modified to allow for the dependence of price on household size and composition. We use individual household data to estimate residential demand for water, provide empirical illustration of the welfare effects of increasing block pricing on demographically different households and show how these effects can be compensated.

JEL Classification: D1, Q25

Keywords: relative equivalence scales, price endogeneity, demand for water.

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1 Introduction

Block pricing and other forms of complex pricing methods are often used in regulated industries to satisfy a variety of objectives, involving both demand-side and supply-side efficiency and equity concerns (Hewitt 2000). In the case of water a standard practice in arid regions is to apply an increasing block pricing structure consisting of a fixed part that is independent of the amount of water consumed and a variable part that consists of a sequence of marginal prices for different blocks of quantity consumed.

This increasing block pricing structure is argued to signal rising supply costs and encourage conservation. It is also argued to be equitable because low income households pay lower rates of water than other households (Maddock and Castano 1991). The latter argument can be criticised on the grounds that water consumption is affected not only by income but also by a number of other, equally important, factors, such as the size and composition of the household, the type of the residence, whether or not the household owns a garden or electrical appliances that use water for cleaning purposes (e.g. washing machine), and many other factors. Whittington (1992) shows that in overcrowded areas increasing block tariff can be regressive if the tariff blocks consist of a small number of big blocks with a small price difference between them, and proposes the setting of a minimum charge for a consumption level sufficient to cover basic needs.

In this paper we question the argument that increasing block pricing is equitable on the grounds that when households vary in size and age structure the notion of income is no longer equivalent to the notion of welfare. Therefore, to be equitable an increasing block price structure applied to residential use of water needs to be supplemented by allowances for the extra burden of this pricing structure associated with family size and age composition. As a money metric measure of these allowances we propose the *relative equivalence scale,* the relative compensation required by demographically different households to maintain the same level of utility under two different price regimes (Blundell and Lewbel 1991).

Estimation of the relative equivalence scale requires modeling consumer behaviour in the context of a utility maximisation framework, yet the presence of an increasing block pricing structure invalidates the application of standard consumer theory tools for the derivation of demand for water. This problem, discussed extensively in the literature of water demand (e.g. Hewitt and Hanemann 1995), arises because the marginal price paid for water is no longer exogenous to the choice of water consumption, with consequences similar to those considered in labour supply (Hausman 1985, Moffitt 1986, 1990) and other cases where the budget constraint is not linear, for example in electricity (Reiss and White 2001) and recycling (Hong and Adams 1999). A further difficulty in the context of our analysis arises from the fact that in order to construct a measure of the welfare effects of increasing block pricing, such as the relative equivalence scale, one needs a model of demand for water satisfying integrability, i.e. the ability to recover the indirect utility function from the parameters of this model.

To cope with the price endogeneity and integrability problems described above, we model household demand for water as the outcome of a two-stage budgeting procedure. Price endogeneity is accounted for at the top budgeting stage by allowing the price block a household is consuming at to depend on a income, demographic characteristics, housing type and size, possession of washing machine and dishwasher and many other household specific variables. Integrability is accounted for at the second budgeting stage by modelling demand for water in the context of the Quadratic Logarithmic Demand System of Banks, Blundell and Lewbel (1997). Notably, this demand system not only is consistent with utility maximisation theory but also general enough to allow for non-linear income effects found to be statistically significant in the empirical analysis of individual household data (Blundell, Pashardes and Weber 1993).

The structure of the paper is as follows. The next section describes the utility maximisation framework in the context of which we model demand for water and consider the welfare implications of increasing block pricing for demographically different households. Section 3 applies the proposed model to individual household data to estimate residential demand for water and the relative equivalence scales showing how demographic differences between households should be compensated under an increasing block price regime. Section 4 concludes the paper.

2 Block selection, expenditure and welfare

Under the assumption that prices are fixed a system of equations representing consumer demand for goods can be obtained by maximising the (direct) utility function $U(q_1, q_2, ..., q_I)$ subject to the budget constraint $\Sigma_i p_i q_i = y$, where q_i is the quantity and p_i the price of good $i = 1, ..., I$; or, equivalently, by mininising the cost function $C(p_1, p_2, ..., p_I, U)$.

A block pricing system invalidates this procedure because it renders the budget constraint piece-wise linear. Taylor (1975) was proposes a method circumventing this problem by allocating consumers to the linear segments of the budget constraint where the standard utility maximisation (cost minimisation) tools are applicable. Thus, assuming that block pricing applies to the first commodity and denoting the marginal price (the price paid for the last unit of consumption) by p^*, Taylor's approach amounts to minimising the cost function $C(\, p^*, p_2, ..., p_I, U)$, yielding commodity demands $q_i(p^*, p_2, ..., p_I, y)$. Nordin (1976) argues that in empirical application y must be modified to correspond to p^*, by subtracting the excess of the actual total payment for the commodity in question over what the total payment would have been if the marginal price had prevailed in all blocks.[1] Other investigators suggest that p^* should also be treated as endogenous because under block pricing the marginal price is affected by quantity demanded (Agthe et al 1986, Deller et al 1986, Nieswiadomy and Molina 1989).

2.1 Block selection

Here, we follow an approach that deals with problems associated with block pricing regimes in a complete demand system context and using a theoretical framework consistent with the fundamentals of consumer behaviour. Our approach rationalises the Taylor-Nordin procedure and price endogeneity as outcomes of a two-stage decision process: first consumers select a block (price tariff) at which they wish to consume, thereby locating themselves to a particular linear segment along the budget constraint; and then select the point along this segment which maximises their utility. Below we describe this two-stage budgeting procedure using *implicit separability,* i.e. assuming that goods enter the cost function partitioned into groups where each group has its own subcost function defined on total utility.[2]

We concentrate on consumer demand for a single commodity with a block pricing structure and consider all other goods as a *Hicksian composite* good with a given price P. Under implicit separability the cost function describing consumer's preferences can be written as

$$C(\mathbf{p}, \mathbf{x}, P, U) = G\left[c_1\left(p_1, P, U\right), ..., c_M\left(p_M, P, U\right), \mathbf{x}, U\right], \tag{1}$$

[1]If there are only two linear segments along the budget constraint, then $y^1 = p_1^1 q_1 + \Sigma_{i>1} p_i q_i, p_i$ and $y^2 = p_1^2 q_1 + \Sigma_{i>1} p_i q_i, p_i$. Under an increasing block pricing system, consumer expenditure at p_1^2 is $y = p_1^1 q_1^1 + p_1^2 q_1^2 + \Sigma_{i>1} p_i q_i, p_i$ where q_1^k, $k = 1, 2$ is the quantity of q_1 charged at p_1^k. Applying Nordin's adjustment to y yields the budget corresponding to the second linear segment of the budget constraint, $p_1^1 q_1^1 + p_1^2 q_1^2 + \Sigma_{i>1} p_i q_i, p_i - [p_1^2(q_1^2 + q_1^1) - p_1^1 q_1^1 + p_1^2 q_1^2] = \Sigma_{i>1} p_i q_i, p_i + p_1^2 q_1$.

[2]In contrast, the more popular concept of *weak* separability implies that the group subcost functions are defined on group subutility - see Deaton and Muellbauer (1980). Also, Moffitt (1990) provides a comprehensive literature review of the various approaches to dealing with non-linearities in the budget constraint.

where p_m, $m = 1, ..., M$ is the m^{th} block price of the commodity of interest, $c_m(.)$ a sub-function reflecting the unit cost of consumption corresponding to the m^{th} block price, and $\mathbf{x}$ a vector of exogenous variables affecting the choice of block. Thus, $c_m(.)$, $m = 1, ..., M$, can be thought of as the linear segments of the budget constraint.[3]

In this context consumer demand for the commodity of interest at the m^{th} block price is obtained by applying Shepherd's lemma to (1),

$$q_m(\mathbf{p}, \mathbf{x}, P, U) = \frac{\partial C(.)}{\partial p_m} = \frac{\partial G[.]}{\partial c_m(.)} \frac{\partial c_m(.)}{\partial p_m}, \tag{2}$$

where $\partial G[.] / \partial c_m(.)$ represents consumer demand for consumption at the m^{th} block price level, and $\partial c_m(.) / \partial p_m$ the quantity demanded *conditional* on the block selection. Thus, $\partial G[.] / \partial c_m(.)$ reflects the choice of a linear segment of the budget constraint and $\partial c_m(.) / \partial p_m$ the choice of a point along this segment.

At the first budgeting stage we assume that consumers consider the unit cost $c_m(.)$ as given, and select to consume at the level minimising the Cobb-Douglas cost function

$$C(\mathbf{p}, \mathbf{x}, P, U) = \Pi_m c_m(.)^{\theta_m(\mathbf{x})} U, \tag{3}$$

where $\theta_m(\mathbf{x}) \geq 0$ for concavity and $\Sigma_m \theta_m(\mathbf{x}) = 1$ for adding up.

Using (2) we obtain the Hicksian demand for the commodity of interest

$$q_m(\mathbf{p}, \mathbf{x}, P, U) = \frac{\theta_m(\mathbf{x}) \Pi_m c_m(.)^{\theta_m(\mathbf{x})} U}{c_m(.)}, \tag{4}$$

and substituting U for the indirect utility function, $y / \Pi_m c_m(.)^{\theta_m(\mathbf{x})}$, where y the level of consumer's budget (expenditure), we obtain the Marshallian demand

$$q_m(p_m, \mathbf{x}, P, y) = Y \frac{\theta_m(\mathbf{x})}{c_m(.)} \frac{\partial c_m(.)}{\partial p_m}. \tag{5}$$

This demand can also be defined in budget share form, $w_m \equiv p_m q_m / Y$, by multiplying the right and left hand side of (5) by p_m and rearranging terms,

$$w_m(p_m, \mathbf{x}, P, y) = \theta_m(\mathbf{x}) \frac{\partial \ln c_m(.)}{\partial \ln p_m}. \tag{6}$$

In empirical application $\theta_m(\mathbf{x})$ can be defined as the probability of selecting to consume at the level corresponding to the m^{th} block price. Assuming that when $\theta_m(\mathbf{x}) = 1$ when

[3] For analytical convenience, at the moment we assume that all households have the same preferences. This assumption is relaxed in the empirical analysis below, where the parameters in (1) are allowed to vary with observable household characteristics.

consumption at the m^{th} block price is selected and $\theta_m(\mathbf{x}) = 0$ otherwise, demand for the commodity of interest can be obtained in the form of a budget share equation by taking the derivative of the logarithm of the cost sub-function $c_m(.)$ with respect to $\ln p_m$.

In the context described above, $\ln p_m$ is the outcome of the first stage optimisation (the selection of consumption at the m^{th} block price), and should be treated as an endogenous variable in empirical application. Below we use a reduced form equation $p_m = f_m(\mathbf{x})$ to account for this endogeneity problem. Notably, this equation can be identified separately from the budget share equation (6) because: (a) the level of consumer's income can be included in the $\mathbf{x}$ vector, on the grounds that the selection of block is determined at a higher budgeting stage (as opposed the budget share which is determined at the lower budgeting stage and is affected by the level of consumer's budget, y, instead); and (b) $f_m(\mathbf{x})$ need not have the same functional form as the budget share equation.

2.2 Budget share

We shall model consumer expenditure on the commodity of interest as the budget share equation corresponding to the Quadratic Almost Ideal Demand System (QUAIDS) proposed by Banks, Blundell and Lewbel (1997). The QUAIDS model belongs to the family of rank-3 demand systems, the most general empirical representation of consumer preferences that satisfies integrability (the ability to recover the parameters of the indirect utility function from empirical demand analysis; Gorman 1980 and Lewbel 1991).[4]

Let us assume that the price corresponding to the block chosen by the h^{th} consumer at the top budgeting stage is p_h^*. Following standard practice we shall term p_h^* as the *marginal* price in the sense that it applies to demand at the margin of consumption. At the moment we shall take p_h^* as given and assume that consumer preferences at the lower budgeting stage are described by the Quadratic Logarithmic cost function (Lewbel 1990)

$$c(p_h^*, P, U_h) = a\left(p_h^*, P\right) + \frac{b\left(p_h^*, P\right) U_h}{1 - g\left(p_h^*, P\right) U_h}, \tag{7}$$

where the price indices $a\left(p_h^*, P\right)$, $b\left(p_h^*, P\right)$ and $g\left(p_h^*, P\right)$ are linearly independent and

[4] Here we have chosen to use a rank-3 demand system because (i) lower rank demand systems are found to be inadequate to capture the nonlinear income effects pertaining to individual household data (Blundell, Pashardes and Weber 1993 and Pashardes 1995), and (ii) integrability will enable us to investigate the welfare implications of alternative pricing policies on empirical grounds.

homogeneous functions assumed to have the (QUAIDS) form,[5]

$$
\begin{aligned}
a\left(p_h^*,P\right) &= .5(\gamma \ln p_h^* \ln p_h^* + \gamma_{12} \ln p_h^* \ln P + \gamma_{21} \ln P \ln p_h^* + \gamma_1 \ln P \ln P) \\
&\quad + a_o + a \ln p_h^* + a_1 \ln P, \\
b\left(p_h^*,P\right) &= \left(p_h^*\right)^{\beta} P^{\beta_1}, \\
g\left(p_h^*,P\right) &= \lambda \ln p_h^* + \lambda_1 \ln P.
\end{aligned} \tag{8}
$$

Imposing adding-up ($a+a_1=1$, $\beta+\beta_1=0$, $\lambda+\lambda_1=1$, $\gamma+\gamma_{21}=0$, $\gamma_1+\gamma_{12}=0$), homogeneity ($\gamma+\gamma_{12}=0$, $\gamma_{21}+\gamma_1=0$) and symmetry ($\gamma_{12}=\gamma_{21}$), substituting in (7) and taking the derivative with respect to $\ln p_h^*$, we obtain the Hicksian budget share equation

$$
w_h = a + \gamma \ln(p_h^*/P) + \beta \left[\frac{(p_h^*/P)^{\beta} P U_h}{U_h - \lambda \ln(p_h^*/P)}\right] + \left[\frac{\lambda}{(p_h^*/P)^{\beta} P}\right] \left[\frac{(p_h^*/P)^{\beta} P U_h}{U_h - \lambda \ln(p_h^*/P)}\right]^2 . \tag{9}
$$

Then, from (7) and the indirect utility function, we have the equation

$$
\left[\frac{(p_h^*/P)^{\beta} P U_h}{U_h - \lambda \ln(p_h^*/P)}\right] = \ln y_h - [a_o + a \ln(p_h^*/P) + \ln P + .5\gamma(\ln p_h^*/P)^2],
$$

where y_h in the budget of h^{th} consumer.

Substituting in (9) we obtain the Marshallian budget share of water

$$
w_h = a + \gamma \ln(p_h^*/P) + \beta \ln Y_h + \frac{\lambda}{(p_h^*/P)^{\beta} P} \left(\ln Y_h\right)^2 , \tag{10}
$$

where $lnY_h = lny_h - [a_o + a \ln(p_h^*/P) + \ln P + .5\gamma(\ln p_h^*/P)^2]$.

We define the price of water paid by the h^{th} household as $p_h = p' s_h$ where p' is the producer's price and $s_h = (1+t_h)$, where $-1 < t_h < 0$ is the surcharge paid and $0 < t_h < 1$ the subsidy received by the h^{th} consumer as a proportion of the producer's price. When the latter and the prices of all goods other than water for domestic consumption are fixed, as in cross-section analysis, we can normalise to $p_h^* = s_h$ and $P = 1$ (i.e. measure prices using their producer's level as base).[6] We can then write (10) as

$$
\begin{aligned}
w_h &= a + \gamma \ln s_h + \beta \left[\ln y_h - a_o - a \ln s_h - .5\gamma \left(\ln s_h\right)^2\right] \\
&\quad + \frac{\lambda}{s_h^{\beta}} \left[\ln y_h - a_o - a \ln s_h - .5\gamma \left(\ln s_h\right)^2\right]^2 ,
\end{aligned} \tag{11}
$$

[5] The general forms of these price indices are: $a\left(\mathbf{p}\right) = a_o + \Sigma_i a_i lnp_i + .5\Sigma_i\Sigma_j\gamma_{ij} lnp_j lnp_i$, $b\left(\mathbf{p}\right) = \Pi_i p_i^{\beta_i}$, and $g\left(\mathbf{p}\right) = \Sigma_i \lambda_i lnp_i$. For more explanation about these and other properties of the QUAIDS model, interested readers are referred to Banks, Blundell and Lewbel (1997).

[6] The budget share equations are homothetic of degree zero in prices. This implies that the units in which prices are measured are irrelevant - see Deaton and Muellbauer (1980b, chr 2) for this and other properties of demand systems.

where s_h reflects the surcharge paid ($s_h > 1$) or subsidy received ($s_h < 1$) at the margin of consumption, as defined above.[7]

2.3 Welfare effects

We use the QUAIDS demand system described above to investigate the welfare effects of block pricing on households with different demographic characteristics and consider money metric measures to compute these effects. We allow for the effects of demographic heterogeneity on consumer behaviour by writing (7) as

$$\ln c(p_h^*, P, \mathbf{z}_h, U_h) = a\left(p_h^*, \mathbf{z}_h, P\right) + \frac{b\left(p_h^*, \mathbf{z}_h, P\right) U_h}{1 - g\left(p_h^*, \mathbf{z}_h, P\right) U_h}, \tag{12}$$

where $\mathbf{z}_h$ is the vector of demographic and other household characteristics. To the extent that demographic characteristics also affect the choice of block at the first optimisation stage, p_h^* is also a function of $\mathbf{z}_h$ and other exogenous variables, $p_h^* = p^*(\mathbf{x}_h, \mathbf{z}_h)$.

We define the *true cost of living index* for a household h at a given level of utility $\overline{u}_h$,

$$I_h = \frac{c(p_h^*, P, \mathbf{z}_h, \overline{u}_h)}{c(p', P, \mathbf{z}_h, \overline{u}_h)} = \exp\left\{\left[a_h^* + \frac{b_h^* \overline{u}_h}{1 - g_h^* \overline{u}_h}\right] - \left[a_h' + \frac{b_h' \overline{u}_h}{1 - g_h' \overline{u}_h}\right]\right\} \tag{13}$$

where $\overline{u}_h = \left[\left(\ln \overline{y}_h - \overline{a}_h\right) \overline{b}_h\right] / \left[\left(\ln \overline{y}_h - \overline{a}_h\right) + \overline{g}_h\right]$,

$$a_h^* = a\left(p_h^*, P, \mathbf{z}_h\right), \quad b_h^* = b\left(p_h^*, P, \mathbf{z}_h\right), \quad g_h^* = g\left(p_h^*, P, \mathbf{z}_h\right),$$

$$a_h' = a\left(p_h', P, \mathbf{z}_h\right), \quad b_h' = b\left(p_h', P, \mathbf{z}_h\right), \quad g_h' = g(p_h', P, \mathbf{z}_h),$$

and the decoration '-' over expenditure y_h and the price functions a_h, b_h and g_h denote their values at $U_h = \overline{u}_h$.

The true cost of living index (13) measures the change in expenditure required by the household facing post-surcharge (-subsidy) prices p_h^* to obtain the same level of utility

[7] The budget elasticity corresponding to (11) is

$$\frac{1}{w_h}\left(\beta + \frac{2\lambda}{s_h^{\beta}}\left[\ln y_h - a_o - alns_h - .5\gamma\left(lns_h\right)^2\right]\right) + 1$$

and the compensated elasticity with respect to s_h

$$\frac{1}{w_h}\left\{\begin{array}{c} \gamma - \beta\left(a - \gamma lns_h\right) + \frac{2\lambda}{s_h}\left(a - \gamma lns_h\right)\left[lny_h - a_o - alns_h - .5\gamma\left(lns_h\right)^2\right] \\ -\frac{\lambda}{s_h^{\beta+1}}\left[lny_h - a_o - alns_h - .5\gamma\left(lns_h\right)^2\right]^2 \end{array}\right\} - 1.$$

Evaluated at $s_h = 1$ these elasticity formulas simplify to $(1/w_h)(\beta + 2\lambda lnx_h) + 1$ and $(1/w_h)\left[\gamma - \beta a - (2\lambda a + \lambda\beta) lnx_h\right] - 1$, respectively.

as at pre-surcharge (-subsidy) prices p'. It can be computed for a given household with characteristics z_h facing a change in price from p' to p_h^* it can be computed at a given utility level $\overline{u}_h$, as defined above, using the parameter estimates of the explicit functional forms of the price functions a_h, b_h and g_h.

To compare the effect of the surcharge (subsidy) on household welfare we use the ratio of the true cost of living indices of two demographically different households, the so called *relative equivalence scale* (Blundell and Lewbel, 1991). Considering a household with given demographic characteristics z_o (e.g. a couple without children) as reference, we define the relative equivalence scale as

$$R_{ho} = \left[\frac{c(p_h^*, P, \mathbf{z}_h, \overline{u}_h)}{c(p', P, \mathbf{z}_h, \overline{u}_h)}\right] / \left[\frac{c(p_o^*, P, \mathbf{z}_o, \overline{u}_o)}{c(p', P, \mathbf{z}_o, \overline{u}_o)}\right] \tag{14}$$

measures the relative compensation required by household h and the reference household to achieve the same level of utility at post-surcharge (-subsidy) and pre-surcharge (-subsidy) prices. For example, if a surcharge t_h and t_o per unit of consumption of a given commodity is imposed on couples with and without children, respectively, R_{ho} would show the compensation required by couples with children to achieve their pre-surcharge utility level relative to the compensation required by couples without children to achieve their own pre-surcharge utility level.

In the case where prices are exogenous, the relative equivalence scale is determined by the extent to which the household demand pattern is affected by demographic characteristics: for instance, $R_{ho} > 1$ when items preferred by households with children increase faster in price than items preferred by households without children; and $R_{ho} < 1$ if the opposite is true. However, under an increasing block pricing structure, the relative equivalence scale is also affected by the extent to which children (and other demographic characteristics of the household) determine the price paid by the household. This can be seen if we define $p_h^* = s_h p'$ and $p' = P = 1$, as previously, and evaluate R_{ho} at $\overline{u}_h = \overline{u}_o = 0$. Then (11) can be written as $w_h = a + \delta(\mathbf{z}_h) + \gamma \ln s_h$, where $\delta(\mathbf{z}_h)$ is some function of demographic and other household characteristics affecting consumer demand, and

$$\begin{aligned} \ln R_{ho} &= (w_h - .5\gamma \ln s_h) \ln s_h - (w_o - .5\gamma \ln s_o) \ln s_o \\ &= (w_h - w_o) \ln s_h + (\ln s_h - \ln s_o) w_o - .5\gamma[(\ln s_h)^2 - (\ln s_o)^2]. \end{aligned} \tag{15}$$

This expression shows that differences in cost between households with and without children (or other characteristics) caused by the imposition of a surcharge on the commodity of interest here, consists of three parts: $(w_h - w_o) \ln s_h$, reflecting differences in the demand patterns of two household types; $(\ln s_h - \ln s_o)w_o$, reflecting differences in the price paid per unit of consumption; and $.5\gamma[(\ln s_h)^2 - (\ln s_o)^2]$, reflecting cost savings from substituting away from the item in question as the block price increases. Extending the analysis to the case where $\overline{u}_h \neq \overline{u}_o \neq 0$ will not change our conclusions, but will complicate computation because R_{ho} will then be also dependent on the level of utility (expenditure) due to the non-homotheticity of preferences.

3 Application to demand for water

In this section we use individual household data drawn from the Cyprus Family Expenditure Survey (FES) for the years 1996/97 to estimate residential demand for water and provide empirical illustration of the model described in the previous section. For each of over 2700 households randomly sampled, the FES reports its annual water bill together with its expenditure on a large number of items, the level and sources of its income and many household characteristics.

3.1 Estimated specification

Water, a scarce commodity in Cyprus, is metered and priced with an increasing block tariff structure. Each of the 37 water authorities on the (government controlled part of the) island, however, has its own pricing policy. This gives rise to a substantial water price heterogeneity across the island, a desirable data feature for our purposes. Using the FES standard geographical code we have allocated households to water authority areas and calculated the level of annual water consumption and the marginal price, s_h, paid for a cubic meter (pcm) of water by each household.[8]

As argued in the previous section, consumer demand under an increasing block

[8]We calculate this using the formula,

$$\begin{aligned} s_h &= \sum\nolimits_{m=1}^{I} q_{hm} p_m, \\ q_{hm} &= T_{hi}/p_m, \\ T_{hm} &= Q_h - \Sigma_m b_{hm-1}, \\ \text{and } T_{hm-1} &= A \text{ if } m = 1, \end{aligned}$$

where: Q_h is the water bill of the h^{th} household; A the fixed charge; p_m, the m^{th} block tariff; and q_{hm} the quantity of water consumed by the h^{th} household under the m^{th} tariff ($h = 1, ..., H$ and $m = 1, ..., M$). The marginal price of water paid by the h^{th} household, p_h^*, is the price paid at $max\ T_{hm}$, the highest tariff block. This is always unobserved because there is no free water allowance in Cyprus (Dandy, Nguyen and Davies 1997).

pricing structure can be modelled as the outcome of a two-stage optimisation procedure involving the choice of block and, thereby, the marginal price (first stage) and the quantity demanded within the block (second stage). The fact that each water authority in Cyprus has its own tariff structure, block pricing across the island is treated here as a continuous variable. More precisely, we normalise to $p_h^* = s_h$ and $P = 1$, as explained in the previous section, and consider the marginal price paid by the h^{th} household to be determined by the reduced from equation,

$$s_h = \varepsilon + \varepsilon_o I_h + \Sigma_k \varepsilon_k z_{kh} + regional\ dummies + v_h, \tag{16}$$

where $\varepsilon, \varepsilon_o, d_m$ and ε_k are parameters; I_h is the level of household income; z_{kh}, $k = 1, ...K$, are household characteristics reflecting the size and age composition of the family, the size of accommodation, the presence of various types of shower and toilette facilities, the ownership of washing machine, dishwasher and other household variables thought to affect the price blocks corresponding to the choice of water consumption (a list of the variables included in the z_{kh} vector is shown in the first column of Table 1); and v_h is an error term.

For demand at the lower stage we use the QUAIDS budget share equation discussed in the previous section and assume that household characteristics enter the price functions (8) linearly,

$$\begin{aligned} a\left(s_h, \mathbf{z}_h\right) &= .5\gamma \ln(s_h)^2 + a_o + a \ln s_h + \Sigma_k \delta_k z_{kh} \ln s_h, \\ b\left(s_h, \mathbf{z}_h\right) &= s_h^{(\beta + \Sigma_k \phi_k z_{kh})}, \\ g\left(s_h, \mathbf{z}_h\right) &= (\lambda + \Sigma_k \xi_k z_{kh}) \ln s_h. \end{aligned} \tag{17}$$

resulting in the budget share equation,

$$w_h = a + \Sigma_k \delta_k z_{kh} + \gamma \ln s_h + (\beta + \Sigma_k \phi_k z_{kh}) \ln Y_h + \left[\frac{\lambda + \Sigma_k \xi_k z_{kh}}{s_h^{(\beta + \Sigma_k \phi_k z_{kh})}}\right] (\ln Y)_h^2 + e_h, \tag{18}$$

where $\ln Y_h = \ln y_h - a_o + (a + \Sigma_k \delta_k z_{kh}) \ln s_h - .5\gamma \left(\ln s\right)_h^2$ and e_h is an error term. The parameters δ_k and γ show the effect of the k^{th} household characteristics and the marginal price on the budget share, respectively. Also β and λ show the effect of the log budget and the log budget square on the budget share, respectively; and ϕ_k and ξ_k show how the latter two effects vary with the k^{th} household characteristics. Notably, the only ϕ_k and ξ_k parameters found to be significant in our empirical analysis are those corresponding the dummy indicating whether the household head is in retirement. The parameter a_o corresponds to the level of 'subsistence' budget.[9]

[9]This parameter is generally fixed in empirical application to avoid difficulties in the joint estimation

3.2 Empirical results

Equations (16) and (18) are estimated simultaneously by nonlinear Full Information Maximum Likelihood (FIML). Table 1 reports the parameter estimates (together with their standard errors and diagnostic statistics) obtained from these equations.[10] As expected, both adults and children in the household have a positive and significant effect on the marginal price through increased consumption. More precisely, an adult in the household contributes to a 2.3% increase in the price paid pcm at the margin of water consumption while the increase in the marginal price caused by a child is 1%. Furthermore, adults have a significant, albeit small, effect on the budget share of water.

The rest of the parameters reported in Table 1 also conform to expectation. The presence of a washing machine in the household increases consumption (and, thereby, the marginal price) and the budget share of water; whereas the effect of a dishwasher is insignificant, indicating that dishwashing by hand does not require less water than machine dishwashing. The size of accommodation has a significant positive effect on the marginal price and the budget share of water. The presence of a shower (in addition to having a bathroom without shower) either inside or outside the house appears to encourage water consumption. In contrast the effect of having toilette facilities outside the house is not significantly different from not having a toilette at all, apparently because, in general, toilettes outside the house do not have a flash. The presence of a toilette inside the house, however, has a significant negative effect on the budget share of water, reflecting the fact that for households with a toilette inside the house, water is more of a necessity than for households without toilette. The opposite is true for the presence of running water facility in the house.

Households with heads in agriculture appear to consume less water than other households. This, however, is likely to reflect the fact that these household tend to buy less water from their local authority because they have access to their own sources of underground water. Households with a retired head do not pay a higher marginal price for water (do not consume more water) than other households in similar circumstances, but have a relatively higher budget share of water. This is not surprising, given that there are many more goods other than water in the consumption opportunities of a

of this parameter and the intercept of the budget share equations. Here we fix a_o to the log of the average budget of households in the lowest 1% of the budget distribution in our sample.

[10]The parameter estimates corresponding to the 37 regional dummies are not reported in Table 1 because are of no interest here. The empirical estimates of these parameters are available from the authors on request.

non-retired than a retired person. Also not surprising is the finding that log income has an insignificant effect on the marginal price of water because, this effect is conditional on the rest of the variables in the log price equation. In other words, it suggests that increased water usage is effected through the presence of a large number of persons in the family living in a large size accommodation with sanitary facilities and not through high income itself.

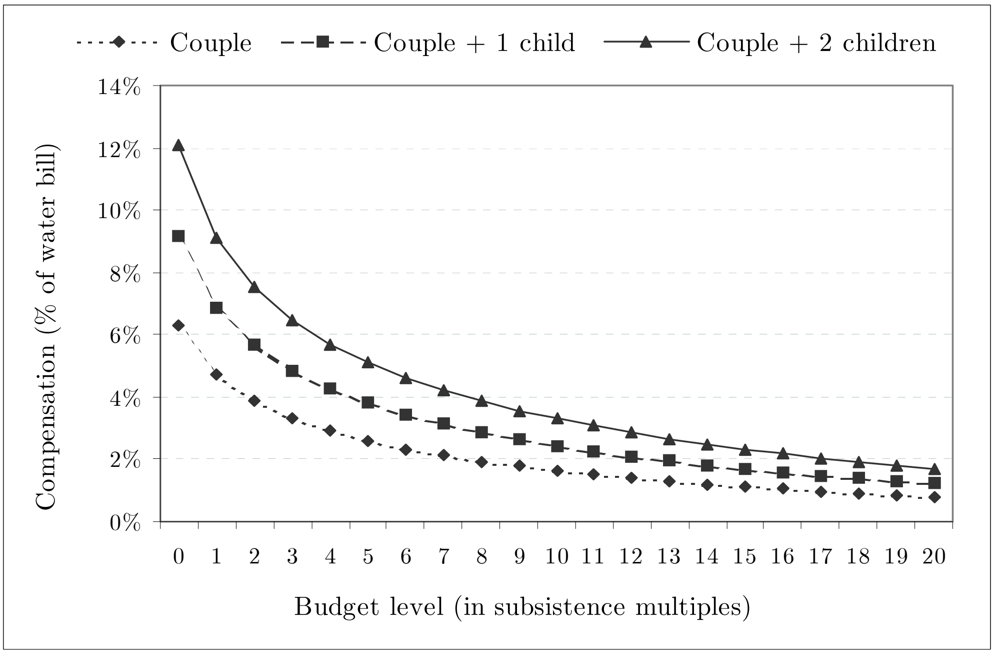
Table 1: Parameter estimates of log price and budget share equations

Variable	Log price		Budget share	
	Parameter	t-ratio	Parameter	t-ratio
Intercept	1.14436	15.0	0.04538	9.9
Number of adults	0.02323	3.9	0.00057	3.2
Number of children	0.01032	2.5	0.00041	3.6
Washing machine	0.10911	8.2	0.00198	5.2
Dish washer	0.00306	0.3	-0.00032	-0.9
Square meters of dwelling	0.00023	2.5	0.00001	2.8
Shower inside	0.07758	1.8	0.00371	2.5
Shower outside	0.08427	2.5	0.00141	1.7
Toilette inside	-0.04785	-0.9	-0.00463	-2.8
Toilette outside	-0.03964	-0.9	-0.00149	-1.4
Running water	0.03233	1.0	0.00396	3.6
Head in agriculture	-0.02286	-1.2	0.00028	0.6
Head retired	-0.00279	-0.2	0.01734	3.2
Sewage system	0.00115	6.3	0.00003	5.0
Log income	0.00660	0.8	-	-
Log marginal price	-	-	0.00142	4.4
Log budget	-	-	-0.01773	-7.7
Log budget square	-	-	0.00148	5.0
Log budget x retired	-	-	-0.00859	-2.8
Log budget sq x retired	-	-	0.00104	2.5
R-Square	.8027		.4223	
Root MSE	.19167		.004865	
Log Likelihood	10420.8			
Number of observations	2468			

The logarithm of marginal price has a significant effect on the budget share of water. The fact that this effect is positive implies an own price elasticity of demand below unity, in absolute size. More precisely, the average price elasticity implied by the parameters reported in Table 1 is around -0.6. The budget level has a negative effect on the budget share, suggesting that water is a necessity (more so for household with a retired head). According to these findings the average budget elasticity of demand for water is around 0.3.

Using the parameter estimates reported in Table 1 and taking the single adult household as reference we have computed the relative equivalence scales at different budget levels (in multiples of subsistence budget, a_o) for three household types: couples without children, couples with one child and couples with two children. The results of these calculations, expressed as a percentage of the average water bill, are shown in the diagram of Figure 1.

Figure 1: Relative equivalence scales
(as a percentage of average water bill)



As expected, households with more members face a higher cost of living and, as argued in the previous section, the additional cost for these households comes from two sources: (i) the increased consumption of water resulting in a higher marginal price of water due to the increasing block pricing structure; and (ii) the increased budget share of water because a household with more members sharing the same budget is a poorer household, spending a higher share of its budget on necessities.

As seen from the diagram of Figure 1, at subsistence income households with two adults need to spend an extra 6.3% of the average water bill to be at the same utility level as single adult households, while this figure doubles when two children are also included in the family. As the budget level increases the additional spending required by households with more members to be on the same utility level as the single adult households decreases. This is because the budget elasticity of demand for water is below unity, therefore, the weight attached to water in the calculation of the true cost of living of the household becomes smaller as the budget level increases.

4 Conclusion

Contrary to equity arguments invoked among other considerations to justify an increasing block pricing regime for water, large families are in a disadvantage under this pricing regime because they face a higher marginal price of water than small families at the same level of utility. We substantiate this argument in the context of a utility maximization framework where household demand for water is modeled as a budget share equation of an integrable complete demand system. We use a two-stage budgeting approach based on implicit separability to model price endogeneity at the theoretical level and use FIML methods to obtain consistent estimates of the water demand parameters at both budgeting stages.

We use the results to construct a relative equivalence scale, measuring the compensation required by large families for paying a higher marginal price of water than small families. Empirical results obtained from individual household date, drawn from the Cyprus Family Expenditure Survey 1996/1997, suggest that the cost of water consumption for households at low budget levels increases due to the block pricing structure by 6.3% of the average water bill when one adult and by 3% when one child is added to the family. For example, if the average water bill is \$100, low budget households pay \$6.3 more for an additional adult and \$3 more for an additional child due to the increasing block price regime. This cost does not, of course, include the additional outlay required to purchase more units of water at base level prices, i.e. in the absence of the increasing block price regime, there would be no additional demographic costs.

Another finding with potentially important policy implications emerging from our analysis is that the cost difference between small and large families caused by increasing block pricing declines with the budget level. Being a direct consequence of the low budget elasticity of demand for water, this finding suggests that when an increasing block pricing regime is imposed on necessities large families at the bottom end of income distribution are the most disadvantaged. This strengthens the argument for compensating differences between small and large families to account for the effects of increasing block pricing.

Although this paper is about behavioural and welfare implications associated with an increasing block pricing regime applied to water, the analysis has applications to other goods and services subject to a changing block price regime (electricity, recycling etc) and other areas where the price differentiation effect on households varies demographic characteristics, such as reduced tax rates on children goods.

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