Residential Water Demand in Portugal:

checking for efficiency-based justifications for increasing block tariffs

Henrique Monteiro

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ISCTE: Department of Economics, UNIDE and Dinâmia

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Portuguese Water Tariffs - Motivation

- Highly complex water tariff structures
  Water supply (for households): Virtually all water utilities use *increasing block tariffs* (IBT) combined with a fixed charge (average number of blocks = 5, max: 30!)
- Other countries also have a tradition of IBT (OECD, 2003: Belgium, France, Greece, Spain, Italy, US, Mexico, Japan, Korea...); the UK does not.

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- IBT aren't usually recommended in economic models for efficiency reasons
- Why are they so popular: affordability; scarcity signals (water conservation); balanced budgets
- Water Framework Directive requirement of adequate cost recovery and efficient pricing by 2010 (including scarcity and environmental costs). Can IBT play a role? Can IBT have efficiency justifications?

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- Second-best Ramsey pricing method (i.e., with a budget balancing constraint)
- Situation of water scarcity (water availability constraint)
- Heterogeneous consumers (θ)
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- Result: IER: $\frac{p_m - \left[\frac{\partial C(w(\theta,\phi),\phi)}{\partial w(\theta,\phi)} + \frac{\mu}{1+\lambda}\right]}{p_m} = \frac{\lambda}{1+\lambda}\frac{1}{|\xi(w(\theta,\phi),p_m)|}$
- $\frac{\mu}{1+\lambda}$, which reflects the scarcity cost. It is a mark-up on cost for all consumers and does not affect the shape of the price schedule
- ϕ means hotter, drier weather (with impacts on water availability, costs and demand)
- Nonlinear pricing results from customer heterogeneity
- The tariff design is dependent on weather and scarcity through the impact of ϕ on price elasticities

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Aims of the current research

- Roseta-Palma and Monteiro (2008) derive the necessary and sufficient conditions for increasing, constant and decreasing nonlinear pricing to be the most efficient solution while respecting all constraints and for the implementation of IBT to be preferred for drier and hotter climates
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- Ultimately they depend on how the price-elasticity of demand varies with consumption levels
- We know that:
  - Nonlinear increasing prices if $\frac{|\partial \xi(w(\theta,\phi),p_m)|}{\partial w(\theta,\phi)} < 0$, i.e., $\frac{\partial \xi(w(\theta,\phi),p_m)}{\partial w(\theta,\phi)} > 0$
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Price-elasticities of demand for several functional forms

- The choice of functional form is not neutral and can have a crucial impact on the results

Table: Commonly used functional forms in residential water demand estimation

Linear	$w = ap + b\theta + c\phi + dz' + f$
Double-log	$\ln w = a \ln p + b \ln \theta + c \ln \phi + dz' + f$
Semilogarithmic (log-lin)	$\ln w = ap + b\theta + c\phi + dz' + f$
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Linear	$a\frac{p}{w} = 1 - \frac{(b\theta + c\phi + dz' + f)}{w}$	>0
Double-log	a	$=0$
Semilogarithmic (log-lin)	$ap = \ln w - (b\theta + c\phi + dz' + f)$	>0
Semilogarithmic (lin-log)	$\frac{a}{w}$	>0
Stone-Geary	$-\frac{g\theta}{wp} = -1 + \frac{[(1-g)h + c\phi + dz' + f]}{w}$	undetermined

Note:
- $a < 0$
- $b, c, g > 0$
- $b\theta + c\phi + dz' + f > 0$
- $\ln w - (b\theta + c\phi + dz' + f) > 0$

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The model

- The estimated model is:

$$consumption_{it} = f(mptotal_{it}, diftotal_{it}, income_{it}, prec_{it}, temp_{it}, \quad (1)$$
$$waterqual_{it}, bathroom_i, elder_i, seasonal\_dwelling_i) + \alpha_i + \varepsilon_{it}$$

$$\alpha_i \sim IID\left(0, \sigma_\alpha^2\right), \qquad \varepsilon_{it} = \varepsilon_{it-1} + v_{it}, \qquad v_{it} \sim IID\left(0, \sigma_v^2\right) \quad (2)$$

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The data

Panel data for the years 1998, 2000, 2002 and 2005. Observations are municipalities.

Table: Definition of variables

Variable	Definition
consumption	Average monthly water consumption (m^3/month)
mptotal	Marginal price of water supply and sewage (€/m^3)
diftotal	Variable part of the water and sewage bill - (MP*Water) (€/month)
fixedtotal	Fixed part of the water and sewage bill (€/month)
Income	Per capita available income (€10^3/person/year)
prec	Total annual precipitation (mm)
temp	Average annual temperature (^{o}C)
waterqual	% of delivered water analysis failing to comply with mandatory parameters
bathroom	% of regularly inhabited dwellings without shower or bathtub
elder	% of population with 65 or more years of age
seasonal_dwelling	% of dwellings with seasonal use

The data

Table: Summary statistics

Variable	N	Mean	Std. Dev.	Min.	Max.
consumption	884	7.46	2.21	2.46	19.50
mptotal	871	0.62	0.39	0.05	4.59
diftotal	875	-0.73	1.24	-14.35	2.50
fixedtotal	864	2.09	1.35	0.00	10.49
Income	1112	3.48	3.27	0.67	29.80
prec	1112	877.53	435.65	205.47	2807.75
temp	1112	15.27	1.34	10.93	18.15
waterqual	1106	4.06	4.40	0.00	40.09
bathroom	1112	9.75	5.54	7.91	33.76
elder	1112	20.83	6.33	7.52	42.02
seasonal_dwelling	1112	23.98	11.13	4.54	54.10

The method (1)

- Known endogeneity problem in the price-related variables (p and D) $\Rightarrow$ instrumental variables (created from the tariff unit prices for specific volumes of consumption, the calculation procedure (whether each unit is charged at the price of its block or at the price of the last block reached and the type of water utility (municipality, private company, ...))
- Anderson, Sargan and Difference-in-Sargan tests are performed to check on instrument relevance and validity and Davidson and MacKinnon exogeneity tests are performed to confirm the problem has been solved.
- Heteroskedasticity and autocorrelation are found $\Rightarrow$ GLS estimator with AR(1) disturbances

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The method (2)

- Breusch-Pagan Lagrangian multiplier test confirms the presence of municipal specific effects
- Hausman test does not reject the null hypothesis of independence between the municipal effects and the exogenous regressors $\Rightarrow$ GLS estimator (random effects) is not only efficient but also consistent and is used.
- A price perception test (Nieswiadomy and Molina, 1991) was performed and confirmed that consumers respond to the marginal rather than the average price.

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Results (1)

Functional form	Linear	Double-log	Log-lin	Lin-log	Stone-Geary
Variable	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)
mptotalz	-1.236***	-0.111***	-0.154***	-0.910***	-
	(0.360)	(0.027)	(0.045)	(0.213)	-
income	0.079***	0.091***	0.010***	0.594***	-
	(0.030)	(0.025)	(0.004)	(0.193)	-
(income*10^3)/	-	-	-	-	0.001***
/mptotalz	-	-	-	-	(0.000)
temp	0.342***	0.682***	0.049***	4.284***	0.330***
	(0.072)	(0.138)	(0.010)	(1.055)	(0.072)
seasonal_	-3.952***	-0.124***	-0.647***	-0.891***	-3.429***
_dwelling	(1.087)	(0.030)	(0.140)	(0.226)	(1.055)
bathroom	-5.815***	-0.043†	-0.867***	-0.382*	-4.608**
	(2.120)	(0.027)	(0.273)	(0.209)	(2.056)
elder	-7.353***	-0.211***	-1.025***	-1.409***	-7.141***
	(1.840)	(0.052)	(0.235)	(0.394)	(1.844)
waterqual	-2.807*	-0.009	-0.374**	-0.065	-2.128
	(1.508)	(0.007)	(0.182)	(0.054)	(1.505)
intercept	5.864***	-0.734**	1.739***	-10.259***	4.841***
	(1.251)	(0.368)	(0.159)	(2.825)	(1.206)

***,**,*, † Significance at the 0.01, 0.05, 0.10 and 0.15 level

Results (1)

Functional form	Linear	Double-log	Log-lin	Lin-log	Stone-Geary
N	873	830	873	830	873
Wald $\chi^2(7)$	188.82	259.42	246.29	211.40	184.07
Prob $>\chi^2(7)$	0.000	0.000	0.000	0.000	0.000
Price-elasticity	-0.101	-0.111	-0.094	-0.122	-0.052
Income-elasticity	0.037	0.091	0.033	0.078	0.001

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The method (3)

- To choose the best functional form the following approaches were used:
  - Encompassing approach (Mizon and Richard, 1986): for nonnested models with the same dependent variable (encompassing model with the additional variables from the alternative)
  - Comprehensive approach (the J test, Davidson and MacKinnon, 1981): for nonnested models with the same dependent variable (encompassing model with the fitted values from the alternative)
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Table: Specification tests results and resulting prefered functional form

Funct.form	Double-log	Log-lin	Lin-log	Stone-Geary
Linear	undetermined	Linear	Lin-log	Linear
Double-log	-	Double-log	undetermined	undetermined
Log-lin	-	-	Lin-log	Stone-Geary
Lin-log	-	-	-	Lin-log

- Lin-log and double-log functional forms are not rejected
- Lin-log would recommend IBT, while double-log would not
- PE test fails to decide between both

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- Water demand responds to marginal and not average price
- Besides the usual explanatory variables, we show the % of seasonally inhabited dwellings and a reduced water quality on delivery can have a significant negative influence on the amount of water households consume.

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Further research - research proposal submitted

- Gather household level data and reach a conclusive choice of functional form
- Use discrete-continuous choice models and estimate the unconditional (on the block choice) price-ealsticity of demand
- Use intra-annual data to study seasonal effects
- Use quantile regression to provide information for the choice of the number and size of blocks
- Combine the current demand analysis with supply information to produce a simulation model, considering the forecasted reductions in water availability in Portugal due to climate change
- Account for uncertainty with robust control

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ISCTE: Department of Economics, UNIDE and Dinâmia

Thank you for your attention!

(henrique.monteiro@iscte.pt)