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# Modeling nonlinear water demand : The case of Tunisia

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## Abstract

The main originality of this paper is to empirically examine the presence of nonlinear mechanism in the residential water consumption equation. Within logistic smooth transition framework (LSTR), we explore the existence of nonlinearity with respect to water price changes in progressive tariff. We use quarterly time series for the period 1980-2007 which describes residential water consumption and its main determinants in Tunisia which apply an increasing multi-step water pricing scheme. Our results provide strong evidence that water consumption respond nonlinearly to price changes for two considered consumption blocks, that is, the price elasticity is higher when water price surpasses some threshold of water price variation. The price elasticity of the small consumers is superior to its counterpart of the big consumers and the residential demand is elastic to its price only for the lower block in high price change regime. Consequently, we propose to increase the length of the lower block of consumption to achieve goals of social equity. We also recommend to increase the tariff progressivity to promote water saving at least for the upper block's consumers

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# 1. Introduction

Water resources are characterized by scarcity, quality problems, bad distribution as well as time and space volatility. Worldwide, water is increasingly viewed as a scarce commodity and should be placed at the center of public and private interests. Water resources are unequally distributed across countries. America has the largest share of total freshwater resources with 45 percent. However, Africa has the lowest share with only 9 percent of world's total freshwater resources. In Tunisia as well as in the other North African countries, the per-capita renewable internal freshwater resource is under the threshold of water scarcity fixed at 1000 cubic meter. It was about 406 cubic meters, in 2008. Residential water consumption, which concerns the satisfaction of essential human uses (drinking, cooking and basic hygienic purposes), requires a minimum of regularity, quality (softness, purity, etc.) and reliability especially during the dry season, which is not always the case in Tunisia. And, residential water demand is really exponentially increasing as a result of a rapid urban development. So Tunisia is committed to manage water demand like other developing countries to boost her frail economy where tourism development requires more water with acceptable quality.

Basically, Tunisian water utility has concentrated constantly on adjusting water supply to meet level-price water demand. The cost of supply enhancement continues to rise as the most accessible sources of water are tapped to capacity or depleted, necessitating rate changes that subsequently affect quantity demanded. Econometric estimates of residential demand try to define water management policies that fail to consider the time-path of adjustment risk outpacing consumers' ability to develop new habits or optimize their stocks of water associated capital, such as landscaping, plumbing fixtures and appliances. Given the public benefits provided by many aspects of water supply and management, the price-setting public institutions should be able in some way to measure the true economic value of water supply and to use this information to establish economically rational water tariffs. Such an issue is particularly important in water-scarce countries in which the price of water does not reflect scarcity, often because management institutions are reluctant to raise prices.

Residential water demand has been a major issue in environmental and resource economics as documented in recent literature surveys (Arbuès et al., 2003; Dalhuisen et al., 2003; Worthington and Hoffman, 2008). Most of this research has focused on developed countries, while very few have studies focused on developing countries (see Nauges and Whittington, 2010). Nauges and Thomas (2003) estimated a dynamic panel data model on a sample of French municipalities and obtained short- and long-run price elasticities, respectively equal to -0.26 and -0.40. Using time-series observations from Seville in Spain, Martinez-Espineira (2007) has derived long-run price elasticity equal to -0.5 from a cointegration model and short-run price elasticity equal to -0.1 from an error-correction specification. The meta-analysis of Espey et al (1997) shows that long-run water price elasticity is superior to short-run elasticity. They demonstrated also that introducing climatic variables such as rainfall and evapotranspiration, in the specification of water demand model affect significantly the estimated water price elasticity especially for the U.S case. In addition, some papers have investigated the role of seasonality in water demand using different econometric methodologies (see e.g. Bell and Griffin, 2011; Griffin and Chang, 1991; Dandy et al., 1997). They show that seasonality play an important role in explaining household behavior.

As a matter of fact, the price elasticity in the existing literature has been estimated within a linear framework using the log-log linear function form of the water demand model. However, assuming that consumer sensitivity to changes in water tariffs is linear and symmetric would not be realistic. We hypothesize that different households behave differently with respect to the magnitude of change in water prices. Also, without considering the presence of a nonlinear mechanism in residential water consumption – depending on a threshold value of water price variation - the literature cannot clearly explain the role played by progressive water tariffs in conserving this precious resource. Thus, while previous empirical works assumed linearity rather than testing it, our study proposes to formally test the presence of the threshold effect in residential water consumption.

The main originality of this paper is to empirically investigate for the existence of a nonlinear dynamic in the residential water demand function. We think that water consumption sensitivity may differ depending on the magnitude of price variation, *i.e.* small vs. large changes. Using the class of logistic smooth transition regression (LSTR) models as developed by Teräsvirta (1994), our paper tests for nonlinearity with respect to water price change as a transition variable. Water price elasticities are then estimated across the two extreme regimes, *i.e.* within lower and higher price change regimes. This enables us to understand the efficiency of the Tunisian water pricing system in conserving water over the last three decades. This article is therefore an original contribution to empirical residential water demand modeling as it proposes a nonlinear analysis of residential water demand using a rich quarterly data set for the case of Tunisia. Our dataset is based on a breakdown of two consumption blocks: a lower block for low-income households and an upper block for high-income households. The lower water consumption block is composed by subscribers, who have their quarterly water consumption below forty cubic meters. However, the upper block is composed by those consuming more than forty cubic meters per quarter. The data series consist of quarterly values, covering the period between 1980 and 2007, of average water consumption, average water price, rainfall, temperature, the number of consumers in each block and household income.

To preview our main results, we found that the water price elasticity for the lower block consumers is higher and water demand becomes elastic when the price variation exceeds a threshold of roughly 5%. This means that lower block consumers are very sensitive to the tariff change when they are obliged to increase their consumption in order to meet their basic needs, especially in summer. Regarding upper block consumers, water demand is slightly sensitive to small price changes, however, when the threshold of a 2.6% price change is surpassed, water price elasticity becomes significantly equal to -0.84.

The paper is organized as follows. In Section 2, we present data set and the empirical approach. The discussion of the main empirical results forms Section 3, before concluding with policy recommendations in Section 4.

## 2. Data description and empirical specification

We use an original data base covering the period going from the first quarter of 1980 to the fourth quarter 2007. The data, collected by the national water distribution company in Tunisia (Société Nationale d'Exploitation et de Distribution des Eaux, SONEDE hereafter), includes quarterly observations on average domestic water consumption, average price, network expansion, rainfall, temperature and yearly household income observations. Since Tunisia, as many countries, uses a nonlinear tariff structure in which prices are differentiated for different brackets of consumption, the choice of the price variable (average or marginal prices) is necessary to achieve a good residential water demand specification. Following Ayadi *et* al. (2002), we choose the average price which is equal to the total bill of the households divided by the volume consumed, as we have semi aggregate data. The average price is a weighted sum of the marginal prices, with the weights being given by the shares of the consumption in each bracket.

The conventional water demand model is often defined, in the literature (see e.g. Arbues *et* al. 2003), as an equation in double log form. The latter links household water demand to its determinants such as price and income, as the main determinants of demand suggested by classical economic theory, then socio-economic factors and climatic conditions (temperature and rainfall) as the control variables . In this study, the demand model is specified at the regional level for each consumption block.

Thus, the demand equation is specified as:

$$c_t = \alpha + \beta p_t + \gamma y_t + \delta' Z_t + \varepsilon_t, \qquad (1)$$

where $c_t$, $p_t$ and $y_t$ denote respectively quarterly average water consumption, average water price (the total bill of the households divided by the volume consumed), and average household income. $Z_t$ is a vector of control variables, including rainfall, $rl_t$, network expansion, $ne_t$ (quarterly share of subscribers to the lower or the upper block) and temperature, $te_t$. The $\varepsilon_t$ is a zero mean error term normally distributed.

In this paper, we assume that consumer behavior responds nonlinearly to the size of water price change, $\Delta p_t$. Consumers are assumed to be more sensitive to higher variation in their water bill, which tends to increase the price elasticity of water consumption. Thus, we consider that water consumption depends on the extent of prices rising in a nonlinear framework. To this end, we define a logistic smooth transition regression (LSTR) water consumption equation which consists of an extension of water consumption model to nonlinear case. We have checked the possibility of cointegrating a relationship into our key variables in water demand equation (1). Individual series in level are non-stationary according to the efficient unit-root test suggested by Elliott et al. (1996), and the Kwiatkowski–Phillips–Schmidt–Shin (1992) test, extended by Carrion-i-Silvestre and Sanso (2006). However, they do not appear to be cointegrated according to Johansen's cointegration tests (1988, 1991). Consequently, log differences of the variables are used in the estimation of the nonlinear water demand equation. The equation to estimate is as follows:

$$\Delta c_t = \alpha + \sum_{j=1}^{N} \lambda_j \Delta c_{t-j} + \sum_{j=0}^{N} \gamma_j \Delta y_{t-j} + \delta' Z_t \\ + \sum_{j=0}^{N} \beta_j \Delta p_{t-j} + \left( \sum_{j=0}^{N} \phi_j \Delta p_{t-j} \right) G(s_t; \gamma, c) + \varepsilon_t, \quad (2)$$

where $G(s_t; \gamma, c) = [1 + exp\{-\gamma(s_t - c)\}]^{-1}$ the logistic transition function driving the nonlinear dynamic, and the lagged price changes as transition variable, $s_t = \Delta p_{t-j}$. A logistic specification is in general appropriate in describing asymmetric dynamic behaviors between negative or positive deviations of the transition variable, $s_t$, from the threshold level $c$. As we assume water price elasticity to be different depending on whether price variation is above or below a given threshold level, thus estimating a LSTR model will be more appropriate for our empirical exercise. According to equation (2), the short-run water price elasticity is given by the following time-varying coefficients:[1]

$$\text{Water Price Elasticity} = \beta_0 + \phi_0 \ G(s_t; \gamma, c) \quad (3)$$

Water consumption sensitivity would take on different values depending on whether the transition variable $s_t = \Delta p_{t-j}$ is below or above the threshold value, $c$. If $(\Delta p_{t-j} - c) \to -\infty$, *i.e.* the price increase is below the threshold, then water price elasticity is equal to $\beta_0$. This corresponds to the elasticity during a *low-price-change regime*, *i.e.* when $G(s_t; \gamma, c) = 0$. However, if $(\Delta p_{t-j} - c) \to +\infty$, *i.e.* the price increase is above the threshold, then water price elasticity becomes $\beta_0 + \phi_0$. This latter corresponds to the water consumption sensitivity during a *high-price-change regime*, *i.e.* when $G(s_t; \gamma, c) = 1$. To determine the lag length of the variables in equation (2), we follow Van Dijk et al. (2002) by adopting a general-to-specific approach to select the final specification. We start with a model with maximum lag length of $N = 4$, then dropping sequentially the lagged variables for which the $t$-statistic of the corresponding parameter is less than 1.0 in absolute value.

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[1] Also, it is possible to define long-run water price elasticity as: $\left[\sum_{j=0}^{N} \beta_j + \sum_{j=0}^{N} \phi_j \, G(s_t; \gamma, c)\right] / \left[1 - \sum_{j=1}^{N} \lambda_j\right]$. One major drawback of this measure its sensitivity to the number of lags introduced in the model, leading to inaccurate long-run elasticity. Hence, in our paper we focus solely on the short-run water price effect as given by equation (3).

As explained by Teräsvirta (1994), the modeling strategy of smooth transition regression (STR) models consists of three stages: specification, estimation, and evaluation. The first stage consists of testing for nonlinearity and choosing the appropriate threshold variable, $s_t = \Delta p_{t-j}$, with the most suitable form of the transition function. In the second stage, the parameters of the STR model are estimated using the nonlinear least squares (NLS) estimation technique which provides estimators that are consistent and asymptotically normal. In the final, evaluation stage, the quality of the estimated STR model should be checked against misspecification as in the case of linear models. Several misspecification tests are used in the STR literature, such as LM test of no error autocorrelation, LM-type test of no ARCH and Jarque-Bera normality test. Also, Eitrheim and Teräsvirta (1996) suggested two additional LM-type misspecification tests, namely an LM test of no remaining nonlinearity and LM-type test of parameter constancy.

## 3. Empirical results

As a first step, the specification test of linearity is conducted following Teräsvirta (1994). We consider the lagged price variation as the driving factor of the nonlinearity, that is, $s_t = \Delta p_{t-j}$. The linearity tests are conducted for each lagged price variation, $s_t = \Delta p_{t-j}$, with $j = 1, 2, 3, 4$. The choice of the adequate lagged price-change as a transition variable by means of linearity tests is reported in Table 2. Accordingly, the LSTR model is found to be the best specification to capture this kind of behavior for the average water consumer in Tunisia.

Next, the NLS estimates of our LSTR models are summarized in Table 3 and Table 4 for the two consumption blocks: lower block consumers and upper block consumers. The price elasticity for the lower block (PELB hereafter) and the price elasticity of upper block (henceforth PEUB) are calculated for the two extreme regimes, *i.e.* $G(s_t; \gamma, c) = 0$ and $G(s_t; \gamma, c) = 1$, as defined in equation (3). We compute the sum of squared residuals ratio ($SSR_{ratio}$) between the LSTR model and the linear specification which suggests a better fit for the nonlinear model. We also check the quality of the estimated LSTR models by conducting several misspecification tests. As reported in Table 2 and Table 3, in most cases, the selected LSTR models pass the main diagnostic tests, *i.e.* no error autocorrelation, no conditional heteroscedasticity, parameter constancy and no remaining nonlinearity.

**Table 1. Linearity tests**

| | **Lower Block** | | | | **Upper Block** | | | |
|---|---|---|---|---|---|---|---|---|
| | $\Delta p_{t-1}$ | $\Delta p_{t-2}$ | $\Delta p_{t-3}$ | $\Delta p_{t-4}$ | $\Delta p_{t-1}$ | $\Delta p_{t-2}$ | $\Delta p_{t-3}$ | $\Delta p_{t-4}$ |
| $H_0$ | 0.000 | 0.000 | 0.056 | 0.000 | 0.001 | 0.002 | 0.101 | 0.142 |
| $H_{04}$ | 0.000 | 0.039 | 0.403 | 0.000 | 0.054 | 0.033 | 0.266 | 0.170 |
| $H_{03}$ | 0.063 | 0.000 | 0.394 | 0.001 | 0.101 | 0.155 | 0.510 | 0.597 |
| $H_{02}$ | 0.000 | 0.000 | 0.002 | 0.000 | 0.002 | 0.005 | 0.007 | 0.085 |
| Specification | LSTR | LSTR | Linear | LSTR | LSTR | LSTR | Linear | Linear |

Note: The numbers are $p$-values of $F$ versions of the LM linearity tests. The first row shows the test of linearity against the alternative of STR nonlinearity. The second to fourth rows are the $p$-values of the sequential test for choosing the adequate transition function. The decision rule is the following: if the test of $H_{03}$ yields the strongest rejection of the null hypothesis, we choose the ESTR model. Otherwise, we select the LSTR model. The last row gives the selected model.

The estimation results in Table 2 and Table 3 show the presence of significant threshold levels of price-change for the two consumption blocks. This reveals the presence of two distinct regimes, as water consumption behavior is expected to be different on each side of the threshold. Thus, it is expected that water price elasticity will differ depending on whether the price changes are above or below threshold level. Also, thresholds do differ considerably across water consumption blocks. For the lower block, the estimated threshold is about 5% ($\hat{c} = 0.048$), which is more significant than the corresponding threshold for the upper consumption block, where the threshold value is equal to 2.6% ($\hat{c} = 0.026$). These results indicate different behavior in the water demand dynamic, namely, it is assumed that small consumers change their consumption behavior only in the case of a higher level of water price variation.

**Table 2. Estimation results for lower block consumers**

$$\Delta c_t = \underset{(0.474)}{0.147} - \underset{(-5.461)}{1.324}\,\Delta c_{t-2} - \underset{(-3.543)}{0.914}\,\Delta c_{t-4} + \underset{(2.058)}{0.297}\,\Delta y_t + \underset{(1.507)}{0.508}\,\Delta y_{t-2} - \underset{(-2.921)}{0.010}\,rl_t - \underset{(-1.659)}{0.317}\,ne_t$$

$$+ \underset{(1.962)}{0.026}\,te_t + \underset{(2.656)}{0.259}\,\Delta p_t - \underset{(-2.095)}{0.272}\,\Delta p_{t-3} - \underset{(-3.483)}{0.344}\,\Delta p_{t-4} + \Big[\underset{(2.656)}{0.757}\,\Delta p_t - \underset{(-2.921)}{0.868}\,\Delta p_{t-1}$$

$$+ \underset{(2.365)}{0.508}\,\Delta p_{t-3}\Big] G(s_t;\hat{\gamma},\hat{c}) + \hat{\varepsilon}_t,$$

$$G(s_t;\hat{\gamma},\hat{c}) = \left(1 + \exp\left\{-\underset{(2.353)}{7.797}\left(\Delta p_{t-4} - \underset{(2.785)}{0.048}\right)\Big/0.246\right\}\right)^{-1}$$

$R^2 = 0.926$; $SSR_{ratio} = 0.655$; $pJB = 0.234$; $pLM_{AR(4)} = 0.807$;

$pLM_{ARCH(4)} = 0.997$; $pLM_c = 0.688$; $pLM_{RNL} = 0.715$

**Water price elasticities**

| **Low price-change regime:** $G(s_t;\hat{\gamma},\hat{c}) = 0$ | **High price-change regime:** $G(s_t;\hat{\gamma},\hat{c}) = 1$ |
|---|---|
| $\text{PELB} = \underset{(-2.656)}{-0.259}$ | $\text{PELB} = \underset{(-8.559)}{-1.016}$ |

Note: Table reports estimation of water consumption equation from LSTR equation (2). PELB are price elasticities of water consumption for lower block consumers. Numbers in parentheses are $t$-stat of estimates. $R^2$ denotes the coefficient of determination and $SSR_{ratio}$ is the ratio of the sum of squared residuals between the LSTR model and the linear specification. The following rows correspond to the misspecification tests: $pJB$ is the $p$-values of the Jarque-Bera normality test, $pLM_{AR(4)}$ is the $p$-values of the LM test of no error autocorrelation up to the fourth order, $pLM_{ARCH(4)}$ is the $p$-values of the LM test of no ARCH effects up to the fourth order, $pLM_c$ is the $p$-values of the LM test of parameter constancy and $pLM_{RNL}$ is the $p$-values of the LM test of no remaining nonlinearity.

Next, as presented in Table 2 and Table 3, the price elasticities PELB and PEUB, for the lower and the upper block respectively, are statistically significant and confirm the findings of the literature. Our NLS estimates indicate a significant-regime dependence of the water price elasticity, in the sense that when the price of water increases above the threshold, its elasticity becomes higher. For low-income households, water demand is more sensitive for large water bill changes. As shown in Table 3, PELB is equal to -1.016 when tariffs increase above the threshold of 5%. For big consumers, PEUB is equal to -0.05 when water price-change is below the threshold of 2.6%, but beyond this threshold level, price elasticity becomes higher and equal to -0.83. It is noteworthy that, when changes in water tariffs are above the estimated threshold, water demand is elastic to its price (unitary elasticity) only for the lower block. This finding is significant in the water demand estimation literature because it demonstrates that the consumer response to water price variation, by reducing excessive water use, depends on the magnitude of changes to the consumer's water bill. However, for the Tunisian case, this result confirms Ben Zaied and Binet (2015) findings in studying the role of seasonality in residential water demand. Indeed, they estimated higher seasonal water price elasticity for the lower block (-1.95) which means that usually low-income households are more sensitive to water price-change compared to high-income households.

The empirical estimation of the nonlinear water demand model demonstrates the relevance of a threshold effect in the residential water demand model. It shows that residential water use responds negatively to the progressive water pricing scheme through a nonlinear mechanism. The latter, which is progressive and nonlinear, has a strategic objective, promoting water saving for the next generation. As we see from these results, the water tariff system becomes efficient and incentivizes water saving only for the high price regime (above the threshold), as price elasticity becomes higher. Lower block consumers, generally low-income households, are more sensitive to water prices than upper block consumers. Consequently, an incentive pricing policy would lead to a loss in the welfare of these largely lower-income families. However, as the price elasticity of the upper block is negative, we believe that a decentralized and effective pricing strategy could result in a decrease in the water consumption of well-to-do people by raising prices in this block. We propose to increase the width of the lower block's brackets to achieve social equity goals. Ben Zaied and Binet (2015) calculated the cost of such measure and demonstrated that is economically tenable as losses in SONEDE budget, due to such tariff change, can be counterbalanced by a small increase in upper block water price. Using disaggregated data for the case of France, Porcher (2014) proposed a modified water pricing scheme to achieve goals of social equity and environmental protection. Our study confirms empirically Porcher (2014) purposes. The main difference of our paper compared to Porcher (2014) is that we use a country level data and a nonlinear time series regression to evaluate different price elasticity with respect to water price-change.

The other water consumption determinants significantly affect quarterly water consumption for the two blocks. The negative effect of network expansion can be attributed to the downward shift of certain consumers from the higher consumption block to the lower one in winter. The climate variable coefficient confirms our initial hypothesis, that rainfall decreases water use and temperature increases water consumption, especially for the upper block. The household income affects positively water consumption as it predicted by microeconomic theory. Low-income households are found to be more sensitive to average income changes.

**Table 3. Estimation results for upper block consumers**

$$\begin{aligned}\Delta c_t = \;& \underset{(1.320)}{0.144} - \underset{(-3.352)}{0.991}\Delta c_{t-1} - \underset{(-3.127)}{0.873}\Delta c_{t-2} + \underset{(2.079)}{0.522}\Delta c_{t-4} + \underset{(2.242)}{0.778}\Delta y_t + \underset{(1.091)}{0.291}\Delta y_{t-1} - \underset{(-1.803)}{0.028}\, rl_t \\ & - \underset{(-1.757)}{0.330}\, ne_t + \underset{(2.035)}{0.198}\, te_t + \underset{(1.713)}{0.051}\Delta p_t - \underset{(-1.517)}{0.508}\Delta p_{t-1} - \underset{(-1.219)}{0.305}\Delta p_{t-2} + \underset{(1.327)}{0.328}\Delta p_{t-3} \\ & + \left[ - \underset{(-4.054)}{0.784}\Delta p_{t-1} - \underset{(-1.341)}{0.504}\Delta p_{t-4} \right] G(s_t;\hat{\gamma},\hat{c}) + \hat{\varepsilon}_t, \\ & G(s_t;\hat{\gamma},\hat{c}) = \left( 1 + \exp\left\{ - \underset{(1.689)}{21.520}\left( \Delta p_{t-2} - \underset{(11.299)}{0.026} \right) \Big/ 0.092 \right\} \right)^{-1}\end{aligned}$$

$R^2 = 0.958$; $SSR_{ratio} = 0.819$; $pJB = 0.216$; $pLM_{AR(4)} = 0.780$;

$pLM_{ARCH(4)} = 0.612$; $pLM_c = 0.374$; $pLM_{RNL} = 0.628$

**Water price elasticities**

| **Low price-change regime:** $G(s_t;\hat{\gamma},\hat{c}) = 0$ | **High price-change regime:** $G(s_t;\hat{\gamma},\hat{c}) = 1$ |
|---|---|
| $\text{PEUB} = \underset{(-1.713)}{-0.051}$ | $\text{PEUB} = \underset{(-4.361)}{-0.835}$ |

Note: Table reports estimation of water consumption equation from LSTR equation (2). PEUB are price elasticities of water consumption for upper block consumers. The numbers in parentheses are $t$-stat of estimates. $R^2$ denotes the coefficient of determination and $SSR_{ratio}$ is the ratio of sum of squared residuals between the LSTR model and the linear specification. The following rows correspond to the misspecification tests: $pJB$ is the $p$-values of the Jarque-Bera normality test, $pLM_{AR(4)}$ is the $p$-values of the LM test of no error autocorrelation up to the fourth order, $pLM_{ARCH(4)}$ is the $p$-values of the LM test of no ARCH effects up to the fourth order, $pLM_c$ is the $p$-values of the LM test of parameter constancy and $pLM_{RNL}$ is the $p$-values of the LM test of no remaining nonlinearity.

## 4. Conclusion and policy recommendations:

The main originality of this paper is to adequately model the nonlinear behavior in residential water demand for the case of Tunisia. The magnitude of price changes is considered and tested as the transition variable within a logistic smooth transition regression (LSTR) model. We then empirically investigate the dynamic of water price elasticity across two regimes, *i.e.* for low and high price variation regimes.

Using quarterly aggregate data over 1980:01-2007:04, as a first step, we perform linearity tests to check for the presence of a nonlinear dynamic in water consumption with respect to price changes as the transition variable. The results presented in Table 1 show the relevance of nonlinearity in describing our data, as we can accept without ambiguity the LSTR specification for the two consumption blocks. In the second step, we estimate different LSTR models for the lower and upper water consumption blocks, and consequently, water price elasticities are estimated under a low and high price variation regime. The estimation results presented in Table 2 and Table 3 show notably that lower block consumers who consume between 0 and 40 $m^3$ per quarter are usually more sensitive to water tariffs compared to upper block consumers who consume more than $40m^3$ per quarter. Moreover, for the lower block, we found a unit elastic water demand ($PELB = -1.016$) when price changes surpass the threshold of about $5\%$. For the upper block, water consumption is less elastic in comparison to small consumers, but still significant when the price variation exceeds a threshold of $2.6\%$ ($PEUB = -0.835$).

For both consumption blocks, our results show that water demand management must be considered seriously in Tunisia as well as the other MENA countries. Water consumption sensitivity (water price elasticity) takes on different values depending on the magnitude of water bill changes, *i.e.* below or above a given threshold value. Moreover, as our results reveal relatively large price elasticity for high levels of water tariff changes, changes in household behavior should be seriously considered in designing a water pricing system, especially in countries characterized by water scarcity, like Tunisia.

We propose to increase the width of the lower block's brackets to achieve social equity goals. Indeed, lower block consumers are generally low-income families. They need to increase their consumption in the summer period, for example, to satisfy their basic needs. However, upper block consumers are high-income families that are less sensitive to water price increases. We thus propose the increase of water tariffs for this category to achieve water conservation goals.

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