environmental sciences proceedings

MDPI

Proceeding Paper

The Generalized Translog Cost Function to Estimate Drinking Water Tariff: Case of Tunisia †

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† Presented at the 7th International Electronic Conference on Water Sciences, Online, 15–30 March 2023; Available online: https://ecws-7.sciforum.net.

Abstract: The present study aims to estimate the marginal cost of drinking water supply and analyze the implications for more efficient, equitable and income-adequate tap water tariffs in Tunisia. Furthermore, this article aims to develop a new pricing model for drinking water. Tunisian water utility pricing focuses on setting water prices to cover average costs, often using designs that increase clogging rates. This results in a large waste of drinking water. To facilitate efficient estimation of pricing models, we attempt to introduce Generalized Translog (GT) cost specifications for multiple products including Box-Cox transformations. It turns out, that the marginal social cost of providing a cubic meter must consist of two components: volumetric charges €0.048/m^3 and connection water charges €0.055/km.

Keywords: Generalized Translog specification; Box-Cox transformation; marginal social cost; drinking water; Tunisia

1. Introduction

In some countries, the public interest is mainly focused on technological solutions to water scarcity (Sibly 2006b). For economists, however, pricing is an important mechanism for determining the efficient allocation of water resources (Zhu and van Ierland 2012). Pricing ensures that available water is used for its most valuable uses, and new supplies are developed only if consumers are willing to pay (Pint 1999). Water scarcity can be addressed if water as an economic commodity is properly managed (Dinar and Nigatu, 2013). To achieve this, the total cost of the water supply must be considered. Rogers et al. (1998) argued that sustainable and efficient water use requires water prices to cover all costs: operation, maintenance, capital and opportunity cost (OC) (Sbily 2006a). Ignoring operation costs can underestimate the value of water and lead to the misallocation of resources (Rogers et al., 1998). The resource is most valuably utilized when the water allocation reflects its full cost (Rogers et al., 2002). Municipal water utilities have traditionally set water prices to cover the average cost (AC) (Pint 1999). However, Griffin (2006) argues that average cost price (ACP) is not a good efficiency booster. Effective pricing is synonymous with marginal cost pricing (MCP). Furthermore, the ACP system used by municipal water utilities does not take into account the scarcity value of natural water (Pint 1999). Tunisia is one of the countries where efficient water pricing has received little attention. Tunisian Water and Distribution Utility (TWDU) addresses the user's chronic water shortage by increasing water supplies and fixing water prices to reach the average cost. Furthermore, Tunisia does not value natural (raw) water: TWDU doesn't pay for the raw water it uses to supply its customers with tap water. Therefore, the price it charges for tap water only takes into account the AC of water collection, treatment, storage, and distribution, not the scarcity value of the resource itself (Tafesse et al. (2017)). Additionally, TWDU appears to be following flawed accounting practices that may understate its cost of capital:

Citation: Amor, T.B. The Generalized Translog Cost Function to Estimate Drinking Water Tariff: Case of Tunisia. *Environ. Sci. Proc.* **2023**, *5*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s):

Published: 15 March 2023

since 2000, for example, no interest and no depreciation have been shown. The cost of handling materials was also ignored. It's entirely possible that reduced cost translates into lower AC, which would ultimately lead to undervaluation of tap water, not to mention the inherent inconsistency of ACP with economic efficiency. In addition to economic efficiency, the criteria for designing water charges should also consider income efficiency and equity, since water is an economic and social good (Hall 2009). MCPs may not address efficiency, equity, and income adequacy simultaneously (Sibly 2006a). Since TWDU is a natural monopoly, AC decreases as output increases, implying that marginal cost (MC) is lower than AC (Tafesse et al. (2017)). As a result, MCP scheme leads to revenue deficiency (Sibly 2006b). It is important to note that tariffs and subsidies are not the only solution to improve access to drinking water in developing countries, it is also important to improve the infrastructure and management of the water systems to ensure a sustainable supply of safe drinking water. In many developing countries, drinking water tariffs are typically low and often do not reflect the true cost of providing the service. For example, in India, the average tariff for domestic households is around $0.25 per month, while the cost of providing the service is estimated to be around $0.50 per month. This can result in inadequate funding for maintenance and expansion of the water supply system, leading to poor service quality and limited access to safe drinking water. (Singh MR et al., 2005). In the city of Kampala, Uganda, the tariff is based on a tiered pricing structure, where the more water a customer uses, the higher the price they pay per unit of water. For example, customers who use less than 20,000 L of water per month pay a lower rate per liter than customers who use more than 20,000 L per month. Additionally, a fixed monthly charge is also applied to cover the cost of maintaining the water supply infrastructure. (Nsubuga 2014).

In Tunisia, water is priced based on Increasing Block Rate (IBR) structure. However, Tafesse et al. (2017) presents several disadvantages of IBR. First, IBR pricing has the effect of insulating ordinary consumers from facing the cost of decreased water availability. Second, with IBR pricing large but low-income families are likely to face a higher price as compared to small but high-income households. Third, it sends the wrong price signals not only to consumers but also to TWDU.

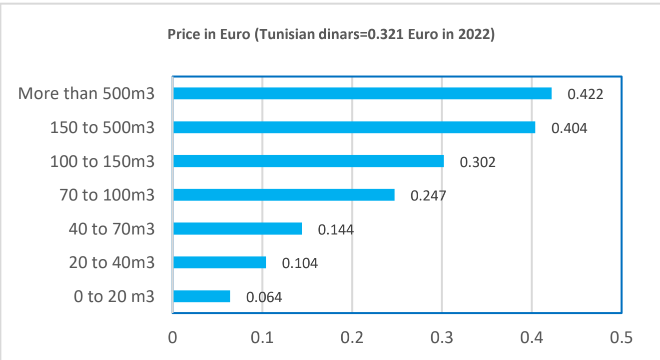

Figure 1. Increasing Block Rate in Tunisian water utility. Source: Tunisian Water Distribution Utility (known among Tunisians as SONEDE) (2018).

Therefore, the MC estimated in this paper serves only as the lower bound for the true MC of Tunisian's water supply. The term marginal social cost (MSC) is used to describe the marginal cost of water supply based on the drinking water marginal value (MV) (Marginal value is the value to a consumer of the last unit of consumption). What we are advocating is the long-term MC (LRMC). It is the incremental cost per unit of water when all factors of production (including capital) change gradually (Tafesse et al. (2017)). The capacity expansion of water supply networks has been sporadic rather than gradual (Sibly 2006a). Turvey (1976) distinguished between distribution networks and centralized systems. The former can scale with many small investments, while the latter often requires large investments over a long period of time. Therefore, it may make sense for Tunisia to consider the distribution network as an incremental variable since the expansion of the distribution network is mainly to achieve growing demand rather than investment. Satisfied with the central region system, LRMC prices outperform short-run MC prices in the water sector and provide stable capital for long-term investments (Economics 1997). Because LRMC-based rate is stable (Sibly 2006b), the LRMC approach has lower administrative costs than the more dynamic short-term MC approach (Garcia and Reynaud 2004).

We apply the Box-Cox cost specification to two products (supply and pipeline connection) that take into account the operation cost of drinking water in the context of a developing country. However, an important question arises regarding the functional form specification of the estimated cost function. Interestingly, experimental applications have focused on a single ad hoc functional specification, primarily Translog and Cobb-Douglas. However, choosing the right functional form is not an easy task. It is well known that functional forms are "data" and "model" specific, and differ in their convergence properties and ability to approximate alternative technologies. Simply put, there is no single form of function in all cases—the appropriate functional specification is case-specific. If the empirical estimates are biased by imposing an inappropriate functional form, the predictive responses obtained from the model may be biased and inaccurate, posing serious design problems. policy and/or policy implications. Thus, when there is no strong a priori theoretical or experimental reason to support a particular functional specification, exploring the sensitivity of the economic optimal, and its effect, on the choice of the functional form becomes important.

The purpose of this study is to estimate the marginal cost of water supply and analyze the implications for more efficient, equitable, and revenue-sufficient system based on a full economic cost approach. To estimate the cost function, we use the Box-Cox transformation. Here, we do not claim any methodological innovation but the inclusion of the value of tap water in the "appropriate" cost specification is a novel contribution to the empirical literature on water pricing in Tunisia.

The remaining part of the paper proceeds as follows: Section 2 presents a brief description of the study area; Section 3 outlines the methodological approaches and model specification followed; Section 4 presents and discusses results while Section 5 concludes.

2. The Study Area

The dataset used in this study consists of an unbalanced panel from TWDU covering 11 years and 21 district management utilities (DMU). In the empirical application, we focus only on the water service and we do not consider sewerage. The descriptive statistics of the variables included in the model are presented in Table 1. Total distribution cost ($\boldsymbol{C}$) equals to operating and capital expenditure. The price of the material ($\boldsymbol{P_M}$) is obtained by dividing material cost by the length of a distribution network in kilometers. Material cost consists of various groups of costs obtained when subtracting capital and labor cost from the district's total cost. The price of capital ($\boldsymbol{P_K}$) is calculated as the ratio of capital cost and capital stock, which is approximated by the capacity of pumps measured in liters per second. Capital cost consists of depreciation and interest, where depreciation accounts for most of the capital cost. The price of labor ($\boldsymbol{P_L}$) is equal to average annual wages, estimated as labor expenditures divided by the average number of employees for a given year. The price of energy ($\boldsymbol{P_e}$) is equal to the energy cost divided by the amount of water supplied.

The first output ($\boldsymbol{q_w}$) is measured as the amount of water supplied to the final customers expressed in cubic meters. The second output (q_{AS}) is the size of the service area expressed in kilometers (connection).

Table 1. Descriptive statistics (Tunisian dinars "(TD)" =0.321 Euro in 2022).

Variable Description	Variable	Mean	Std. Dev.	Minimum	Maximum
Total annual cost (TD)	C	*5,990,438*	*4,490,933*	*135,738*	*2.34e+07*
Price of labor (TD)	L	*10,189.06*	*7254.575*	*550*	*81,683*
Price of capital (TD)	K	*207.75*	*163.9824*	*10*	*2375*
Price of water (TD)	M	92.096	90.683	9.271	106.784
Price of energy (TD)	E	*34,924.9*	*28,564.01*	*566*	*300,075*
Water supplied (m³)	Q	*10,885.62*	*8400.726*	*2426*	*34,678*
Size of Service Area (km)	AS	*54.25*	*15.48593*	*22*	*100*

3. Model Specification

Martins et al. (2012) propose a cost function with two outputs: water loss and service output. Garcia and Thomas (2001) define the water industry as a multi-product firm producing two outputs: losses and the actual water produced. Kim (1995) identifies U.S. water utilities as multi-product firms providing residential and non-residential services. Hayes (1987) regards the cost structure of the water industry in the U.S. by considering it a multi-product firm producing wholesale retail products. Following the lines of argument in favor multi-product approach, the present study treats TWDU as a twooutput firm producing connection (q_{AS}) and distribution (qw) water outputs. A time variable t has been included in the model to account for a hicks-neutral technical change, as in Ray (1982). Besides qw, q_{AS} and, t, the multi-product cost function includes prices of capital (p_k), labor (p_l), energy (p_e), and material (p_M) as its arguments. That i, C = C (qw, q_{AS}, p_k, p_l, p_e, p_M, t) implicitly.

According to the well-known Generalized Translog (GT) Specification, the cost function is given by (Caves et al., 1980):

$$\ln C = \alpha_0 + \sum_i \alpha_i q_i^{(\pi)} + \frac{1}{2}\sum_i\sum_j \alpha_{ij} q_i^{(\pi)} q_j^{(\pi)} + \sum_i\sum_k \alpha_{ik} q_i^{(\pi)} \ln p_k + \sum_k \alpha_k \ln p_k + \frac{1}{2}\sum_k\sum_l \alpha_{kl} \ln p_k \ln p_l + \alpha_t t + \varepsilon \quad (2)$$

where C is cost of production, q_i refers to outputs (water distribution and connection), p_k indicates factor prices, and the superscripts in parentheses π represent Box-Cox transformations of outputs:

$$q^{(\pi)} = (q^{\pi} - 1)/\pi \text{ for } \pi \neq 0 \text{ and } q^{(\pi)} \longrightarrow \ln(q) \text{ for } \pi \longrightarrow 0$$

The associated input cost-share equations are obtained by applying Shephard's Lemma to expression Equation (2):

$$S_k = \partial \ln C / \partial \ln p_k = \sum_i \alpha_{ik} q_i^{(\pi)} + \alpha_k + \sum_l \alpha_{kl} \ln p_l + \varepsilon \quad (3)$$

Setting $\pi \to 0$ in [1,2] yields the Standard Translog (ST) specification, with all output terms in the cost function and the corresponding cost-share equations assuming the usual logarithmic form. For small values, the estimated GT function is an approximation in the form of the ST function. Because of its log-additive output structure, ST suffers from the well-known failure to assess cost behavior when any output is zero. This has been shown to lead to inappropriate and/or highly volatile estimates of economies of scope and product-specific economies of scale (Bottasso et al., 2011).

An estimate of the MSC of output i (MSCi) is computed as follows:

$$MSC_i = \partial C / \partial q_i = \left(\partial \ln C / \partial q_i \right) . C = (\alpha_i q_i^{\pi-1} + \sum_j \alpha_{ij} q_j^{(\pi)} q_i^{\pi-1} + \sum_k \alpha_{ik} q_i^{\pi-1} \ln p_k) . C \quad (4)$$

where $\hat{C}$ = fitted value of the cost function (Equation (1)) as in Kim (1995) and $\xi_i = \partial \ln C / \partial \ln q_i$ elasticity of cost for output i. Measures of economies of scale (ES) are also measured as follows (Coelli et al., 2005):

$$ES = \left[\sum \xi_i\right]^{-1} \quad (5)$$

TWDU would face increasing, constant, or decreasing returns to scale if ES is greater than, equal to, or less than one.

4. Estimation and Empirical Results

Data on costs, output quantities, and input prices have been obtained by integrating the information available in the annual reports and cost accounting of TWDU. All coefficients of the multi-product cost function (Equation (2)) are computed mutually with their associated input cost-share (Equation (3)). To stave off singularity of the covariance matrix the capital share equation (S_k) was deleted, and only the labor (S_l), energy (S_e), and material (S_M) share equation were included in the systems. Before the estimation, all variables were standardized on their respective sample means, estimates were obtained via a non-linear GLS estimation (NLSUR), which is the non-linear counterpart of Zellner's iterated seemingly unrelated regression technique procedure to ensure estimated coefficients are invariant concerning the omitted share equation (Zellner, 1962). Our NLSUR estimation was carried out in R using the system fit package (Henningsen and Hamann, 2007). Assuming the error terms in the above models are normally distributed, the estimation of different parameter and log-likelihood ration for the estimated cost function and related labor, energy, and material share equation can be respectively computed.

The summarized results of the NLSUR estimates of the Generalized Translog cost specification and its share equation are presented in Table 2. In the first row, the value of the Box-Cox parameter (π)) for the GT specification is positive (0.0787) and significantly different from zero (p-value = 0.027). Smaller values indicate that the GT model is very close to the standard or Simple Translog form (ST), which suffers from the same drawbacks as the ST specification when used to estimate firm cost characteristics for multiple products.

Table 2. NLSUR estimation of (GT).

Variable	Parameter	Estimate	Student's t-Test	Variable	Parameter	Estimate	Student's t-Test
Box-Cox Parameters	π	0.078	2.878	q_w*lnp_m	α_{ASM}	0.023	1.15
Constant	α_0	1.775	2.536	lnp_k*lnp_k	α_{kk}	0.094	4.7
q_w	α_w	0.184	2.115	lnp_k *lnp_l	α_{lk}	−0.079	−2.633
q_{as}	α_{AS}	0.187	1.069	lnp_k*lnp_e	α_{ke}	−0.049	−2.45
lnp_k	α_k	0.382	34.727	lnp_k*lnp_m	α_{kM}	−0.048	−4
lnp_l	α_l	0.173	7.864	lnp_l*lnp_l	α_{ll}	0.051	7.286
lnp_e	α_e	0.228	10.364	lnp_l*lnp_e	α_{le}	0.008	1.143
lnp_m	α_M	0.22	8.8	lnp_l*lnp_M	α_{lM}	−0.047	−5.222
q_w*q_w	α_{ww}	0.087	2.719	lnp_e *lnp_e	α_{ee}	0.039	7.8
qw*qas	α_{rw}	0.254	4.618	lnp_e *lnp_m	α_{eM}	−0.018	−2.571
q_{as}*q_{as}	α_{rr}	0.377	1.551	lnp_m*lnp_m	α_{ww}	0.053	3.533
q_w*lnp_k	α_{wk}	0.037	2.643	t	α_t	0.004	4
q_w*lnp_l	α_{wl}	−0.001	−0.091	R^2 Cost function		0.98	
q_w*lnp_e	α_{we}	−0.018	−2.571	R^2 Labor share equation		0.95	

q_w*lnp_m	α_{wM}	−0.018	−2	R^2 Energy share equation	0.94
q_w*lnp_k	α_{ASk}	−0.042	−1.313	R^2 water share equation	0.92
q_w*lnp_l	α_{ASl}	0.034	1.36	VIF(mean)	1.89
q_w*lnp_e	α_{ASe}	−0.011	−0.55	Log-likelihood	−194

The R^2 for the cost function and the cost-share equations are very similar. McElroy's (1977) R^2 (R^{2*}) can be used as a measure of the goodness of fit for the NLSUR system. The model (Table 2) appears to fit the data well and explains more than 95% (R^2) of the variation in the dependent variable. q_w and q_{AS}, all input prices, are shown to be positive and important parameters, as one would normally expect: the cost of water supply increases with output and input price levels, ceteris paribus. However, the parameter of q_w has a positive sign, which does not seem surprising. Note, however, that water supply costs also include costs associated with avoiding water loss that may occur if leaks are not repaired. Water distribution requires network maintenance costs, leading to higher overall water supply costs as waste is offset by more expensive production.

The positive and significant parameter of the interaction between q_w and q_{AS} (α_{wAS}) implies that an increase in q_w would necessitate an increase in the MC of q_{AS}. Yet, this implies that the MC of q_{AS} would depend on the level of q_w. These results combined imply that there would be cost advantages in producing q_{AS} and q_w jointly in Tunisia.

At last, it is cheaper to fix the leak (to meet demand) than to pump more water in Tunisia. This result suggests that there are incentives to reduce urban water loss and supports concerns that available water should be used cautiously. Reducing water loss has economic and financial implications, among other things.

From an economic point of view, it alleviates water scarcity; financially, it avoids the potential loss of revenue affecting water prices: as Cousin and Taugourdeau (2015) point out, if water loss occurs, TWDU can charge consumers higher fees d to compensate for waste, resulting in a deadweight loss. The parameter t is positive and significant, indicating that for a fixed level and entry price, costs increase over time. This could be one possible explanation for the rising cost of water supply over time.

MSCs were calculated based on Equation (3). Note that because of the inclusion of the price, rather than the stock, of capital in the cost function, the estimated MC is LRMC. This implies that not only expenditures on variable inputs but also expenditures on network expansion are accounted for, as Renzetti (1992) notes. The positive sign (Table 3) of the MSC of q_w indicates an increase of €0.048 in the cost of water supply if one m^3 of water is produced. Similarly, for an additional meter of network connection generates an additional cost of about €0.055 per km for each TWDU subscriber.

Table 3. *MSC* and *ES* Estimation.

	Water Demand: q_w	**Connection: q_{AS}**
MSC	€0.048/m^3	€0.055/km
elasticity ξ_i	0.31	0.45
ES	1.316	

To understand to what extent water is underpriced in Tunisia, we calculated IBR prices ($\tilde{p}$) as $\tilde{p} = \sum_i w_i p_i$, where p_i is the average price in block i (Figure 1); w_i = the share of the total water consumed in block i and compared it with the estimated MSC. The difference between $\tilde{p}$ and MSC for q_w is negative, suggesting that the current IBR-pricing in Tunisia leads to a considerable difference between what it costs the society to supply an additional m^3 of water and the price actually paid by consumers (q_w is priced, at a rate of 21% below their MSC).

The degree of ES has a value of 1.316 (Table 3). This value means a 10% increase in all inputs gives rise to a 13.16% (more than proportionate) increase in aggregate water output. This implies the conformity of TWDU to the natural monopoly nature of water utilities. This entails a higher AC than the MC of water supply in Tunisia and has implications for the cost recovery if water prices are set at a rate equal to the estimated MSC: revenues will be lower than costs, leading to a deficit.

Apart from the inherent problems of IBR-pricing, the revealed underpricing effect of IBRs in Tunisia calls for a more appropriate pricing scheme. As well, since IBRs are inflexible, their application stands against economic efficiency on account of the inconsistent nature of water availability in the city, where water variability is rampant. Failure to cover the cost of water provision is another problem since $\bar{p}$ is lower than MSC.

On average, Tunisia suffers a revenue deficit of approximately (MSC-$\bar{p}$) in supplying q_{AS} and q_w. Though MCP is superior to the IBR-pricing on efficiency grounds, MSC-pricing will not address the revenue sufficiency criterion, and since the MSC (for a given level of output) is a fixed value, poor and rich households will face the same water price, disregarding equity. Given the underpricing and revenue non-sufficiency effects, in Tunisia, we recommend a two-part tariff, consisting of a volumetric charge (VC) and a connection charge (CC) to serve the efficiency and revenue sufficiency goals simultaneously. This is needed to cover total costs (Sibly 2007a). Since it is independent of the volume consumed, CC is a load related to the connection of the network of TWDU. It does not influence consumers' choice of volume but the distance between the subscriber and TWDU at the power plant. Thus, setting volumetric charges of €0.048/m^3 and €0.055/km, together for q_w and q_{AS}, respectively can be proposed for Tunisia. This implies that water prices would be 3.2 times higher than the current ones.

5. Conclusions

We empirically estimate *MSCs* of water supply in Tunisia using a Generalized Translog cost function specification. In particular, we include the value of natural water in the cost function to capture the OC of urban water. This is a new contribution to the water pricing literature, especially for regions where natural water is taken for granted and no value is assigned to it. Our results show that IBR prices in Tunisia are lower than the estimated MSC of TWDU. Water supply (q_w) is priced more inefficiently than its *MSCs*. As mentioned in the Introduction, our analysis excludes externalities related to urban water supply. Therefore, IBR prices are even much lower than genuine MSCs, which is a necessary condition for rising water prices in Tunisia. Not only is inefficiency, but insufficient recovery of water supply costs is a problem: TWDU has a revenue deficit in water supply.

Moreover, MSC pricing is inappropriate because it does not address revenue adequacy and equity issues. To fill the gap between MSC pricing and TC revenues, Tunisia proposed a two-part tariff: setting a volume fee of €0.048/m^3 for qw and a connection fee of €0.055/km for q_{AS}, which seems to be the lower layers of the technology considered serve the purpose of efficiency and yield safety. Furthermore, fixed charge is a monthly or quarterly charge that is applied to cover the cost of maintaining the water supply infrastructure, such as the cost of building and maintaining treatment plants, reservoirs, and distribution networks. This charge depends on the emplacement of water consumption meter (measured in €/km: connection marginal cost). Volumetric Charge: This is a charge that is based on the amount of water a customer uses, typically measured in €/cubic meters. The volumetric charge is usually tiered, meaning that customers who use more water will pay a higher price per unit than customers who use less water. This type of pricing structure is intended to encourage conservation of water resources and can also help to cover the cost of providing service to customers in more remote areas.

Issues of equity would also be addressed, either by charging different connection fees for different groups of consumers, or by charging low-income consumers with connection fees after paying for water supply. The introduction of MSC-based flexible volume rates will require some additional costs.

However, since the estimated MC is a LRMC, it may not be flexible enough and its costs may outweigh the benefits of introducing a more efficient, fair and adequately revenue water price, which illuminates how effectively water should be priced in the study area. Fixing water prices at the estimated MSC has two positive effects. First, higher prices are said to incentivize households to conserve water, which will lead to better use efficiency, assuming people become more cautious with water as prices rise. Second, charging higher prices will partially help TWDU recoup its utility costs. Therefore, it is necessary to increase the price of MSC for water supply in order to send the correct signal to water users about the social cost of a unit increase in their demand.

When water prices are lower than social utility costs, users do not view water as an economic resource. When the price increases to the estimated MSC, users gain a better understanding of the cost of meeting their water needs and have a greater incentive to use water more prudently. Although our analysis in this paper focuses on water pricing in Tunisia, the approach can be applied to many cities in developing countries where water pricing does not meet the conditions of efficiency and sufficient income.

References

1. Cambini, C.; Piacenza, M.; Vannoni, D. Restructuring Public Transit Systems: Evidence on Cost Properties from Medium and Large-Sized Companies. *Rev. Ind. Organ.* **2007**, *31*, 183–203, https://doi.org/10.1007/s11151-007-9153-9.
2. Caves, D.W.; Christensen, L.R.; Tretheway, M.W. Flexible Cost Functions for Multiproduct Firms. *Rev. Econ. Stat.* **1980**, *72*, 477–481, https://doi.org/10.2307/1927120.
3. Cousin, E.; Taugourdeau, E. *The Trade-off between Water Loss and Water Infrastructure Quality: A Cost Minimization Approach*; Université Panthéon-Sorbonne (Paris 1), Centre d'Economie de la Sorbonne: Paris, France, 2015. Available online: http://centredeconomiesorbonne.univ-paris1.fr/documents-de-travail (accessed on).
4. Hall, D.C. Politically feasible, revenue sufficient, and economically efficient municipal water rates. *Contemp. Econ. Policy* **2009**, *27*, 539–554, https://doi.org/10.1111/j.1465-7287.2009.00164.x.
5. Diakité, D.; Semenov, A.; Thomas, A. A proposal for social pricing of water supply in Côte d'Ivoire. *J. Dev. Econ.* **2008**, *88*, 258–268, https://doi.org/10.1016/j.jdeveco.2008.03.003.
6. Dinar, A.; Nigatu, G.S. Distributional considerations of international water resources under externality: The case of Ethiopia, Sudan and Egypt on the Blue Nile. *Water Resour. Econ.* **2013**, *2*, 1–16, https://doi.org/10.1016/j.wre.2013.07.001.
7. Economics, L. *Water Pricing: The Importance of Long-Run Marginal Costs*; London Economics: London, UK, 1997.
8. Fraquelli, G.; Piacenza, M.; Abrate, G. Regulating Public Transit Networks: How do Urban-Intercity Diversification and Speed-up Measures Affect Firms' Cost Performance? *Ann. Public Coop. Econ.* **2004**, *75*, 193–225, https://doi.org/10.1111/j.1467-8292.2004.00250.x.
9. Garcia, S.; Reynaud, A. Estimating the benefits of efficient water pricing in France. *Resour. Energy Econ.* **2004**, *26*, 1–25, https://doi.org/10.1016/j.reseneeco.2003.05.001.
10. Garcia, S.; Thomas, A. The Structure of Municipal Water Supply Costs: Application to a Panel of French Local Communities. *J. Prod. Anal.* **2001**, *16*, 5–29, https://doi.org/10.1023/a:1011142901799.
11. Grebenstein, C.R.; Field, B.C. Substituting for water inputs in U.S. manufacturing. *Water Resour. Res.* **1979**, *15*, 228–232, https://doi.org/10.1029/wr015i002p00228.
12. Hayes, K. Cost structure of the water utility industry. *Appl. Econ.* **1987**, *19*, 417–425.
13. Kim, H.Y. Economies of Scale in Multi-Product Firms: An Empirical Analysis. *Economica* **1987**, *54*, 185–207, https://doi.org/10.2307/2554390.
14. Kim, H.Y. Marginal cost and second-best pricing for water services. *Rev. Ind. Organ.* **1995**, *10*, 323–338. Available online: https://www.jstor.org/stable/41798579 (accessed on).
15. Leathers, H. Allocable fixed inputs as a cause of joint production: an empirical investigation. *Agric. Econ.* **1992**, *7*, 109–124. Available online: https://doi.org/10.1016/0169-5150(92)90002-g (accessed on).
16. Martins, R.; Coelho, F.; Fortunato, A. Water losses and hydrographical regions influence on the cost structure of the Portuguese water industry. *J. Prod. Anal.* **2012**, *38*, 81–94. Available online: https://www.jstor.org/stable/43549674 (accessed on).
17. McElroy, M.B. Goodness of fit for seemingly unrelated regressions: Glahn's R2y.x and Hooper's r^2. *J. Econ.* **1977**, *6*, 381–387, https://doi.org/10.1016/0304-4076(77)90008-2.
18. Mellah, T.; Amor, T.B. Performance of the Tunisian Water Utility : An input distance function approach. *Util. Policy* **2016**, *38*, 18–32. https://doi.org/10.1016/j.jup.2015.11.001.
19. Nsubuga, F.N.W.; Namutebi, E.N.; Nsubuga-Ssenfuma, M. Water Resources of Uganda: An Assessment and Review. *J. Water Resour. Prot.* **2014**, *06*, 1297–1315, https://doi.org/10.4236/jwarp.2014.614120.
20. Piacenza, M.; Vannoni, D. Choosing among alternative cost function specifications: an application to Italian multi-utilities. *Econ. Lett.* **2004**, *82*, 415–422, https://doi.org/10.1016/j.econlet.2003.09.020.

21. Pint, E.M. Household Responses to Increased Water Rates during the California Drought. *Land Econ.* **1999**, *75*, 247–277, https://doi.org/10.2307/3147009.
22. Pulley, L.B.; Braunstein, Y.M. A Composite Cost Function for Multiproduct Firms with an Application to Economies of Scope in Banking. *Rev. Econ. Stat.* **1992**, *74*, 221–230, https://doi.org/10.2307/2109653.
23. Ray, S.C. A Translog Cost Function Analysis of U.S. Agriculture, 1939–77. *Am. J. Agric. Econ.* **1982**, *64*, 490–498, https://doi.org/10.2307/1240641.
24. Renzetti, S. Evaluating the welfare effects of reforming municipal water prices. *J. Environ. Econ. Manag.* **1992**, *22*, 147–163, https://doi.org/10.1016/0095-0696(92)90011-k.
25. Renzetti, S. Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions. *Can. J. Econ.* **1999**, *32*, 688–704, https://doi.org/10.2307/136444.
26. Reynaud, A. An Econometric Estimation of Industrial Water Demand in France. *Environ. Resour. Econ.* **2003**, *25*, 213–232, https://doi.org/10.1023/a:1023992322236.
27. Rogers, P.; Bhatia, R.; Huber, A. *Water as a Social and Economic Good: How to Put the Principle into Practice*; Global Water Partnership/Swedish International Development Cooperation Agency: Stockholm, Sweden, 1998. Available online: https://hdl.handle.net/10535/4989 (accessed on).
28. Rogers, P.; Silva, R.D.; Bhatia, R. Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy* **2002**, *4*, 1–17, https://doi.org/10.1016/s1366-7017(02)00004-1.
29. Sibly, H. Efficient Urban Water Pricing. *Aust. Econ. Rev.* **2006**, *39*, 227–237, https://doi.org/10.1111/j.1467-8462.2006.00415.x.
30. Sibly, H. Urban Water Pricing. *Agenda A J. Policy Anal. Reform* **2006**, *13*, 17–30, https://doi.org/10.22459/ag.13.01.2006.02.
31. Singh, M.; Upadhyay, V.; Mittal, A. Urban water tariff structure and cost recovery opportunities in India. *Water Sci. Technol.* **2005**, *52*, 43–51, https://doi.org/10.2166/wst.2005.0424.
32. SONED. Direction des statistiques et de la planifications (2018). Rapport des statistiques de la SONEDE. Available online: https://www.sonede.com.tn/fileadmin/medias/documents/RS2018.pdf (accessed on).
33. Gezahegn, T.W.; Zhu, X. How should urban water be priced?—An empirical analysis for the city of Mekelle, Ethiopia. *Urban Water J.* **2017**, *14*, 409–415, https://doi.org/10.1080/1573062x.2016.1175484.
34. Tsegai, D.W.; Linz, T.; ; Kloos, J. Economic analysis of water supply cost structure in the Middle Olifants sub-basin of South Africa. Bonn: Center for Development Research. *SSRN* **2009**. https://doi.org/10.22004/ag.econ.49926
35. Tsur, Y. Economic Aspects of Irrigation Water Pricing. *Can. Water Resour. J.* **2005**, *30*, 31–46, https://doi.org/10.4296/cwrj300131.
36. Turvey, R. Analyzing the Marginal Cost of Water Supply. *Land Econ.* **1977**, *52*, 158–178, https://doi.org/10.2307/3145293.
37. Whittington, D. Possible Adverse Effects of Increasing Block Water Tariffs in Developing Countries. *Econ. Dev. Cult. Chang.* **1992**, *41*, 75–87. Available online: http://www.jstor.org/stable/1154220 (accessed on).
38. Zellner, A. An Efficient Method of Estimating Seemingly Unrelated Regression and Test for Aggregation Bias. *J. Am. Stat. Assoc.* **1962**, *58*, 348–378. https://doi.org/10.1007/978-3-642-20059-5_10.
39. Zhu, X.; van Ierland, E.C. Economic Modelling for Water Quantity and Quality Management: A Welfare Program Approach. *Water Resour. Manag.* **2012**, *26*, 2491–2511, https://doi.org/10.1007/s11269-012-0029-x.