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Tariff structures for water and sanitation urban households: a primer

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Abstract

Water tariffs are a powerful management tool. Indeed, they can be seen as a conceptually simple way to promote multiple, possibly conflicting, objectives. Those trade-offs cause discrepancies between stakeholders and may produce undesirable results. The residential urban domain is particularly sensible to those predicaments. To shed some light on the matter, this paper carries out a literature survey on empirical studies, with emphasis on different tariff structures. In total, 185 publications were identified concerning the importance of tariff structures in achieving specific local objectives, or perspectives, of those who demand and supply water. These studies examine, occasionally comparing: (1) the degree to which specific objectives are achieved; (2) how the desired outcomes of a particular structure depend on the customers' sensitivity when receiving a price signal; and (3) the drivers of the decision-makers in the tariff-setting process. A major result is the empirical evidence that the way prices are used matters almost as much as whether they are used or not.

Keywords: Literature survey; Residential; Tariff structures; Urban; Water supply and sanitation

1. Introduction

Water and sanitation services (WSS) are essential to support a balanced development, integrating economic, social and territorial cohesion. To fulfill those human needs, due to the complexity of the WSS systems, the WSS provision should consider a holistic and long-term perspective regarding cost recovery (Brattebø *et al.*, 2013). This suggests that it is imperative for utilities to generate revenue to support these costs if they are to provide improved services, especially, when system coverage, performance, run down infrastructure, investments, stringent regulation and higher competition in demand (for a scarce commodity) are common problems (Organisation for Economic Co-operation and Development; OECD, 2009). Thus, diversified sources of finance have been adopted, particularly by requiring a payment from users (inducing the user-pay and polluter-pay principles). This entails the setting of tariffs. Note that to streamline concepts, tariffs are the system of procedures and elements, which determines a

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customer's bill. Any part of that bill is called a charge; and any unit price can be called a rate (OECD, 1999).

Particularly, in the water pricing arena, the scientific advance was preceded by the general public utility literature (Berg & Tschirhart, 1995), inheriting important features. Yet, Hanemann (1993), by comparing it with the electricity industry, highlights that there is a need for a distinct approach. This is attributed in part to the unique features of water related industries (e.g. higher capital intensity and technical characteristics, institutional status, environmental importance) that are connected to the public/private economic nature of those services and their social value.

The debate on those terms led to a growing acknowledgment of water tariffs as a conceptually simple way to promote multiple objectives, such as: financial sustainability and economic efficiency, equity, fairness and resource conservation (Rogers *et al.*, 2002). However, those objectives may be difficult to reconcile, leading to discrepancies between stakeholders and producing undesirable results, as well as conflicts of interest, making the study of tariff structures crucial for policy guidance.

Most of the previous objectives presuppose that prices can change consumers' behavior. Whether this is so, is an empirical matter that certainly can vary with different circumstances. Tariffs seem to be effective or ineffective as tools for influencing behavior depending on how they are deployed/structured. Thus, a major point we wish to emphasize is if it matters how prices are used.

Pragmatically, water utilities often fail to achieve their objectives due to faulty rate setting practices, stressing, perhaps, arbitrariness in price-setting strategies (Hoque & Wichelns, 2013). Thereby, as expected, the recovery of financial costs alone stands as a difficult milestone, disregarding the recovery of environmental and social costs (Zetland & Gasson, 2013). Nonetheless, tariffs should avoid working as a compensation mechanism for situations of inefficiency on the supply side. Furthermore, the tariff setting procedure, in terms of achieving the desired objectives, is significantly reshaped with the changes brought upon by the type of service (e.g. water supply, wastewater), 'service' demand and use (e.g. industrial, domestic, agriculture), and in broad terms, the development context (e.g. developed and developing countries).

This article focuses, mainly, on residential water use (in both WSS), owing to its role in the urban context (OECD, 1999). Besides, the tariff setting, from the residential domain point of view, is prone to controversy, and so, more appealing. This way, to better understand the development of publishing trends and which results are the most decision-relevant seem to be of paramount value. Therefore, the objective of this research is to survey empirical studies, emphasizing key features, trade-offs and the degree to which specific tariff structures achieve local objectives.

This paper is organized as follows: after this brief introduction, the second section presents the major features of research surveyed in the literature according to the methodology chosen, covering the type of publications, their time pattern and the countries screened. The water tariff schemes and possible applications covered are presented in Section 3, followed in Section 4, by the issues addressed in the studies reviewed. Finally, section five draws some final conclusions.

2. Characteristics of water tariff research

2.1. Narrative review

To enable a coherent analysis of the literature concerning the WSS tariff structures in the residential urban domain, the research carried out will be characterized in this chapter. Indeed, the literature on water tariffs is quite abundant, including several studies related to their impact in achieving specific objectives, or perspectives, of those who demand and supply water. Nonetheless, the scope here lies on the structure itself, rather than on the level, since when the analysis is restricted to the tariff level only, its structural importance may not be grasped.

A daunting example is the research related to the impact of water tariffs on customers. Such literature is incredibly vast and has been surveyed by numerous authors (for instance, see Worthington & Hoffman, 2008). In addition, a few meta-analysis studies have also been performed, first by analyzing price elasticities (Espey *et al.*, 1997), later together with income elasticities (Dalhuisen *et al.*, 2003), and recently, with household size elasticity (Sebri, 2014).

Therefore, the research conducted (up to April 2014) tried to gather the studies where the tariff structural components were highlighted, either due to comparisons of different tariff structures or by focusing on the role of specific tariff elements, but always bearing in mind the urban residential domain. For this purpose, specialized and general academic journals were sought, as well as other sources. However, academic journals benefit from the scrutiny of impartial reviewers, and thus, we focused on them. From a total of 185 publications identified, only those classified as journal articles (62%) represent an exhaustive research[1]. The working papers (9%) identified are those which were unpublished (to avoid double counting). Books (5%), book chapters (10%), and mainly, reports (11%) and PhD dissertations (3%) are only a key sample gathered through the research method used (included separately to improve the survey, granting a framework for comparison).

To avoid a possible random selection bias, an in-depth research procedure was adopted to retrieve empirical studies. It covered an extensive keyword-based research by using academic databases, such as JSTOR, ScienceDirect, Springer and Wiley. Further online retrieval engines were used such as EBSCO, Google Scholar and ISI Web of Knowledge. To improve the data gathered we consulted the websites of international organizations, such as the World Bank and OECD, in addition to other water sector related institutions, as the American Water Works Association and the International Water Association.

2.2. Type of journals

To assess the journals that published all those 115 articles gathered, we had to sort them out according to their subject categories. That is, since most of those journals (70%, covering 83% of all publications) are listed in the ISI Web of Knowledge database from Thomson Reuters, and a few more (17%, covering 10% of all publications) in the Scopus database from Elsevier, it is possible to categorize each journal according to its subject categories. The journals were then classified according to whether they had water related subject categories (Water Journals); if not, whether they had environmental related subjects (Environment). In addition, if the journals did not fall in the previous categories, they were arranged into subjects related to 'Business and Economics', and then 'Political Science and Public Administration (and Development)' related features, and finally, the remaining fell in the 'Others' category. Figure 1 shows the number of journals and the number of articles that fell into each category.

[1] Owing to limited space, some of the studies reviewed were not directly cited, instead the focus relies on the main issues raised. A list of the remaining publications is available from the authors upon request.

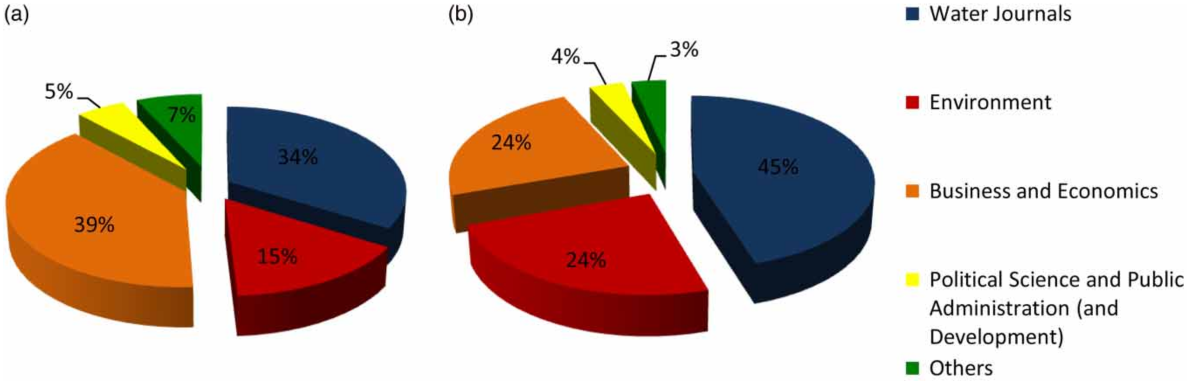

Fig. 1. Publications by types of journals. (a) Based on the number of journals. (b) Based on the number of articles in those journals.

Another interesting trend is the number of empirical studies by academic journal title (Figure 2), where there are a few journals tied with 11 publications, namely, *Water Policy, Land Economics* and *Water Resources Research* journals. The 115 publications were identified in 58 different journals.

2.3. Time pattern of publications and countries covered

The surveyed literature shows an interesting time pattern. The earliest publication found was Howe & Linaweaver (1967), where the authors formulate models of residential water demand and estimate the

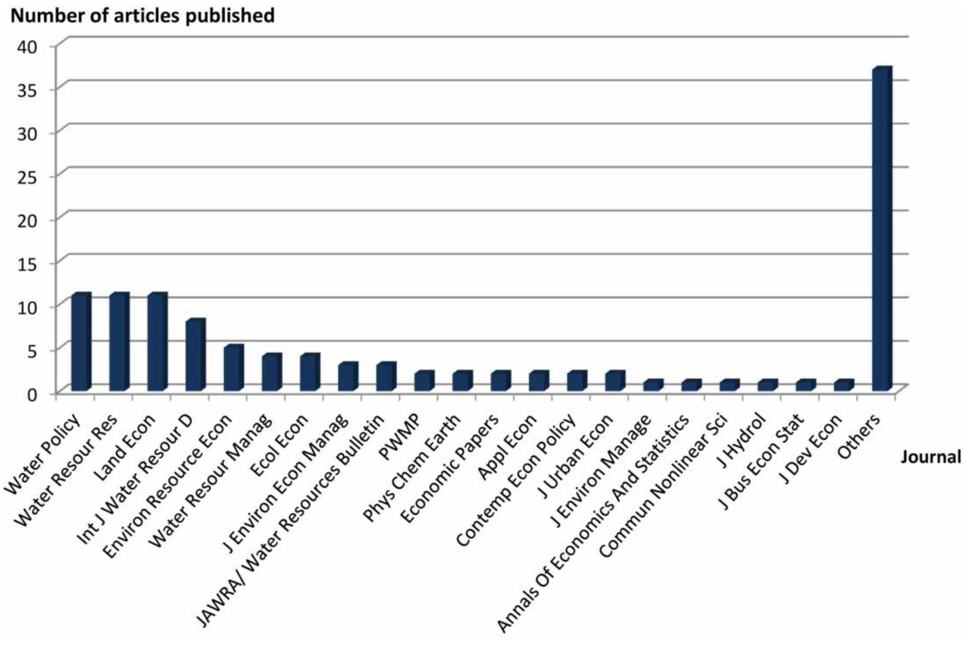

Fig. 2. Publications by academic journal title.

relevant parameters from cross-sectional data. For the first time, it was possible to differentiate not only between domestic (inside) and outside uses, but also among metered, flat-rate and other important features. The role of demand functions in pricing and system design was also discussed. The previous study is a clear instance of the work developed in the following years, mainly in the USA. Indeed, as observed in Figure 3, until 2000 the water tariff infrastructure studies were probably scarcely published/developed, but from then on, a significant increase was observed.

The mentioned increase may be connected to the efforts made in international events (e.g. UN setting in 1992; World Water Commission in 2000) which had a major impact in the general society. Since that period, other countries besides the USA were studied and, progressively other issues were addressed as the realities changed. The evaluation developed by Donkor (2010) of equity propositions, in a particular Ghanaian price setting is a clear example. In addition, data availability (which for these kind of studies is typically scarce, e.g. high level of disaggregation needed), interests in particular hypotheses (e.g. degree to which objectives are achieved under specific tariff settings) or comparisons per se (e.g. consequences in demand estimation) were important drivers in country selection patterns.

The subsequent highlighted countries are Spain, Australia and France; although there are significant studies covering all five continents. This trend is clearly related to the appearance of cutting-edge research centers worldwide. The previous features support the results that there is still an overwhelming tendency to cover developed countries. Furthermore, results may vary significantly depending on each country development status, as the reality is indeed different.

3. Water and sanitation tariff structures

Major challenges are presented when selecting a tariff structure that is responsive to the philosophy and objectives of both the utility and its community. The importance in this selection relies on its role as a major source of revenue, and because pricing policies may support the community's social, economic, political, and environmental concerns (AWWA, 2012). The controversy takes place when the utilities develop faulty methods, or are unaware of the consequences of misapplying successful policies

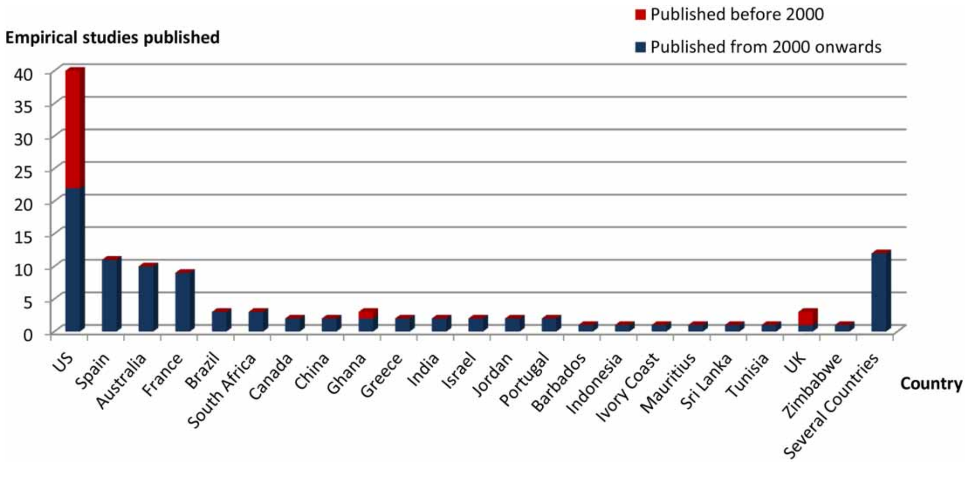

Fig. 3. Empirical studies published, by country studied.

elsewhere, resulting in an association fallacy. Indeed, tariff structure suitability is site specific in a relevant way.

From a wider point of view, utilities should consider several elements when attempting to design an adequate tariff, which may range from considering a classification of customers (i.e. residential/industrial, or in further detail such as residential by income), to the establishment of billing frequency and the charges' features to apply to those customers. The mentioned features cover the actual price (level), the tariff structure (mainly how customers are charged), and the accompanying measures (OECD, 2009).

The level of the tariff, if founded on a cost based approach, as recommended by the European Environment Agency (EEA, 2013), is a function of the utility's costs and customer demands[2]. The design, however, is a function of sometimes competing objectives. An appropriate selection should support and optimize a blend of various utility objectives, and should work as a public information tool in communicating these objectives to customers. Therefore, adapting from Tsagarakis (2005), a tariff structure can be a function of different components, as indicated by Equation (1).

$$\textbf{Tariff} = f(\textit{Fixed component} + \text{Volumetric component} + \text{Adjustment components} + \text{Other charges}) \quad (1)$$

The interaction of those components can give rise to diversified tariffs. Table 1 describes the main components identified in the literature (Tsagarakis, 2005; OECD, 2009; AWWA, 2012). Tariff adjustments, as well as a selected sample of cities where those structures have been applied and theoretical settings that should foster (or not) their use, are also highlighted.

To improve comprehensibility, pictorial representations of typical schemes were added (Figure 4).

From Table 1, there is an evident requirement of significant data to adjust some components, which means that the availability and quality of such information may render an appropriate (or inappropriate) use of a selected tariff. Still, policy-makers should always weigh the administrative cost against the benefits acquired (Dahan & Nisan, 2007). An important case is the estimation of demands with different characteristics (e.g. seasonal). The more accurate the estimate of the demand for water, the more efficient policy-makers can be in designing policies to influence water use (Espey *et al.*, 1997).

Another important feature is related to simplicity. There is a need to avoid complicated tariff structures, for example, the number of blocks considered for a volumetric charge, or too many adjustment components (e.g. time of use/peak, spatial, budget adjustments) as identified in Equation (1), as they are both more costly to implement and harder for customers to understand, hampering their response (see Arbués & Villanúa (2006) for the interesting case of Zaragoza in the 1990s). Also, even if more complex tariffs may dominate simpler ones by allowing the inclusion of additional details, they also require more information on the structure and distribution of demand. Pragmatically, utilities can safely pursue relatively simpler tariff structures, without foregoing significant objective opportunities (Herrington, 2007). Indeed, the desired outcomes of a tariff structure depend on customers receiving a price signal or an understanding of the consequences of their consumption on their bill. For a utility to maximize its price signal, customers must have timely information, and the signal must be meaningful

[2] In that context the role of different marginal costs (e.g. short-run; long-run) is paramount (for a deep analysis, see AWWA (2012) and EEA (2013)). Still, note that cost analysis and its role in the determination of appropriate tariff levels goes beyond the scope of this paper.

Table 1. Summary of different tariff policies identified in the literature.

Tariff	Definition	Possible adjustments	Theoretical settings	Selected sample of cities[c]
Fixed, flat	Each user pays a fixed fee that does not change with the volume of water use	Uniform across customers, or differentiated based on some customer characteristic[a]	Does not require a meter. Simple (administratively), stabilizes revenues, low economic efficiency, low equity	Dublin (Ireland)[*ws*], Karachi (Pakistan)[*ws*], Amsterdam (The Netherlands)[*sa*], Johannesburg (South Africa)[*sa*].
Uniform, single block (UT)	Single volumetric rates, a single rate per cubic meter is applied regardless of volume consumed	Can be used with uniform or differentiated fixed charges. The fixed charge can be negative (coupon)[b]	Administratively (adm.) simple, encourages conservation (conserv.), gives the sign of water scarcity	Beijing (China)[*ws*], Manchester (UK)[*ws*]. Bangkok (Thailand)[*sa*], Munich (Germany)[*sa*].
Increasing, ascending, inclining blocks (IBT)	The volumetric charge increases in steps with volumes consumed, from one water usage block to the next	Either the volumetric rates applied to each block or the size of the blocks are adjusted based on specific customer characteristics[a]	Encourages conservation, gives the sign of water scarcity, promotes equity	Lisbon (Portugal)[*ws*], Dakar (Senegal)[*ws*]. Colombo (Sri Lanka)[*sa*], Tokyo (Japan)[*sa*].
Decreasing, descending, declining blocks (DBT)	The volumetric charge decreases in steps with volumes consumed, from one water usage block to the next	Either the volumetric rate of each block or the size of the blocks are adjusted to usage patterns and demand requirements	Cost reflective, does not encourage conservation, it applies to areas where there is plenty of water to sell	Lille (France)[*ws*], Toronto (Canada)[*ws*], Kathmandu (Nepal)[*ws*], Glasgow (Scotland)[*sa*].
Increasing rate, sliding scale (IRT)	The unitary volumetric price for all water use increases as water usage increases	Can be used with *per capita* adjustments, or based on specific customer characteristics[a]	Considerably simple, encourages conservation, gives the sign of water scarcity, promotes equity	Bilbao (Spain)[*ws*], Seixal (Portugal)[*ws*], Tunis (Tunisia)[*ws*], Leon (Spain)[*ws*].
Wbud	Volumetric block rate structure in which the blocks are defined uniquely for each customer	The blocks are based on a determination of 'need' for each customer, as large volume may not mean wasteful use	Conservation awareness, difficult to reconcile with cost of service, equity and efficient principles, adm. complex, regressive in customer impact	Irvine (USA)[*ws*], San Jacinto (USA)[*ws*], Riverside (USA)[*ws*], Los Angeles (USA)[*ws*].
Seasonal	Rates are higher during the season of higher demand than during the off-peak season	It may be applied to any of the other structures (e.g. a uniform volumetric rate)	Encourages conservation, where seasonal demands are the target conservation efforts	Seattle (USA)[*ws*], Bratislava (Slovakia)[*ws*], Tucson (USA)[*ws*], Madrid (Spain)[*ws*].

(*Continued.*)

Table 1. (*Continued*)

Tariff	Definition	Possible adjustments	Theoretical settings	Selected sample of cities[c]
Time of use, peak load	Rates are higher during peak hours or days of the week	It may be applied to any of the other structures (e.g. a uniform volumetric rate)	Advanced metering systems required. Encourages conserv. when demand is high	Hervey Bay (Australia)^{ws}, Bristol (UK)^{ws}, Melbourne (Australia)^{ws}, London (UK)^{ws} [d].
Spatial	Users pay for the actual cost of supplying water to their establishment	It may be applied to any of the other structures (e.g. a uniform volumetric rate)	Cost of service and allocative efficiency principles, low equity, low affordability	Denver (USA)^{ws}, Springfield (USA)^{ws}, Napa (USA)^{ws}, Oklahoma (USA)^{ws}.

[a]For example, size of supply pipe or meter flow capacity; property value; number of water-using appliances; wealth index; household size and number of dependants.
[b]The fixed component may be applied to any volumetric rate, but may complicate considerably.
[c]In the selected cities, there is the possibility to find those tariff structures in water supply (superscript: ^{ws}) and/or sanitation (superscript: ^{sa}) services.
[d]The cities selected cover specific pilot projects regarding the use of smart meters for either end-use/demand analysis or pricing reforms.

to them. The element of time is critical, with greater frequency generating greater awareness of the relationship of cost to volume of use (Howe, 2005), without disregarding that with lesser frequency, the resulting charge is higher, leading consumers to be more aware of pricing features.

Moreover, water supply and sanitation tariffs are increasingly linked, despite the gap found (only 46% considered any sanitation input). Generally, sanitation (e.g. sewerage) is a fixed percentage of water consumption or a fixed fee (when priced), not considering household characteristics, among others (trend also highlighted by OECD (2009) and Hoque & Wichelns (2013)). In general, as seen in Table 1, there are specific rates that are mainly found in the USA, such as the water budget (Wbud) and spatial tariff features (Raftelis, 2014). From an international perspective, the case of Portugal is quite unique, since the sector specific regulator (ERSAR) promotes the use of increasing block tariffs (IBTs) through tariff recommendations, which explains the increased tendency regarding their adoption (Pinto & Marques, 2014). A distinct particularity is the use of a proxy in the time of use/peak load tariff adoption, such as those cities which promoted specific pilot projects to induce end-use/demand analysis or pricing reforms, being possible drivers of their use (Boyle *et al.*, 2013).

4. Issues addressed by the studies

4.1. Categorization

Recognizable patterns were found in the issues addressed by the empirical studies surveyed in the literature. Regarding WSS tariff structures in the residential urban domain, the following topics were identified.

Tariff structure objectives: the degree to which specific objectives are achieved.

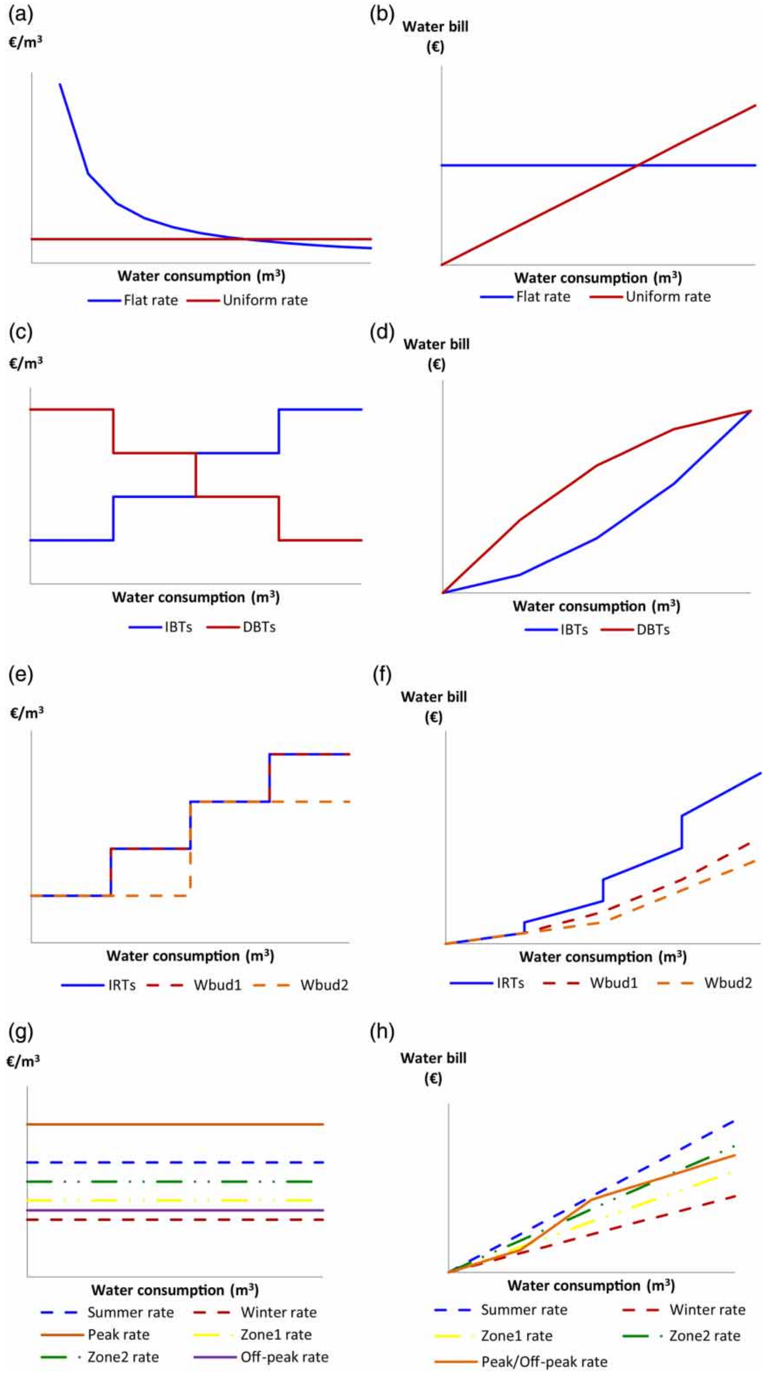

Fig. 4. Typical schemes: uniform and flat rated (a) cost per unit consumed and (b) total cost per consumption values; IBTs and DBTs (c) cost per unit consumed and (d) total cost per consumption values; IRTs and Wbud (e) cost per unit consumed and (f) total cost per consumption values; and seasonal, time peak and spatial rates (assuming a volumetric uniform rate) (g) cost per unit consumed and (h) total cost per consumption values.

Customer interpretation and price elasticities: how the desired outcomes of a particular structure depend on the customers' sensitivity when receiving a price signal.

Policy drivers: the drivers of the decision-makers in the tariff setting process.

Note that although several studies cover more than one category, it is possible to gather them according to the main topic covered. The topics and results are briefly summarized below.

4.2. Tariff structure objectives

The setting of water tariffs aims to promote multiple objectives such as net revenue stability, economic efficiency, environmental sustainability, equity, public health, simplicity and acceptability (Rogers *et al.*, 2002). In Table 2, those objectives are grouped according to the OECD (2009) dimensions.

As a consequence of this multi-objective context, tariff design is a complex procedure due to potential trade-offs. Thus, utility managers will have to prioritize objectives depending on the context (Table 3).

To understand how different pricing structures can be used to achieve the previous objectives, one has to perceive tariffs (i.e. water bills) as what they are. Following Griffin (2001), tariffs are a request for payment for a valued, delivered service, not a tax invoice for funding government programs. In this context, the objectives to be accomplished have to be selected with care. One of the most debatable cases is

Table 2. Policy objectives' dimensions and components.

Dimensions	Components	Practical example	Sample of studies
Environmental sustainability	Avoid depletion of critical natural capital, by promoting an efficient use: (1) encourage water saving; (2) discourage wasteful water use.	Volumetric rate that is able to provide incentives for consumers to conserve water.	Stevens *et al.* (1992); Montginoul *et al.* (2005); Smith & Wang (2008)
Economic efficiency	Allocate water to users to maximize social welfare: (1) prioritizing uses with highest value to society; (2) compare costs with value, i.e. do not misallocate economic resources.	A volumetric rate based on marginal costs principle.	Garcia & Reynaud (2004); Sibly (2006); Porcher (2014)
Financial sustainability	Balancing revenues from users with the full costs of supply[a] (while not allowing situations of inefficiency on the supply side).	A fixed tariff that is able to achieve stable revenues in the needed amount.	Howe (2005); Montginoul (2007); Mylopoulos & Fafoutis (2012)
Social concerns	Adequate and affordable access to a minimum quantity of water at fair and equitable conditions: horizontal equity where similar situations are expected to be treated in the same manner; vertical equity where different economic situations are treated differently.	A tariff with social measures (as rebates or extensions and discounts on volumetric rates), only works if correctly targeted.	McMaster & Mackay (1998); García-Valiñas *et al.* (2010); Martins *et al.* (2013)

[a]See Rogers *et al.* (2002) for a fuller description of what the full cost of supply entails.

Table 3. Trade-offs that affect tariff levels and structures.

Trade-offs identified	Possible situations	Practical example	Sample of studies
Environmental sustainability vs. Economic efficiency	Efficient resource allocation may not induce water savings.	Volumetric rate based on marginal costs that are insufficient to create conservation incentives.	Massarutto (2007); Rosenberg (2009); Wasimi & Hassa (2012)
Environmental sustainability vs. Financial sustainability	Environmental requirements may either not assure the proper funding, by increasing revenue variability, or, may raise costs increasing revenue needs, which may induce tariff implementation struggles.	Volumetric rates based on conservation tariffs may induce proper incentives, but can negatively impact utility revenue, such as increasing revenue variability.	Pint (1999); Borisova & Rawls (2010); Rinaudo *et al.* (2012)
Environmental sustainability vs. Social concerns	Volumetric pricing vs. low income elasticity. Reduce access to freely available resources. Free amount vs. efficient use.	Volumetric charge high enough to induce conservation, but is regressive in terms of affordability.	Dube & Van der Zaag (2003); Martínez-Espiñeira (2003); Barraqué (2011)
Economic efficiency vs. Financial sustainability	Full cost recovery vs. marginal cost pricing.	A volumetric rate based on marginal costs may not ensure stable revenue flows compromising future investment.	Dalhuisen & Nijkamp (2002); Hall (2009); Wichelns (2013)
Economic efficiency vs. Social concerns	Give priority to access by high-value uses vs. merit uses.	A volumetric rate based on marginal costs may not be affordable to poor households.	Johnson (1971); Castro-Rodríguez *et al.* (2002); Garcia-Valiñas (2005)
Financial sustainability vs. Social concerns	Move to fuller cost recovery through tariffs may negatively affect affordability.	A flat tariff that assures stable revenues in the needed amount may not be affordable to poor households.	Whittington (2003); Bithas (2008); Ruijs *et al.* (2008)

when water is subsidized, as it might not be the most desirable way to solve the social problem at hand (Barraqué, 2011). While lower tariff rates are recurrently targeted for low-income groups, lower revenues can result in financial consequences for the water companies (Ruijs *et al.*, 2008), possibly translated in reduced investments in poorer areas of the city, preventing the poor from obtaining access to the water supply (Whittington, 2003). However, that does not mean that the mentioned objective should be foregone, as it might be important to do so, on the grounds that everyone should be able to afford a basic (lifeline) quantity of water consumption (García-Valiñas *et al.*, 2010).

The first studies gathered that establish a comparison between tariff structures and several objectives were those developed by Johnson (1971). The author effectively illustrates that no structure is superior to all others on the accomplishment of all objectives, even though some fare better in the general picture (always depends on the objectives prioritized and the set of unique circumstances facing each utility). Later studies also highlight those issues: Dalhuisen & Nijkamp (2002) and Rosenberg (2009).

Of particular interest is how to incorporate the components referred to in Equation (1). To balance tariff structure components in light of the mentioned trade-offs is a difficult and hardly comparable task, due to each utility specific context (e.g. costs, demand, institutional, geographic factors). Nonetheless, the following must be highlighted.

A fixed charge is selected, not only due to its ability to collect stable revenues reducing financial risks which may derive from the relative volatility of water consumption (risk aversion attitude), but also the concern to recover significant fixed (sometimes sunk) costs. Still, it may be regressive, as it is a fixed amount of money that every user must pay regardless of the user's ability to pay and level of use (McMaster & Mackay, 1998), possibly dominating the bill of small customers (Griffin & Mjelde, 2011). Besides, effectiveness of tariff levels and structures (e.g. in collecting revenues) should not be assessed, single-handedly, from the final user's viewpoint, but rather the whole value chain of WSS. Thus, while providing correct signals to customers, tariffs should not provide a wrong signal to service operators/investors (Massarutto, 2007).

A somehow similar fixed charge can be interpreted as a minimum water consumption amount, or a free allowance, which is charged at a zero marginal price. That basic amount is charged compulsorily (e.g. in Brazilian WSS). The use of free allowances is regularly criticized as they lead to significant efficiency losses. Users do not face a marginal incentive to conserve water and may end up consuming more than they would have (environmentally inefficient) if charged a positive price at the margin (Castro-Rodríguez *et al.*, 2002).

The volumetric charge, due to the increasing importance of demand management, is being widely adopted, either in its simpler linear (uniform) form or diversified non-linear forms. The decreasing ones (e.g. DBT), justified by the assertion that higher levels of consumption are cheaper (at the margin) to serve, are being considerably left aside. Hence, we will concentrate on the increasing ones (e.g. IBT) which are often championed as a way of signaling rising supply costs and encouraging conservation. The IBT design features cover the number of blocks; the volume of water use associated with each block; and, the price to be charged for each block.

IBTs allow the utility to provide a first block that can satisfy marginal subsistence (lifeline) at below-cost, and further blocks that can restrain increasingly lavish uses (Bithas, 2008). However, the validity of using IBTs to improve equity among users depends on a strong positive relationship between water use and household characteristics (e.g. number of residents, income). Water consumption may not increase (decrease) along income scale, either due to a decline (rise) in household size or the adoption of large minimum charge consumption blocks. Nonetheless, it will do if demographic features, regional variations in demand, a large extent of metering and appropriate water tariff design (even without further income/household considerations) characterize the utility context (Madhoo, 2011). But in most cases, some household reforms have to be considered (for household size differences, and multiple meter connections cases, see Dahan & Nisan (2007) and Donkor (2010)). Conversely, sometimes those reforms can hinder small households. To solve the identified equity problems, further reforms have to be made, perhaps, based on the development of water consumption guidelines depending on the household size, and standards to satisfy the basic water needs. The resulting reforms may be centered in the adjustment of every single design feature (Arbués & Barberán, 2012).

Therefore, the quantity of blocks and their size is a complicated matter. Two blocks would be a simple and straightforward solution, but it may not correspond to the reasons why, and the ways in which, people use water. Three would capture a division between basic, discretionary and wasteful uses; the relative prices would be set according to that norm (creating a price differential as defended by Hanemann (1993)). Any fourth block would need a specific justification (e.g. to avoid any type of consumption in that zone) as the blocks should be as few as necessary (Herrington, 2007). The block size is another issue, mainly the first block upper limit may considerably exceed the 'lifeline amount'. Then, those customers would be paying too little for that excess of water (i.e. misapplied subsidies), receiving inappropriate signals in the promotion of a moderate use of a scarce resource (Martins *et al.*, 2013).

Depending on the objectives, further reforms can be considered by increasing particular block prices or decreasing particular block volumes, or by removing, splitting, or adding additional blocks in simple ways, with perhaps different thresholds for distinct consumers, as suggested by Hall (2009). Thus, allowing the expansion of the set of policy options, possibly included in the tariff design, would increase political feasibility.

4.3. Customer interpretation and price elasticities

The link between water pricing structures and the level of achievement of some objectives depends, in particular, on the type of price toward which households are sensitive. In addition, if price knowledge is endogenous to the household and there is a potential source of variation in demand, assumptions about the household's perceptions may bear significant variations. Knowledge of average and marginal prices can lead to different econometric specifications of the residential demand function and, thereby, possibly generate conflicting expectations of pricing policy effects on consumption.

The seminal studies of this area, which borrowed significantly from a parallel literature in the energy industry (i.e. electricity), used not only the marginal price or the average price, but also what became known as the Nordin difference variable (D). The purpose was to take into account the income effect imposed by the pricing schedule when estimating demand (Nordin, 1976). A specification of that effect was defined as the difference between the actual total water bill and what would be paid by residential customers if every m^3 was purchased at the marginal price. In fact, such specification was adopted and revised by several studies on the estimation of water demand under block pricing structures, in order to capture the influence of block rates (Howe, 1982).

The customers' knowledge of marginal price, or their reaction to average prices, are issues that still remain unclear to researchers (Nataraj & Hanemann, 2011). Furthermore, such specifications may change according to the tariff structure in place. Yet, if customers are not informed about the structure, e.g. not knowing when they change block (Nataraj & Hanemann, 2011), or not fully understanding how their bill is calculated within those tiered rate structures (Nieswiadomy & Molina, 1989), they will react to average prices. Moreover, the reliance on high fixed charges in two-part tariff structures is likely to increase misperception of the marginal price of water (Worthington *et al.*, 2009). The introduction of IBTs can also produce a perverse increase in total demand due to price decreases in the lower blocks (Wichman, 2014). This inconsistency may be attributed in part to differences in level of data aggregation (for possible requirements regarding the use of individual household level data, see Schefter & David (1985)).

Another serious concern, for academics, is the role of the functional form for the water demand equation, as it determines the restrictions on the price elasticity of demand. Monteiro & Roseta-Palma (2011) compare the properties of broadly used functional forms, showing that the most appropriate tariff hinges crucially on that choice. The consequences of the functional form's selection are not to be underestimated, as the connection between variables may be misinterpreted leading to different conclusions regarding, for example, tariff level (or structure) and water use. The estimation technique used also seems to considerably affect the results (Olmstead, 2009).

Therefore, the concept of elasticity has to be carefully analyzed, due to the assumptions made when selecting the calculation method (i.e. how the variables interact). Particular studies suggest that demand is more elastic under IBTs than under uniform tariffs and/or DBTs (Nieswiadomy & Molina, 1989; Olmstead *et al.*, 2007). Although in some studies DBTs exhibit higher elasticity (Stevens *et al.*, 1992), all studies vary in data set characteristics, price perception variable and estimator model used. In the publications gathered, the variation in estimated elasticities is associated with differences in the underlying tariff structure (Reynaud *et al.*, 2005; Olmstead *et al.*, 2007). But, correlation does not demonstrate causality. The concern is that some unobserved characteristic of households within a community may drive a utility's choice of tariff structure and that this characteristic could be correlated with price elasticity.

In comparing elasticities across different studies, the meta-analysis faces many confounding factors that differentiate the studies in their samples. Empirical estimates vary widely, depending on differences in population characteristics, site characteristics (such as temperature and precipitation), and differences in tariff systems as well as biases and misspecifications in the econometric analyses used to determine the elasticities (Dalhuisen *et al.*, 2003). Those differences in estimated elasticities are positively correlated with differences in per capita income pertaining to the underlying study area. Hence, the question of which 'income group' has the lower price elasticity must be determined empirically (i.e. case specific) rather than on *a priori* grounds.

Sebri (2014) in his meta-analysis highlights studies where the long-run price (household size) elasticity estimates are higher (lower) in absolute values. Therefore, basing long-run policy instruments on short-run elasticities may lead to some distortions. Other mentioned studies suggest that price (also income and household size) elasticities differ across the geographic location, namely in the USA, Europe and other parts of the world, as well as according to the development level of countries (developing vs. developed countries).

The formulation of appropriate pricing policies for urban water requires knowledge of price, income and household size elasticities of demand. These elasticities have implications when forecasting demand, as changes in tariff structures can have due consequences in, among others, revenue stability, conservation and reduction of peak demands on the system. The dependence of 'price responsiveness' on 'billing price information' is an important issue (Binet *et al.*, 2014). Gaudin (2006) shows that billing price information increases the value of price elasticities.

4.4. Policy drivers

To understand the selection of particular tariff structures, the role of utility managers' attitudes and perceptions of alternative structures are of significant importance for the likelihood of their adoption. The water managers' essential nature may influence that likelihood, but also utility size (quantity delivered) and the geographic/administrative region can affect the adoption of a particular tariff structure. Boyer *et al.* (2012), in their US-based case, highlight that the importance of the cost of delivery and the need to subsidize non-water operations were found as significant drivers for adopting IBTs or uniform tariffs (UTs). Significantly, the managers' perceptions about particular factors, such as rising regulatory costs, the need for infrastructure investment, conservation, requirements of government grants or loans, and fairness, were significant predictors of tariff structure selection.

Besides cost factors, also the operating ratio (financial ratio), temperature, application of 'outside' rates, and the utilities' emphasis on affordable rates may affect combined water and sewer bills, although the existence of combined bills are weakly associated with community income and the proportion of customers below the poverty line (Thorsten *et al.*, 2009). Further studies also found that bills are significantly and positively correlated to bills paid in nearby utilities (Chica-Olmo *et al.*, 2013). Those authors concluded that in the absence of an agency to regulate and control tariff design and price levels, nearby municipalities are found to approve similar tariffs (by observing neighbors). In this sense, more than likely, local governments seek to avoid the perception of comparative disadvantages in water tariff payments.

But, significant differences still exist. Martínez-Espiñeira *et al.* (2012) highlight that although there might be reasonable grounds for some of those differences in prices, it is also evident that further factors are linked to the introduction of such comparative grievances among citizens in their access to a merit good, such as water. Elements of discrimination found are the ideology of local government (i.e. political party in power) and the type of ownership of the water supplier (i.e. private or public). Those influences, despite being widely covered in the literature, mostly compare the tariff's level instead of their structure.

Further exogenous factors are linked. Locations with sunnier, warmer and drier weather conditions, are more likely to adopt IBT structures. This result is consistent with rational price discrimination as water needs are more heterogeneous under such conditions. Accordingly, tariff structures may be affected by the influence of those exogenous factors, leading to different price elasticities (Monteiro & Roseta-Palma, 2011). Specifically, if utilities are under the use of conservation programs or a lower annual rainfall, there is a greater probability that the utility will choose an IBT.

5. Concluding remarks

This literature survey examined several empirical studies of water tariff structures, specifying those publication trends, namely referring to publication patterns and the type of journals. Furthermore, those publications were divided in accordance with the perspective adopted.

First, personal views become important here. There is no 'magic bullet' policy that can be expected to satisfy all the multiple and sometimes contradictive objectives that managers look for when setting tariffs. Still, there are appropriate tariff structures for different needs, bearing the possibility of different types of customer winning and losing. The success may be achieved at the 'cost' of other household groups who in effect provide the cross-subsidy. Hence, an issue is whether those cross-subsidies are targeted in the most appropriate way. Besides, such reforms may increase the administrative complexity of water tariffs. The case studies are usually data demanding as each case is dependent on its own context (e.g. political, hydrological). Therefore, assumptions and conclusions should be considered with care.

Also, the conflicts and priorities in tariff structures, as well as the institutional and physical systems' ability to deal with them, evolve over time. As stated by Martins *et al.* (2013, p. 209):

> '*Improved income may enable a community to face the costs needed to obtain previously unaffordable services, technological improvements might render their provision cheaper, more effective governance institutions might emerge, and social learning processes might generate new cultural frameworks that enable the community to accept previously unacceptable solutions.*'

In fact, by comparing the results of Section 2 with those of Section 3 (see the case of the USA), one may infer that learning processes could relate to the efforts made in research and in the formation of water consumption 'rules/habits', lending additional legitimacy to increasingly complex tariff setting efforts.

The goal of highlighting key features and the degree to which specific tariff structures achieve local objectives lead decision-makers to entail different solutions to assess the inherent trade-offs, and thus the value of studying tariff structures. Nevertheless, sometimes tariff objectives are clumsily chosen, and incorrectly adapted (e.g. in structural choices, as in specific IBT schemes), all in all jeopardizing a fuller role of tariffs by putting at risk the achievement of further objectives. Concerning how the desired outcomes of a particular structure depend on the customers' sensitivity when receiving a price signal, there is a need to contextualize, as they may also depend on income and household size elasticities of demand, and acknowledge the methods used, as they may affect the results achieved. As for the drivers of the decision-makers in the tariff setting process, one can highlight that the adoption of similar tariff structures is proportional to those used in the utilities' vicinity, or that specific tariffs may be selected in accordance with the managers essential nature or specific exogenous factors.

In practice, due to general *ad hoc* strategies, some regulatory activities could be advised in order to avoid situations of unfairness in the access to water. Hence, a key recommendation can be made in line with Martínez-Espiñeira *et al.* (2012), which relies on the establishment of binding criteria to guide the design of tariffs. This kind of regulation should establish guidelines on aspects such as the number of blocks of the tariff structure, consumption volumes per block, and the establishment of a more homogeneous price for the lifeline amount. In short, the regulation should introduce elements to limit, not to completely eliminate, the current arbitrariness that allows the absence of legislation for the management units of water service in the design of water rates. This is a significant issue to the lower levels of water consumption, and to avoid situations of unfairness among citizens in access to clean water.

The role of tariff structures cannot be denied as a valuable policy in promoting water conservation and enhancing social equity. In any event, although the type of rate structure has a significant impact on residential water demand, the price charged for water is related, to a great extent, to how much is consumed. Undoubtedly, utility managers should always place considerable emphasis on both the price level and the tariff structure.

Furthermore, different countries struggle with different needs, some seem more daunting as they question human integrity. There are several countries (mostly developing ones) that still require a significant system expansion. Therefore, willingness-to-pay needs to be measured on a local basis, which is certainly not the same for the different cultures and hydrological features.

But while relatively sophisticated approaches have been developed to simulate ex-ante the impacts of various tariff systems, few of these approaches can easily be deployed by water professionals at the local level, without involving complex econometric analyses, highlighting, sometimes, a missing link between academics and practitioners. Hence, we suggest here a broad knowledge on tariff setting and design, remembering that full potential or even, good practice, are unattainable if instituted in isolation. If carefully considered, the results obtained in the literature can be bundled together so that the whole will be much more than the sum of the parts.

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