Abstract

A strong seasonal demand for water occurs in many tourist areas, which might exacerbate the water shortage problems. Water pricing is a key instrument for water use management; therefore, the objective of this work was to design a variable water rate to examine the seasonal water demand in water-scarce regions. The proposed water rate combines the peak-load pricing (PLP) and increasing block rate (IBR) strategies. PLP results in full cost recovery of urban water services; however, IBRs penalise excessive water consumption. Moreover, the proposed water rate structure allocates the costs among users depending on their consumption. Subsequently, an empirical application was developed for a Spanish tourist town illustrating the usefulness of the water rate proposed. In conclusion, the combination of the PLP and IBR approaches is a useful water-pricing strategy for increasing the sustainability of the urban water supply under the conditions of seasonal water demand and water shortage.

Keywords: Environmental and resource costs; Full cost recovery; Increasing block tariffs; Peak-load pricing; Seasonal water demand; Tourist municipalities

1. Introduction

Water is an essential resource to sustain life; therefore, water scarcity and droughts are a growing concern. Almost one-fifth of the world’s population lives in areas where water is physically scarce (World Health Organization (WHO), 2009). According to the Water Information System for Europe (WISE), in Europe, water scarcity affects over 10% of the European Union’s (EU) population, and almost 20% of its territory consists of Mediterranean regions, which are facing the most acute problems (WISE, 2008). Due to population growth, urbanisation, increased household size, industrial uses, and climate change, the conditions of water scarcity are becoming more problematic (WHO, 2009).
Tourism results in a high seasonal visitor concentration during certain months of the year, causing a peak water demand. The increased water demand is motivated not only by the seasonal population, but also by the additional heavy demands for lawn sprinkling and swimming pools (Olmstead et al., 2007). In many regions, this peak period occurs in the summer season, when the water sources are even scarcer; that is, the peak water demand coincides with the dry season (Salgot & Tapias, 2004), exacerbating the water shortage problems (Shen, 2012).

In recent years, major changes in the perception of urban water management have been suggested, as the demand side of policy has taken the lead over the conventional supply-side measures (Barberán & Arbués, 2009; García-Valiñas et al., 2010). This is consistent with a global trend in favour of incentive-based instruments compared with the classical approach of ‘command and control’ (Kanakoudis, 2002; Reynaud, 2008).

In this scenario, water pricing is a key instrument for water demand management as outlined by the Water Framework Directive (WFD, Directive 2000/60/UE). The WFD emphasises full cost recovery of water services and the implementation of water-pricing policies as an incentive for users to use water resources efficiently.

Nearly 30 years ago, Millerd (1984) pointed out several factors responsible for the absence of water-pricing controls: (i) water was considered a necessity, not subject to conventional economic analyses like other commodities; (ii) public health and engineering concerns dominated water supply decisions; (iii) water was regarded as abundant and easily accessible; and (iv) political considerations in local rate regulations translated into continuing pressure to maintain low rates. To date, changes in these perceptions have been noted and a new paradigm in urban water management has been adopted; however, substantial work must be accomplished to introduce water-pricing policies to improve and maintain the urban water cycle sustainability.

An economic literature review shows that numerous studies addressing several water-pricing topics have been conducted. Many works aimed to estimate water demand functions and calculate price elasticities (Rogers et al., 2002; Salman et al., 2008; Olivier, 2010; Madhoo, 2011; Mylopoulos & Fafoutis, 2012). Many studies have examined the design of water rates for different countries and municipalities under different scenarios to achieve different objectives. For example, Pashardes & Hajispyrou (2002), Barberán & Arbués (2009), Reddy (2010), and Martins et al. (2013) were primarily interested in equity aspects. Other authors, including Beecher et al. (1990), Renzetti (1992), and Teodoro (2002), also integrated resource conservation into the design of water rates. More recently, and particularly since the WFD was implemented in the EU, how water rates can contribute to full cost recovery of providing water services has been of greater interest (Tsagarakis, 2005; Massarutto, 2007; Sanz et al., 2011; Kanakoudis et al., 2011, 2012; Hernández-Sancho et al., 2012; Molinos-Senante et al., 2013).

Nevertheless, to our own knowledge, the previous studies have not specifically examined the seasonal water demand in water-scarce regions by providing a water rate design. In this context, the objective of this study was to design a water rate model aiming to recover the full cost of urban water services (including environmental and resource costs), integrating seasonality into the water demand present in many tourist municipalities. In doing so, the peak-load pricing (PLP) and increasing block rate (IBR) strategies were combined to propose a variable charge rate. From a policy perspective, the proposed rate will be useful for water authorities and regulators since the PLP allows the recovery of treatment and supply costs in both the off-peak period and the peak water demand period; alternatively, the IBR structure penalises excessive water consumption and reflects environmental and resource costs,
as illustrated by Lavee et al. (2013), who concluded that a drought surcharge led to a significant reduction in the residential water demand.

The utility of the proposed variable water rate was illustrated by developing an empirical application for a Spanish touristic municipality with high seasonality in water demand. The current resident population pays part of the higher costs of providing water during the peak relative to the off-peak season. Hence, there is room to improve the management and sustainability of the water supply in this municipality.

2. Basis of the proposed water rate

Water tariff design should be performed with several criteria in mind. For example, in the European context and following the WFD, Barberán & Arbués (2009) based their water rate design on the following general principles.

- **Full cost recovery**: the revenues collected from water rates should cover the cost of supply, thereby guaranteeing ongoing service provision in the long term. Moreover, Article 9 of the WFD states, ‘Member States shall take into account the principle of recovery of the costs of water services including environmental and resource costs.’
- **Efficiency**: water services should be provided in a way that maximises the society’s net benefits.
- **Equity**: two approaches should be differentiated, namely the benefit principle and the ability-to-pay principle.
- **Simplicity**: water rates should have a simple structure to minimise the management costs and be easily understandable to users.

From an economic point of view, the first objective of a water utility pricing scheme is to generate revenues to cover the costs fully. However, a pricing rule may also address two other functions, namely to allocate costs between users and to provide incentives for efficient use and water conservation (Reynaud et al., 2005). It should be noted that the basic condition for the application of a pricing instrument is the ability to measure water consumption at the final user level, preferably through meters. Nevertheless, it should be taken into account that water metering errors are very difficult to quantify precisely (Kanakoudis et al., 2013). Although large non-revenue water levels negatively affect the financial viability of water utilities (Ndirangu et al., 2013), this study focuses on residential water consumption, which, in water-scarce regions, is usually metered.

According to the cost recovery principle, whereby an individual or group imposes an extra cost on the system, this individual or group should be accountable for the extra cost. In other words, if the costs of supplying two users are different, then their payments should reflect the cost differences. For example, Whittington (2003) suggested the adoption of several water-pricing policies in water-scarce regions of South Asia to allocate the available water supplies to high-value users. Therefore, the prices reflected the opportunity cost of the resources used to deliver water; consequently, the efficient allocation of scarce inputs will improve (Millerd, 1984).

PLP involves the application of differential tariffs that reflect the different costs associated with providing services during peak and off-peak periods. Beecher et al. (1994) showed that the costs of supplying water at these different times might vary. According to the PLP approach, the water rates depend on the season in which the water is delivered. The great advantage of this strategy is that it encourages conservation when
water is at its most valuable (Commonwealth Scientific and Industrial Research Organisation, 2001). Under a PLP strategy, the rates are reduced or normal during off-peak water demand periods and increased in peak months when the demand is higher and the water availability can periodically be lower. On the contrary, in the context of seasonal water demand, a single and common water rate generates inefficiency (Castell & Tanchudo, 2002). A single rate falls between the peak period rate and the off-peak period rate. This ‘average’ rate does not promote water saving when the water availability is lower and the cost of delivery is higher. Water managers should therefore install additional facilities during months of high water demand to supply underutilised water during the off-peak period. In so doing, under extreme seasonal water demands, PLP might prevent the construction of new water supply infrastructures.

Reynaud (2008) reported two main motivations for implementing PLP. First, a higher social value exists for water during the summer, when high competition across water users might result in scarcity rents. Second, the share of outdoor usage during the peak period is more price-reactive than indoor water consumption. Consequently, the consensus among researchers is that the residential water demand in summer is more sensitive to price changes (Griffin & Chang, 1991; Lyman, 1992; Reynaud, 2008).

The IBR approach is another water rate strategy that is widely used in sunnier, warmer, and drier weather conditions (Hewitt, 2000), as it also transmits water scarcity information to users (Reynaud et al., 2005). IBRs are a form of multi-part tariff, whereby the volumetric charge increases in a stepped manner as consumption increases. The rationale given for adopting IBRs (apart from the recovery of efficient costs) centres around the philosophy that IBRs encourage water conservation, because the strategy increases the price of water as consumption increases (Olmstead et al., 2007).

The number of blocks, the volume of water use associated with each block, and the prices to be charged within these blocks are variable depending on the objectives of the water managers. The IBR design has social implications, and regulators might be reluctant to limit the size of the initial block because of political pressures (Boland & Whittington, 2000). Nevertheless, IBRs are by far the most common charges for water services (Martins & Fortunato, 2007).

Several studies have assessed the residential demand’s response to critical PLP in the electricity field (Herter et al., 2007; Pflug & Broussev, 2009; Zöttl, 2010); however, very few studies have focused on PLP under the urban water demand framework. The majority of these studies estimated the seasonal residential water demand (Lyman, 1992; Renzetti, 1992; Reynaud, 2008) and concluded that peak-load water pricing might be an effective tool to manage the water demand. Similarly, Reynaud (2008) demonstrated that it is always possible to find a suitable water price, for instance by moving from a single price for peak and off-peak periods towards seasonally differentiated rates, resulting in an increase in the aggregate consumer surplus and a decrease in the aggregate water consumption.

Against this background, it has been illustrated that PLP can be used in combination with IBRs to design water rates for seasonal water demand in water-scarce regions. The two main objectives of the proposed water rate are full cost recovery of the water services, including environmental and resource costs, and reduced water consumption during the peak period.

3. Proposed water rate

Most water tariffs integrate two components: a fixed component and a variable component based on the volume of water consumed. In this study, we propose a water rate that serves to integrate the effects of the seasonal water demand into the tariff. Hence, we focus on the variable component of the tariff.
From the water utility point of view, fulfilment of the full cost recovery criterion requires that the income gained from selling the water is equal to or higher than the treatment and supply costs for a one-year time period, that is, including both the peak and the off-peak period.

No water transport system is without a certain number of loss points due to leakage. These losses assume that not all of the water initially delivered and treated by each water source arrives at households, and therefore is metered and paid for. In other words, water losses are to be blamed for important revenue reductions for the water utilities involved (Kanakoudis et al., 2013). Losses should therefore be integrated into the variable charge by defining the parameter efficiency ($E_z$) of each water source. This represents the percentage of treated water that arrives at each household, that is, the difference between the treated water and the water lost in the water supply networks.

The total cost of supplying water is estimated using the quantity of water treated ($V_i/E_z$) as a variable, and the income is calculated based on the quantity of water that is metered ($V_i$) as a variable (see Equations (1) and (2)).

The annual income is estimated considering the volumetric charge for water in the off-peak period ($\beta$) and the peak period ($\alpha$) and the water volume sold in each period as follows (Equation (1)):

$$I = \beta \sum_{i=1}^{j} V_i + \alpha \sum_{i=1}^{12-j} V_i$$

where $I$ is the total income in €/year; $V_i$ is the volume of water sold monthly (m$^3$/month); $\beta$ is the volumetric charge in the off-peak period (€/m$^3$); $\alpha$ is the volumetric charge in the peak period (€/m$^3$); and card($j$) is the number of months of the water off-peak period.

Regarding costs, the fixed and variable costs of all the available water sources must be considered. In this context, conventional and non-conventional water sources can be used as urban water resources. Conventional water sources involve surface ($S$) and groundwater ($G$). Non-conventional water sources include desalinated ($D$) and reclaimed water ($R$). A third potential source of water comes from inter-basin water transfers ($T$).

The total annual cost of treating and supplying urban water can be expressed as follows (Equation (2)):

$$C = \sum_z FC_z + \sum_{i=1}^{12} \sum_z V_{iz} \cdot E_z \cdot VC_{iz}$$

where $C$ is the total cost of treatment and water supply in €/year; $FC_z$ is the fixed cost of each water source (€/year); $V_{iz}$ is the water volume sold monthly (m$^3$/month) for each water source; $E_z$ is the efficiency of the water distribution network for each water source; $VC_{iz}$ is the variable cost of each water source, which also varies depending on the month, since water treatment is affected by economies of scale (€/m$^3$); and $z = S \cup G \cup D \cup R \cup T$.

1 The water supply efficiency from the storage tank (after the treatment) to households does not depend on the source of the water. However, the efficiency from the origin of the water to the water treatment plant depends on the source of the water. Hence, a different value of efficiency must be considered for each water source.
The total amount of water sold must be higher than or equal to the total water delivered, that is, the following constraint should be considered (Equation (3)):

\[
\sum_{i=1}^{12} V_i \leq \sum_{i=1}^{12} \sum_{z} \frac{V_{iz}}{E_z}
\] (3)

Taking into account the total income \((I)\) and total costs \((C)\), the relationship between the peak \((\alpha)\) and the off-peak \((\beta)\) variable charge can be estimated as follows (Equation (4)):

\[
\alpha = \frac{\sum_{z} FC_z + \sum_{i=1}^{12} \sum_{z} (V_{iz}/E_z) \cdot VC_{iz} - \beta \sum_{i=1}^{12-j} V_i}{\sum_{i=1}^{12-j} V_i}
\] (4)

Once the variable charge for water during the off-peak period \((\beta)\) has been defined by the water supply managers, based on several criteria, such as equity or affordability, Equation (4) establishes the charge for the peak period \((\alpha)\), which recovers the full water treatment and supply costs. If the primary goal of the PLP mechanism is to reduce the peak-period water consumption, the procedure will be the opposite, that is, pre-established water demand price elasticity during the peak period, and, based on the desired water consumption reduction, the peak variable charge \((\alpha)\), as defined by the water managers, and the off-peak variable charge \((\beta)\) can be estimated through Equation (5). It is clear that the principle of full cost recovery remains fulfilled:

\[
\beta = \frac{\sum_{z} FC_z + \sum_{i=1}^{12} \sum_{z} (V_{iz}/E_z) \cdot VC_{iz} - \alpha \sum_{i=1}^{12-j} V_i}{\sum_{i=1}^{12-j} V_i}
\] (5)

Provided with a value of \(\beta\), \(\alpha\) is the minimum variable charge that must be applied in the peak period for full cost recovery of water treatment and supply. However, under the WFD, the cost recovery principle goes further and requires that the prices paid by users also cover the environmental and resource costs. The first cost refers to ecosystem damage, since obtaining water for humans involves reductions in water body levels, which may harm ecosystems. The latter costs are especially important in water-scarce areas; when a water resource is partly or fully depleted, there is less water available for other users (WISE, 2008).

The minimum variable rate charged in the peak \((\alpha)\) and off-peak \((\beta)\) periods (Equations (4) and (5)) should be increased by an extra factor \((\gamma\) and \(\rho\), respectively), which reflects the environmental and resource costs of the water delivered to the urban municipality. The values of \(\gamma\) and \(\rho\) should be variable depending on the hydrological status of the water body where the urban area is located and on the penalty assessed for excessive water use determined by water managers. Specifically, the following criteria should be considered to define \(\gamma\) and \(\rho\): (i) the water scarcity level in the region; (ii) the use of conventional and/or non-conventional water resources; and (iii) the quantity of energy required to treat and supply the water, depending on its source.

The volumetric charge has clearly shown that IBRs provide a good incentive to save water (Organisation for Economic Co-operation and Development (OECD), 1987); therefore, we propose to combine this strategy with the PLP described previously for recovering the full cost of water services, including
environmental and resource costs. Our proposal is as follows: the first block rate should ensure water treatment and supply cost recovery, that is, it should be $\beta$ in the off-peak period and $\alpha$ in the peak period. The rate of the following blocks should increase based on the environmental costs and the relative scarceness of water in each municipality. Hence, the water rates for the second and successive blocks in the off-peak period should be $\beta + K\rho$, and for the peak period they should be $\alpha + K\gamma$ ($K > 0$). The number of blocks should depend on the necessity to add extra penalties for excessive water consumption.

Graphically, the proposed variable rate for the off-peak and peak periods is represented as follows (Figure 1).

From a policy perspective, it should be noted that water pricing must reflect the true costs of water use including environmental and resource costs. Therefore, the proposed water rate will be very useful to policy makers and water regulators since it will allow the encouragement of economic efficiency and the environmental sustainability of water use. The combination of the PLP and IBR approaches is a good strategy to achieve full cost recovery of water services and environmental goals such as water conservation.

4. Case study

The study site selected to illustrate the utility of the proposed tariff is the city of Xàbia, which is a tourist municipality located on the Spanish Mediterranean coast (Figure 2). The permanent population in Xàbia is 32,983 inhabitants (2012 census), and 54.9% of the residents are non-Spanish. Tourism offered 12,722 beds in 2012 (Valencian Institute of Statistics, 2013), plus secondary owned households that are only occupied during holidays. In fact, the number of main households was 12,236, while there were 7,712 secondary households (ARGOS, 2013).

The strong tourist activity provides qualitative data to indicate marked seasonality in the urban water demand. Figure 3 shows the monthly water consumption in 2012 in Xàbia. Two water consumption periods, peak and off-peak, are clearly distinguishable. The peak water consumption period corresponds

![Graph](https://iwaponline.com/wp-content/uploads/2014/05/fig1.png)

Fig. 1. Variable rate for the off-peak and peak water demand periods in water-scarce regions.
approximately to the summer season (June–September) when the urban water demand is on average 15,638 m³/day. The off-peak period corresponds to the remainder of the year (October–May) and the urban water demand is on average 7,851 m³/day. The water demand during the peak period is just under double that in the off-peak period (Aguas Municipales de Jávea Sociedad Anónima (AMJASA), 2013a).

Two factors contribute to the seasonality of the urban water demand in the city of Xàbia. One is the larger amount of households and hotel accommodation occupied during the summer. It was verified that the water consumption per capita with full-time resident primary households remained almost constant, that is, the water consumption per capita did not increase in the summer season in primary households, but the number of households occupied in the summer increased. Second, greater water consumption
was confirmed for outdoor usage in the peak period in secondary housing; most residences were not flats but chalets with grass gardens and swimming pools.

In Xàbia, the city council provides urban water services under the company AMJASA which is publicly owned but receives an independent budget from the city council. Xàbia is located in a water-scarce area without important surface water bodies and reservoirs. Therefore, during the 1990s the only water source was groundwater. However, the increased water demand, primarily due to tourism, resulted in significant water deficits, water rationing, and loss of water reserves at the end of the 1990s. Therefore, in 2002, a water desalination plant with a capacity of 27,000 m$^3$/day was constructed and became fully operational. The total cost of the facility was €24 million, and it was financed without public subsidies. Consequently, water users pay for the facility through their water bills. Although Xàbia’s wastewater treatment plant treats approximately 5,000 m$^3$/day of wastewater, which might be recycled (following the implementation of tertiary treatment), currently, due to jurisdictional problems, the water cannot be supplied for urban non-potable water use (AMJASA, 2013b).

The current water tariff consists of two components, one fixed and the other volume-based. The first component is paid for by all households in each period (2 months), regardless of their water consumption level. This charge is linked to the household water meter gauge (see Table 1). The variable charge is an increasing blocks tariff, although every cubic metre is billed at the same rate as the last cubic metre consumed. The rate increases progressively, and in the fourth block it is 12.4 times higher than in the first block (Table 1). Consequently, most of the primary households maintain constant water consumption throughout the year and the household payment corresponds to the second block, that is, the household pays €0.63/m$^3$. However, the secondary households during the off-peak period pay the rate corresponding to the first block (€0.15/m$^3$), while in the peak period they pay the third and fourth blocks (€1.37 and 1.86/m$^3$, respectively) of water rates (AMJASA, 2013a). Moreover, each new water connection must provide a one-time fee, which has two components, a contribution to the desalination plant and a contribution to network renovations.

Currently, the volume rates are calculated based on the annual average cost of water treatment and supply. However, the fixed and variable costs of desalinated water are higher than those of groundwater. Therefore, the permanent population of Xàbia is paying for the construction and maintenance of a

Table 1. Xàbia’s water-pricing structure (2013).

<table>
<thead>
<tr>
<th>Fixed charge</th>
<th>Variable charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter’s gauge (mm)</td>
<td>Charge (£/bimonth)</td>
</tr>
<tr>
<td>&lt;= 13</td>
<td>20.53</td>
</tr>
<tr>
<td>&gt;13 ≤ 15</td>
<td>27.34</td>
</tr>
<tr>
<td>&gt;15 ≤ 20</td>
<td>48.60</td>
</tr>
<tr>
<td>&gt;20 ≤ 25</td>
<td>75.93</td>
</tr>
<tr>
<td>&gt;25 ≤ 30</td>
<td>109.39</td>
</tr>
<tr>
<td>&gt;30 ≤ 40</td>
<td>194.39</td>
</tr>
<tr>
<td>&gt;40 ≤ 50</td>
<td>303.73</td>
</tr>
<tr>
<td>&gt;50 ≤ 60</td>
<td>476.39</td>
</tr>
<tr>
<td>&gt;60 ≤ 65</td>
<td>513.33</td>
</tr>
<tr>
<td>&gt;65 ≤ 80</td>
<td>777.58</td>
</tr>
<tr>
<td>&gt;80 ≤ 100</td>
<td>1,214.97</td>
</tr>
</tbody>
</table>

Source: AMJASA (2013b).
facility (desalination plant) that would not be necessary if the seasonal population associated with tourism and secondary households were not so important. Therefore, to a large degree, the current water rates penalise the permanent population. Hence, the implementation of the PLP mechanism combined with the IBR structure proposed in Section 3 will serve to recover the full cost of water services as well as improving equity and reducing water consumption in the summer season.

Estimates of \( \alpha \) based on values of \( \beta \) (Equation (4)) for Xàbia municipality and integrating water sources as groundwater and desalinated water are expressed as follows (Equation (6)):

\[
\alpha = \frac{FC_G + FC_D + \sum_{i=1}^{12} (V_{iG}/E_{iG}) \cdot VC_{iG} + \sum_{i=1}^{12} (V_{iD}/E_{iD}) \cdot VC_{iD} - \beta \sum_{i=1}^{4} V_i}{\sum_{i=1}^{8} V_i}
\]  

Starting from a \( \beta \) value of €0.00/m\(^3\), and following successive increases of €0.05/m\(^3\), Figure 4 shows the volume rates of \( \alpha \) that should be applied in the peak period to recover water treatment and supply costs. As \( \beta \) increases, the \( \alpha \) value clearly decreases, until reaching the value of €0.56/m\(^3\), where \( \beta \) and \( \alpha \) are equal, that is, the volume rate in the off-peak period is equal to the volume rate in the peak water demand period. Comparing these results with the current water rate paid by most of the main households (€0.63/m\(^3\)), it is illustrated that the permanent Xàbia population is paying for part of the higher water costs during the summer season.

If the primary objective of the PLP strategy is to reduce the water consumption during the peak period, the opposite approach should be followed, that is, knowing the water elasticity price demand during the peak period and considering the desired reduction in water consumption, estimate the value of \( \alpha \), and once it has been defined, the variable rate for the off-peak period (\( \beta \)) can be estimated using Equation (7). Previous studies (AMJASA, 2013a) have calculated that the water price elasticity demand for outdoor usage in Xàbia is approximately \(-0.6\). The water elasticity price demand is subject to a certain degree of uncertainty; therefore, to overcome this limitation, a sensitivity analysis was performed. Hence, to estimate \( \alpha \) and \( \beta \), not just the elasticity value of \(-0.6\) was used, but also the values of \(-0.5\) and \(-0.7\). The use of three different values of water elasticity price demand instead of a specific value allows us to narrow the uncertainty and make more reliable estimations of \( \alpha \) and \( \beta \). Based on these elasticity values, Table 2 provides the volume rates for the peak and off-peak periods required to achieve

![Fig. 4. Variable rates in the peak period \( \alpha \) depending on the variable rate in the off-peak period \( \beta \) expressed in €/m\(^3\).](https://iwaponline.com/wp/article-pdf/16/5/930/405425/930.pdf)
several decreases in water consumption. For example, for an elasticity of $-0.6$, doubling the water variable rate during the peak period can result in approximately a 20% water consumption decrease and a simultaneous marked reduction in the volume rate during the off-peak period:

$$\beta = \frac{FC_G + FC_D + \sum_{i=1}^{12} (V_iG/E_iG) \cdot VC_{iG} + \sum_{i=1}^{12} (V_iD/E_iD) \cdot VC_{iD} - \alpha \sum_{i=1}^{8} V_i}{\sum_{i=1}^{4} V_i}$$

(7)

Once the rates of the first block have been calculated, the next step is to estimate the parameters $\rho$ and $\gamma$ for the off-peak and peak periods, respectively. In doing so, the water managers in Xàbia should consider two factors. First, during the peak period, the daily volume of desalinated water is approximately three times higher than during the off-peak period. The second factor is related to energy consumption, and consequently greenhouse gas (GHG) emissions, which for each cubic metre of water supplied from desalination plants are approximately double those from groundwater sources (AMJASA, 2013a).

An interesting approach to define the values of $\rho$ and $\gamma$ might be to estimate CO$_2$ and other GHG prices. Although Ha Duong (2009) demonstrated that different concepts of CO$_2$ prices vary based on the methodology, shadow pricing for these pollutants is a viable proxy to obtain a first order of magnitude increase in water rates to account for the environmental and resource costs. Similarly, and based on the output distance and revenue functions, previous studies have calculated CO$_2$ shadow prices. For example, Gupta (2005) identified the mean value of CO$_2$ emission costs as between €57.39 and €80.70/tonne, and Harkness (2006) calculated these costs as €30.25/tonne. More recently, Berre et al. (2013), using an activity analysis framework and data envelopment analysis approach, estimated GHG shadow prices according to farmers’ and society’s point of view. The results indicated that the GHG shadow price according to society opinion was 40.86% of the desirable output price. Following this approach, and using the values of $\beta$ and $\alpha$ as a proxy for the price of the desirable output, the parameters $\rho$ and $\gamma$ were estimated. As for the estimation of $\alpha$ and $\beta$, three water elasticity prices were used, as shown in Table 3.

### Table 3. Variable water rates for peak ($\alpha$) and off-peak ($\beta$) periods expressed in €/m$^3$ depending on the reduction in water consumption during the peak period for three water elasticity price values.

<table>
<thead>
<tr>
<th>Reduction in water consumption (%)</th>
<th>Elasticity price $-0.5$</th>
<th>Elasticity price $-0.6$</th>
<th>Elasticity price $-0.7$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha$ (€/m$^3$)</td>
<td>$\beta$ (€/m$^3$)</td>
<td>$\alpha$ (€/m$^3$)</td>
</tr>
<tr>
<td>3</td>
<td>0.620</td>
<td>0.500</td>
<td>0.610</td>
</tr>
<tr>
<td>5</td>
<td>0.660</td>
<td>0.460</td>
<td>0.643</td>
</tr>
<tr>
<td>7</td>
<td>0.700</td>
<td>0.420</td>
<td>0.677</td>
</tr>
<tr>
<td>9</td>
<td>0.740</td>
<td>0.380</td>
<td>0.710</td>
</tr>
<tr>
<td>11</td>
<td>0.780</td>
<td>0.340</td>
<td>0.743</td>
</tr>
<tr>
<td>13</td>
<td>0.820</td>
<td>0.300</td>
<td>0.777</td>
</tr>
<tr>
<td>15</td>
<td>0.860</td>
<td>0.260</td>
<td>0.810</td>
</tr>
<tr>
<td>17</td>
<td>0.900</td>
<td>0.220</td>
<td>0.843</td>
</tr>
<tr>
<td>19</td>
<td>0.940</td>
<td>0.180</td>
<td>0.877</td>
</tr>
<tr>
<td>21</td>
<td>0.980</td>
<td>0.140</td>
<td>0.910</td>
</tr>
<tr>
<td>23</td>
<td>1.020</td>
<td>0.100</td>
<td>0.943</td>
</tr>
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</table>
From a policy point of view, it should be highlighted that in water-scarce areas, water-saving policies should be on the agenda as a priority aiming to improve the sustainability of the urban water cycle and to ensure the minimisation of the water supply costs. As the empirical application has illustrated, the proposed water rate is a useful demand management policy. Its implementation would involve a decrease in the consumption of water during the peak period, as shown in Table 2. Moreover, the resource and environmental costs would be integrated into the water bill (Table 3), contributing to educating citizens about the true value of such a scarce resource as water.

As the water demand grows, there is an evident need to manage water systems better. In the context of the WFD, whereby the full cost of water services must be recovered, responsible water consumption becomes a key element. The combination of the PLP and IBR strategies in a water rate would contribute to achieving this goal, as has been verified through the empirical application developed.

It should be remarked that to implement the proposed water rate successfully, some conditions should be met: (i) policy makers and politicians should be committed to the aim of improving the sustainability of the urban water cycle; (ii) water users should be aware of the true cost of the water supply; and (iii) all the revenues of the water tariff must be allocated to the recovery of the cost of the water supply. This last condition may seem irrelevant; however, Cabrera et al. (2009) pointed out that in Spain part of the water tariffs finance other projects, even though water is subsidised and not all the costs are recovered.

From a social point of view, the implementation of a PLP strategy would contribute to avoiding the permanent population of an urban area having to pay extra for the water supply motivated by the increase of the population during the dry season. Moreover, the non-resident people are those with the largest water consumption per capita. In other words, the modification of the current water rate scheme will create incentives for those who generate the greatest external cost to reduce their water use.

### 5. Conclusions

In order to incorporate seasonality into urban water pricing, we propose a water tariff based on the PLP and IBR strategies. Consequently, the criteria of efficiency, full cost recovery (including
environmental and resource costs), and simplicity are achieved. Our study examined a variable tariff charge. The first tariff block, $b$ and $a$ representing the off-peak and peak periods respectively, allows full cost recovery of the treatment and supply of urban water. The charges determined for each block include the environmental and resource costs, and the appropriate values should be assigned by water managers, depending on the specific environmental features of the region, as well as extra penalties for excessive water consumption, as necessary.

The proposed rates are useful for municipalities with high seasonality in water use and where water is scarce. This strategy results in recovering the financial costs of water services as well as the environmental and resource costs. This dynamic water rate proposal is characterised by the following merits: (i) it ensures full cost recovery of water services, including environmental and resource costs; (ii) it provides incentives for efficient water use and water conservation; (iii) it allocates costs between users, depending on their consumption, which serves to improve equity; and (iv) it incorporates the costs of seasonal water demand in water-scarce regions.

The empirical application developed for a Spanish municipality with strong seasonal water demands verified the utility of this proposed water rate strategy. It was previously confirmed that the municipality required an improvement in the water rates, and our objective was to achieve equilibrium between full cost recovery, equity, and efficiency criteria.

In conclusion, the combination of PLP and IBR approaches is a useful water-pricing strategy to increase the sustainability of the urban water supply, since it contributes unequivocally to water demand management improvement and full cost recovery of urban water services.

Acknowledgements

The author wishes to acknowledge the assistance from the Aguas Municipales de Jávea Sociedad Anónima-AMJASA and the financial aid received from the European Commission through the project (LIFE 10 ENV/ES 000520) and from the Generalitat Valenciana government (APOSTD/2013/110). She would like also to thank two anonymous referees for their valuable comments and suggestions.

References


Received 11 November 2013; accepted in revised form 19 February 2014. Available online 27 March 2014