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Water scarcity and affordability in urban water pricing: A case study of Chile

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ABSTRACT

Water demand management is one of the main issues in the water policy agenda. The objective of this work is to design a water rate model that internalizes the scarcity value of water and at the same time improves social concerns such as equity and affordability. The proposed water rate focuses on the variable component of the tariff and follows an increasing block strategy. An empirical application is developed for two Chilean regions. This application illustrates that the implementation of the proposed water rate creates incentives to improve water use sustainability and equity among users.

1. Introduction

At present, several factors such as population growth, rapid urbanization, higher water contamination and pollution, and increased water demands due to increased economic growth are putting considerable pressure on available water resources. With increasing water scarcity and decreasing supply augmentation options, water managers and policy makers worldwide are turning to water demand management solutions (Saleth and Dinar, 2000). Water demand management is now one of the main issues in the water policy agenda (Franceys and Gerlach, 2011).

Under this scenario, economic policy instruments have received widespread attention over the last three decades, and have increasingly been implemented to achieve environmental policy objectives. Water pricing is one of various economic policy instruments that could be used to affect the environmentally, socially, and economically efficient use of water (Dinar et al., 2015). A water tariff can take many different forms. Each form or design addresses a specific objective. In general, the main objectives pursued by water tariffs are (1) economic efficiency, (2) water conservation incentives, (3) equity, and (4) affordability (Grafton et al., 2015).

Numerous studies addressing urban water-pricing topics have been conducted (e.g. Barbosa and Brusca, 2015; Chun, 2014; Farolfi and Gallego-Ayala, 2014; Sibly and Tooth, 2014; Guerrini and Romano, 2013; Olmstead and Stavins, 2009; Letsoalo et al., 2007). From a policy perspective, the European Union Water Framework Directive promoted taxing water users in a way that reflects the scarcity value of water. Additionally, several countries have revised their water pricing policies in such a way so as to help manage reduced water supplies. For example, the prices of water in Israel reflect the true scarcity value of the resource (Becker, 2015). In Mexico, water users have faced different water tariffs depending on their geographical situation in order to reflect relative water scarcity (Guerrero-Garcia-Rojas et al., 2015). Thus, water pricing is an important means to reduce water consumption (Dalhuisen et al., 2003). However, the effectiveness of these water pricing policies depends on the type of tariff and its value (Beecher and Kalmbach, 2013).

Most metered water tariffs include a combination of fixed and uniform volumetric variable charges (Molinos-Senante, 2014).

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Several OECD countries, for example Australia, Austria, Denmark, Finland and the United Kingdom, with successful water pricing schemes use a two-part tariff structure. This form of water tariff has fixed and variable elements. In countries that apply this two-part tariff, the fixed element varies according to some characteristic of the user, and the variable element often uses average cost pricing. Rogers et al. (2002) points out that one of the main advantages of the two-part tariff system is the stabilized revenue base it affords the supplier.

An important issue when setting water tariffs as a demand management economic policy instrument is equity. Affordability and water poverty are a real issue in several countries since a lack of access to improved water and sanitation services (WSS) has significant impacts. Basically, the different types of policies that have been applied to insure affordability can be classified as (i) income-support policies and (ii) tariff related policies (OECD, 2003). An example of income-support programs is the provision of subsidies directly to the most vulnerable households; such as the Chilean case (Donoso, 2015). On the other hand, Spain applied tariff related policies, in order to ensure affordability and equity, by applying discounts to water tariffs to low income families (Calatrava et al., 2015). However, in several cases, tariff related policies to insure affordability have led to a tariff structure that does not satisfy economic efficiency or generates water conservation incentives.

Thus, policy makers face the challenge of setting water tariffs which deal with multiple objectives such as increasing water use efficiency, ensuring equity and affordability and improving water conservation mainly in water-scarce regions. Moreover, although the tariff setting procedure is generaly regulated by a local or national regulator, it also faces several challenges. Thus, usually regulation focuses on the overall annual revenue but it does not address the issue of tariffs structure. Indeed, water sector worldwide has the tendency to be guided by the subsidiarity principle (Pinto and Marques, 2015a). It should be noted that there are several water tariff structures such as uniform volumetric variable charge (UVC), increasing block tariff (IBT), decreasing block tariff, increasing rate tariff, seasonal tariff, time of use tariff and spatial tariff. All of them have strengths and weaknesses. Hence, the selection of a tariff structure presents a major challenge since it is responsive to the philosophy and objectives of the water company, the regulator and the citizens (Pinto and Marques, 2015b).

In this context, the objective of this study is to design a water rate model that internalizes the scarcity value of water, and at the same time is considered fair and equitable by end users. Moreover, it would improve water use sustainability, since by integrating the water scarcity value, consumers face a higher tariff in areas characterized by higher water scarceness incentivizing them to reduce their water consumption. In order to illustrate the usefulness of the proposed water rate, an empirical application is developed for two regions in Chile with different characteristics: (i) the Atacama region which is an extremely arid area and; (ii) the Aysén region which has abundant water resources.

Currently, in Chile as in many countries the volumetric water charge is uniform. While this water rate structure presents some advantages, it does not directly integrate the value of the water resource. Hence, the water rate proposed involves replacing the UVC by an IBT strategy. This IBT is designed so that large water consumers subsidize low water consumers that usually are low-income households. Although the case studies developed in this paper focused on two Chilean regions, the proposed water rate structure could be applied also in other countries which face water scarcity and present water affordability problems. In this context, in many countries, water is increasingly scarce and therefore, water companies and regulators have already implemented incentives to conserve water (Dinar et al., 2015). Regarding affordability, the social dimension of water sustainability is now on the political agenda in several countries (Barraqué and Montginoul, 2015). Hence, different supporting measures for the poorest families have been implemented.

From a policy perspective, the proposed water rate will be highly useful for authorities and water regulators. On the one hand, the unit water price for the second block involves a “penalization” for high water consumption. Since this block is set above average cost, it generates an additional revenue which finances the water supply subsidy cost to low-income households; hence, the proposed tariff does not place an additional burden on fiscal funds. On the other hand, the proposed water rate introduces a water scarcity factor allowing for the differentiation between regions according to their water scarcity problems. Areas characterized by higher water scarcity would present higher second block rates. This also generates extra revenue which we propose be destined to implement water conservation measures in water-scarce regions. This paper contributes to the current strand of literature by proposing a water rate model that internalizes the scarcity value of water and also improves equity. Unlike other water tariff structures, the one proposed in this paper is based on a cross-subsidy since high water users pay for low users who usually are low-income households.

Following this introduction, the paper is divided into five additional sections. Section 2 describes the basis of the proposed water rate. Section 3 describes the main features of the Chilean urban water and sanitation services. Section 4 presents the two case studies selected while Section 5 discusses the results for these two case studies. Finally, conclusions are presented in Section 6.

2. Water tariff system proposal

2.1. Historical and legal framework

Most metered water tariffs include a combination of fixed and variables charges (Molinos-Senante, 2014). However, taking into account that the objective of this study is to design a water rate that serves to integrate an environmental criteria (water scarcity) and to improve social concerns (equity and affordability) we focus on the variable component of the tariff. Moreover, the volumetric component provides consumers with some degree of flexibility in controlling their water bills, based on their consumption. Thus, water tariffs can play important roles in promoting behavioural changes and in improving affordability and access for the poor (Hoque and Wichelns, 2013).

It should be noted that our study does not focus on introducing new concepts and formulas to establish the variable tariff since in Chile this process is well established through the Executive Decree 453 of the 1998 Law N° 70 (see Section 3). We focus on designing a variable water rate strategy that improves the sustainability in the use of water.

UVC tariffs are widely implemented since they have the advantage of being easily understandable for consumers and it enables water utilities to perform straightforward calculation of water bills. Moreover, they can be as efficient as IBT obtaining revenues if the rate is fixed at an appropriate level (Whittington, 2011). However, it does not integrate the scarcity value of the water in the bill since the result of water waste in not directly communicated via a higher water bill. In this context, to increase water efficiency a clear economic signal must be sent to customers (Barr and Ash, 2015).

An alternative approach to the UVC is an IBT strategy. There are three main features of the IBT structure that support its implementation. First, an IBT is considered as a conservation-oriented rate design since it transmits water scarcity information to customers (Reynaud et al., 2005). Secondly, the IBT approach promotes

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equity by allowing for cross-subsidization between poor residential customers and wealthy households (Martins et al., 2013). In other words, an IBT approach promotes efficiency in the use of water and also equity since it is based on the idea that water wasters should pay and therefore, initial volumes would make water less expensive for the poor (World Bank, 2011). In third place, it can raise sufficient revenues to recover costs. Nevertheless, in practice, IBT sometimes fails to meet some of their objectives, in part because they tend to be poorly designed. Thus, many IBT do not recover the costs because the upper consumption blocks are not priced at sufficiently high levels and/or because the first consumption block is so large that almost all residential consumers only consume in that level (Whittington, 2011). Moreover, whenever the IBT is not well designed, it might penalize poor families with large households and/or shared connections, becoming a regressive tariff structure (Whittington, 2006).

In this context, an important issue in the design of an IBT is the definition of the first block (unit price and volume of water). Regarding the unit price of the water, according to Wichelns (2013) the consumption in the first pricing block should be subsidized while the volumetric rate in the second pricing block should be sufficient to cover the operational costs and subsidies provided to customers in the first block. With respect to the volume of water to be considered in the initial block, Ward and Pulido-Velazquez (2009) stressed that the first block should be set taking into account the water quantities that are required to meet household's basic needs. In this sense, Martins et al. (2013) defined the Essential Minimum Quantity (EMQ) as the water consumption needed to maintain acceptable or minimum living standards. The World Health Organization (Reed, 2005) specified that EMQ involves individual's indoor needs for "drinking, cooking, personal washing and washing clothes which is 40 L per person per day".

It is essential to consider the water utilities point of view in the design of the alternative water rate. Thus the revenue obtained by a water utility for the provision of drinking water with the proposed tariff must be equal to current revenues under UVC. Moreover, in many countries such as Chile, the central government has developed a system of subsidies aimed to the most vulnerable households (see Section 3) which covers a percentage of the water bill. This subsidy must also be considered in the proposed tariff structure.

2.2. Tariff system proposal

Taking into account the premises previously described, we propose a volumetric water rate based on an increasing block strategy which involves two blocks. The proposed water rate is based on the following idea:

$$R_{FB} + R_{SB} = CR_{UR} + ER_s + ER_{WS} \quad (2)$$

where R_{FB} and R_{SB} represent total perceived revenue from the first and second block, respectively, CR_{UR} is the current revenue received under the uniform rate tariff structure, ER_s represents the required extra revenue to cover subsidy costs, and ER_{WS} is the additional revenue due to the increased tariff to signal water scarcity. That is, total revenue obtained with the proposed water rate (first and second block) must be equal to the current income that a water utility perceives plus an additional income to pay the subsidy to low-income households. In regions with water scarcity problems, an additional income must be obtained to implement a program of measures for water resource conservation. The proposed water rate would allow the water utility to obtain the same income that it currently perceives and therefore, its financial sustainability is not compromised. Moreover, the subsidies to the basic water supply services would no longer be paid by the central government but by the largest water users, reducing fiscal pressures. This cross-subsidization significantly improves the equity of the water tariff. At the same time, the central government has additional available economic resources for other national needs. Finally, the income generated by the water scarcity factor would allow the water tariff to reflect the true value of the water, which is an essential issue to be sustainable in water scarce regions.

Subsequently, the components of Eq. (2) are defined in order to establish the unit price of the water for each block.

Revenue from the first block:

$$R_{FB} = V_{FB} * 0.15 * T_o * TH \quad (3)$$

where: V_{FB} is the upper limit of water volume in the first block (m^3/month/household); T_o is the current uniform water price (\$/m^3) and; TH is the total number of households. The current water price (T_o) has been multiplied by 0.15 since the current system of subsidies in Chile covers up to 85% of the water bill.[1] Thus, compared with the current price of the water, the proposed price for the first block considers a subsidy of water consumption. As is shown in Eq. (4), the V_{FB} should be defined based on the EMQ concept proposed by Martins et al. (2013) which is 0.04 m3/day/person. It should be noted that the value proposed by Martins et al. (2013) has been modified by multiplying the average household size (AHS) by 1.5 since the size of low-income households is usually on average 50% larger than the average household of the region. The idea behind this approach is not to penalize the households that are larger than the average. Thus:

$$V_{FB} = 0.04 * 1.5 * AHS * 30\ days \quad (4)$$

Revenue from the second block:

$$R_{SB} = (V_T - V_{FB}) * T_2 * HWOS \quad (5)$$

where: V_T is the total volume of water consumed (m^3/month/household); T_2 is the unit water price in the second block (\$/m^3) and $HWOS$ is the number of households without subsidy to water supply bill.

Current revenue:

$$CR_{UR} = V_T * T_o * TH \quad (6)$$

Extra revenue to pay subsidies:

$$ER_S = V_{FB} * 0.85 * T_o * HWS \quad (7)$$

where: HWS is the number of households with subsidy of their water supply bill.

Extra revenue associated to water scarcity:

$$ER_{WS} = (V_T - V_{FB}) * T_2 * HWOS * SF \quad (8)$$

where: SF is a scarcity factor. It is the variable introduced in the water tariff proposed to reflect the scarcity value of water. This factor thus is variable depending on the water availability of each region. In particular, it varies between 0 and 1. A scarcity value of 0 means that there is no water scarcity and therefore, the water utility should not obtain any income for this item, since there would be no need for scarcity signalling. A value of 1 is associated with large water scarcity problems. Hence, it is necessary to increase

[1] Highly vulnerable households receive a subsidy that covers a 100% of their water bill up to an established limit. The difference (85%) would continue to be funded by fiscal funds. The implementation of the proposed water rate in other countries should adjust this figure to its subsidy system.

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water tariffs in the second block so as to incentivize consumers to conserve water. This increased tariff generates additional revenues, which the operator must invest in order to implement a program for the adoption of water conservation measures and to develop environmental education campaigns.

All parameters of Eqs. (3)–(8) are known except T_2 and thus using Eq. (2), T_2 can be easily determined.

In the case of Chile, the proposed water rate satisfies the principles of i) economic efficiency, ii) water conservation incentives, iii) equity, and (v) affordability, established in the Tariff Law - D.F.L. MOP N°. 70/88 and the Rates Regulation Act - S.D. MINECON 453/89. Thus its potential implementation would not require major legal reforms. It would also be applicable to other countries which face varying degrees of water scarcity, where it is a priority to incentivize water conservation in more arid geographic areas. In the following sections an empirical case is developed for two urban settings in an arid area and a water abundant area.

3. Chilean urban water and sanitation sector

Chile is a middle income country that has implemented significant reforms to improve WSS. In 1990, the Chilean Government created the water and sewerage industry regulator, the "Superintendencia de Servicios Sanitarios" (SISS). In 1998, the Chilean Government adopted Law 19549, which significantly modified the Chilean legal framework for WSS. This legislation was the main driver to transfer the ownership operation of Chilean WSS operators from the public to the private sector through concessions. As a result, currently, 96% of customers are supplied by private water companies. In particular, there are 53 water and sewerage companies that provide WSS to 16 million of people in 364 cities (SISS, 2014). They function as private companies, although the state investment company, ECONSSA, still owns a considerable number of shares in most companies (Hearne and Donoso, 2005). Five of Chile's 13 regional water companies were fully privatized with partial sale to multinationals in 1998.

The Chilean water industry is characterized by: (i) separating the role of the regulatory agency from the service provider; (ii) establishing efficient tariffs that allow operators to finance operation, investment requirements, and obtain a minimum return on their investments; and (iii) establishing a subsidy to insure affordability for low-income families. In addition, Decree 1199–2005 of the Ministry of Public Works (*Ministerio de Obras Públicas,* MOP) establishes the WSS concession regulations and quality of service standards for WSS operators (Molinos-Senante et al., 2015).

Under this legal framework, the WSS concession grants an exclusive provision of water and sanitation services right to an operator in a given urban area. The concession holder is obliged to satisfy water quality standards, conform to the tariff regime, and implement the required investment plans so as to insure a continuous water supply. This investment plan establishes the infrastructure requirements in order to meet increasing water demand ensuring supply continuity and quality of service. Should the WSS provider not satisfy these requirements, they lose the WSS concession.

On the other hand, the state's role is to monitor and regulate both public and private WSS operators. The Chilean WSS regulatory agency, the SISS, (i) grants WSS concessions; (ii) monitors the compliance of the development plan established by the operator and accepted by the SISS; (iii) sets efficient tariffs that ensures full cost recovery; and (iv) monitors the continuity and quality of the water and sanitation provision service. In addition, the SISS applies fines to those operators which present quality of service deficiencies, discontinuities in water provision, damage to water supply networks, violations that endanger people's health, and non-compliance with the mutually agreed development plan (Molinos-Senante and Sala-Garrido, 2015). It should be noted that the different regulation models involve diverse incentives to water companies to improve the quality of service (Simoes and Marques, 2012).

The objectives are Chilean tariff model are to:

1. Finance the WSS operator's operating costs and maintenance and investment requirements so as to insure continuity of water supply and quality service;
2. Finance a minimum agreed operational margin that covers the private operator's capital opportunity cost;
3. Incentivize efficiency gains in the provision of WSS services;
4. Transmit efficiency gains to customers through tariff reductions; and
5. Provide water value signals so that consumers internalize the scarcity value of water in their region.

Under this framework, WSS provider's tariffs are based on a two part tariff, a variable tariff ($\$/m^3$) and a fixed tariff ($). The Executive Decree 453 of the 1988 Law N° 70, of the MOP establishes a variable tariff which is set for periods of high demand, during summer months, (peak variable tariff $\$/m^3$) and for non-peak periods (non-peak variable tariff $\$/m^3$). The peak and non-peak tariffs are considered so as to internalize changes in seasonal demand and thus cover differences in the provision costs of the service. The fixed charge per customer (connection), is a function of the connection diameter and metering costs.

The affordability criteria is met by the provision of subsidies directly to the most vulnerable households. Households are classified based on an annual survey (*Encuesta Casen*) which estimates household per capita income. In order to qualify for the subsidy, households must not have payment arrears with the service provider. The central government transfers the block subsidy to the municipalities; the latter use this to pay a share of each of the eligible household's water bill; the payment share ranges from 15 to 85 per cent of the water bill, with the poorest families getting the highest share. The subsidy covers a consumption of up to 15 m^3/month. The Social Development Ministry (*Ministerio de Desarrollo Social,* MDS) uses the household survey information for each Region of Chile to determine the size the block subsidy that needs to be transferred to the municipalities. The WSS providers bill the benefiting households for the net of subsidy amount, but indicating the full consumption cost, and then charge the municipality for the subsidies granted.[2] The municipality will be charged interest for late payment, and the WSS provider can discontinue service to benefiting households if there is non-payment by the municipality. In 2011, 15% of WSS provider customers were benefited (6% of total sales), at a cost of US$80 million, and an average monthly subsidy per household of US$10.

Fig. 1 shows that water tariffs have sent the right signals to consumers so as to conserve water, since average monthly customer consumption has fallen since 1998 from approximately 25 m^3/customer/month to 18.6 m^3/customer/month in 2014. There are also other factors that have contributed to reduce water consumption per capita such as the severe drought that Chile is suffering since 2007 and also the notable information campaigns about water conservation practices carried out by the largest water companies and overall by the national regulator (SISS, 2014).

The Tariff Law - D.F.L. MOP N°. 70/88 and the Rates Regulation Act - S.D. MINECON 453/89 establish the water tariff setting

[2] This practice does not distort the price signals.

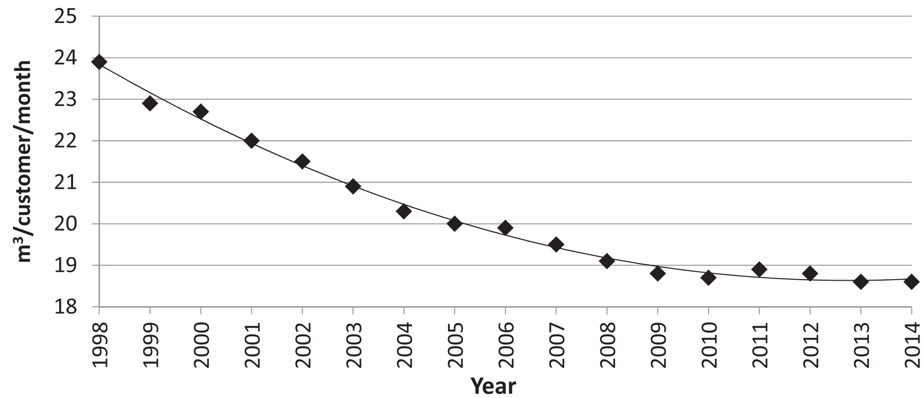

Fig. 1. Average monthly household water consumption (m^3/customer/month).
Source: SISS (2014).

procedure. The SISS prepares terms of reference (ToR) for the tariff studies which will be conducted by the water supply operator as well as the SISS. The results of each study are exchanged by both parties and an agreement on water tariffs is negotiated. If an agreement is reached the tariffs are set in a Decree signed by the Minister of Economy and ratified by the Nation's Comptroller. If no agreement is reached, an expert committee reviews both studies and determines the final water tariff; the expert committee's decision cannot be appealed by any of the parties. The water tariff set by the expert committee is expressed in the final water tariff decree. Fig. 2 summarizes this water tariff setting procedure.

In order to estimate the variable charge, the Chilean tariff law introduced the concept of a model of an efficient WSS operator. This model operator is designed such that it is a technically and economically[3] efficient provider. The final model WSS operator considers the rules and regulations in force and the geographic, demographic and technological constraints which frames their

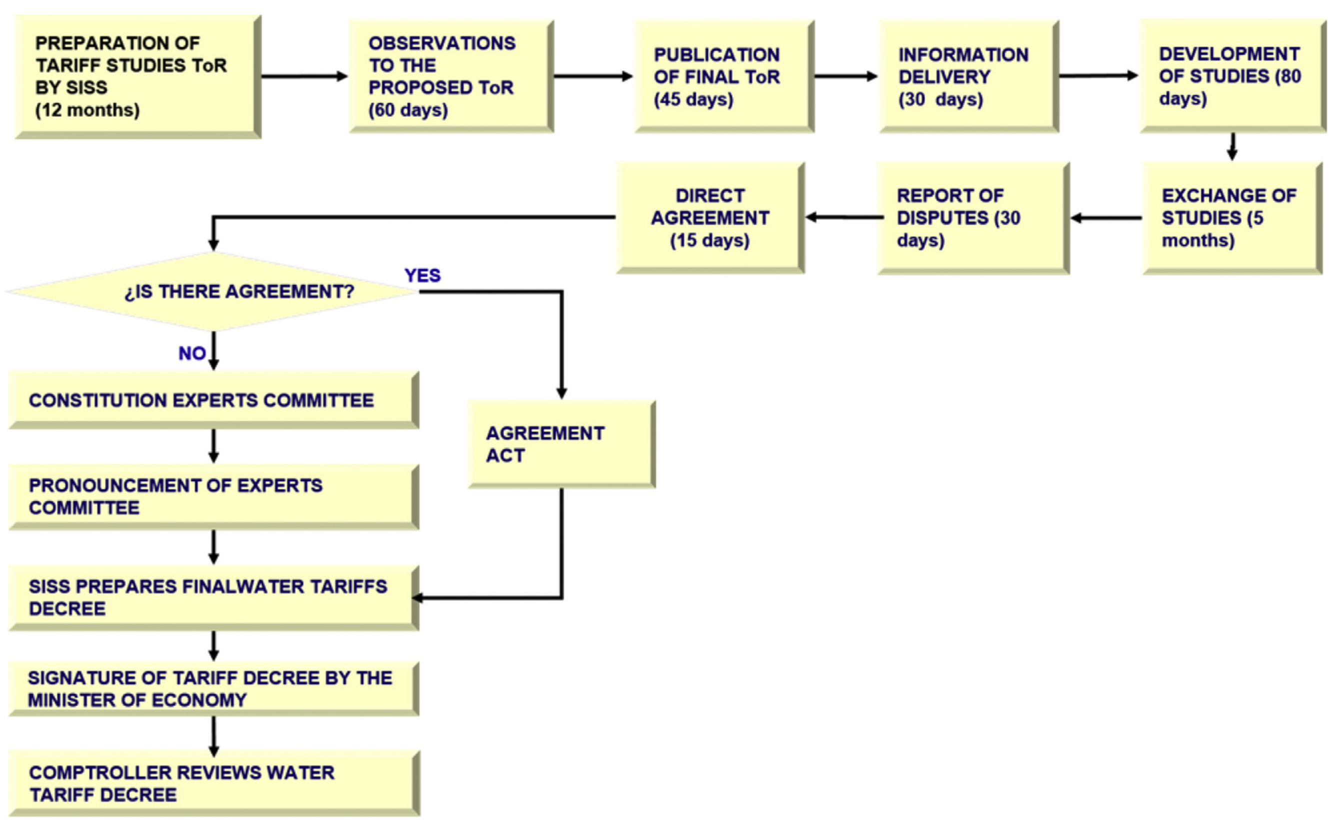

Fig. 2. Water tariff setting procedure.
Source: SISS (2015).

[3] Economic efficiency in this case implies minimum operating costs. The model operator considers the use of the best available technology so as to insure minimum service costs.

operation. Each WSS operator's model essentially considers (i) an institutional and administrative framework which takes into account the various functions it must implement, and (ii) a physical and technical system definition for each stage of water and sanitation provision (water production, distribution, collection and treatment). Setting tariffs based on this model operator insures that consumers do not pay for the inefficiencies of the real WSS operator. Additionally, the tariffs acts as an incentive for the operators to increase efficiency so as to obtain higher revenues.

Water tariffs are set so as to cover investment and operating costs as well as to collect the funds to cover the minimum guaranteed returns. Formally the tariff (τ) is such that:

$$\tau = \frac{AI + OC + MR + T}{C} \tag{9}$$

where *AI* represents the annualized value of the required investments by the model operator,[4] *OC* is the annual operating and maintenance costs, *MR* is the minimum guaranteed returns,[5] *T* are the taxes that the operator must pay, and *C* represents the total annual projected water consumption for the next 5 years in the concession area. One of the investment costs considered in the calculation of the *AI* is the market value of the necessary water rights. Thus, water tariffs should reflect the scarcity value of water.

The variable tariff should be consistent with the first best solution where marginal benefits are equal to long-run marginal costs.[6] However, the determination of the relevant marginal costs in the WSS sector needs to take into account economies of scale and indivisibility of investments, and given that cost functions are noncontinuous, the strict definition of marginal costs are not applicable. Thus, alternative formulas are used to reasonably approximate long run marginal costs. The Executive Decree 453 of the 1988 Law N° 70, of the MOP establishes that long run marginal costs will be approximated by the incremental development cost (IDC). The IDC is the value that applied to the incremental forecasted demand, for a horizon of 15 years, generates the necessary revenues, so as to cover incremental operation efficient costs and the required investments associated to an optimized expansion project of the WSS firm. The incremental development cost is determined such that the net present value of the optimized expansion project is equal to zero (D.F.L. No 70/1988). Finally, since tariffs set at marginal costs does not guarantee WSS operator returns, tariffs are adjusted according to total long term average costs of providing the WSS service.

4. Case studies

Chile's unique geography provides a variety of climatic conditions which involves that precipitation ranges from near zero in the north to an annual 2000 mm in the south (Hearne and Donoso, 2005).

Moreover, as can be seen in Fig. 3, there exists significant regional differences in water availability per person: from Santiago to the north, water availability is below 1000 m^3/person/year, while south of Santiago water availability is much larger reaching over 10,000 m^3/person/year (World Bank, 2011).

According to this unequal distribution of water resources, we have selected two Chilean regions as case studies. The first one is the Atacama region which is located in the north of Chile with an area of 75,176 Km^2 and a population of 254,336 inhabitants. The second selected region as case study is the Aysén region which is located in the south of the country. Its area is 108,494 Km^2 and its population is 91,492 people (SUBDERE, 2015).

As it is illustrated in Fig. 3, the Atacama region belongs to the dry pacific system with 208 m^3/year of water available per person. On the other hand, the region of Aysén belongs to the south pacific system and its availability of water is the largest of the country, 2,993,585 m^3/person/year. However and surprisingly, this divergence in the availability of water is not reflected in the urban water consumption level.

Fig. 4 shows the average urban water consumption in Atacama and Aysén regions. In both regions, the urban water consumption pattern is very similar. Between the years 2000 and 2010, water consumption remained almost constant around 160 L/person/day while as of 2011 there was a significant decrease in the consumption of water. Surprisingly, water consumption per capita in the southern region was smaller than in the northern region, where water scarcity is a significant limiting factor.

According to the principles governing the water tariff setting procedures in Chile (see Section 3), water scarcity should be reflected in the water tariff of each water utility. In this sense, permanent water-use rights values in the north of the country are greater than in the south, which indicates that the water market in Chile at least in part reflects the relative scarcity of water (Donoso, 2015). However, as the water tariff is based on several operational and investment costs, water scarcity value differences across regions are not reflected in the urban water tariffs. Fig. 5 shows the total price paid by the urban consumers, including the fixed and variable parts of the tariff, assuming a consumption of 20 m^3/month in Atacama and Aysén regions. It is illustrated that until 2013, the urban water tariff in the region of Aysén was larger than in Atacama Region. For the first time in 2014, this pattern changes and currently, in average values, the total water price paid by the citizens in Atacama for a consumption of 20 m^3/month is 35,936 Ch$[7]/month while in Aysén is 33,243 Ch$/month. Nevertheless, Fig. 5 evidences that current water tariffs in both regions do not reflect water availability. Moreover, Fig. 5 illustrates that between 2000 and 2014, the price paid for WSS doubled in Aysén Region and almost tripled in Atacama Region. As a result the funds required from the central government to finance the subsidy to WSS for low-income households also increased significantly (see Fig. 6). However, in relative terms, the percentage of households benefited by the subsidy to WSS over the total of households is larger in Aysen than in Atacama. Access to WSS in Chile is not a minor issue since currently in the Atacama and Aysén regions more than 1/4 and 1/3 of the households, respectively, need subsidies to pay WSS. Hence, this issue cannot be ignored in the design of water rates in Chile (SISS, 2014).

5. Empirical application of the water rate proposed to the case studies

In order to illustrate the usefulness of the proposed water rate, an empirical application was developed for the two regions selected as case studies. Table 1 shows the value of the parameters defined in Eqs. (3)–(8) for Atacama and Aysén regions to establish the unitary price of the water for the two blocks.

[4] The procedure considers that the model operator initiates its concession with no previous investment.

[5] The minimum guaranteed returns considers the operator's own assets. Existing infrastructure is not factored in the *AI*, for example, if the distribution network was financed with public funds it is not considered an asset in the calculation of returns, but it is considered as part of the annualized investment costs.

[6] Long-term infrastructure investment costs are included in the water and sanitation services tariff rates.

[7] On September 15, 2015, Ch$1 was US$677 and €766.

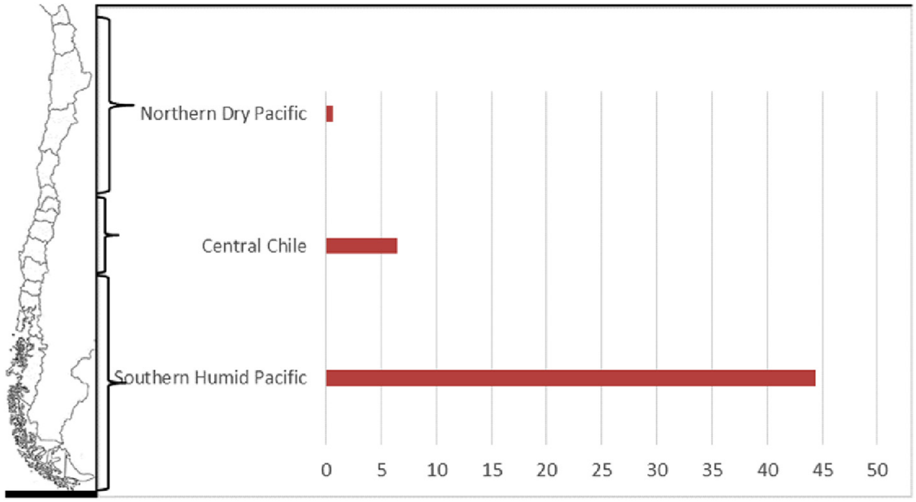

Fig. 3. Average water availability for each hydrological system in m^3/s.
Source: Peña et al. (2011).

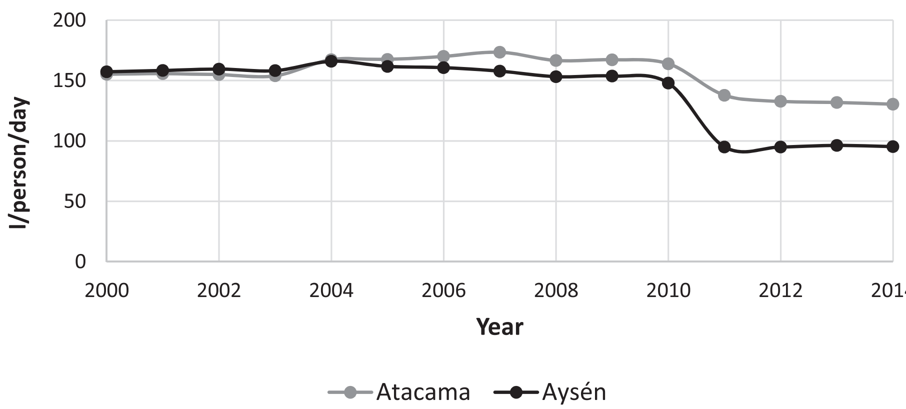

Fig. 4. Evolution of urban water consumption in Atacama and Aysén regions.
Source: SISS (2014).

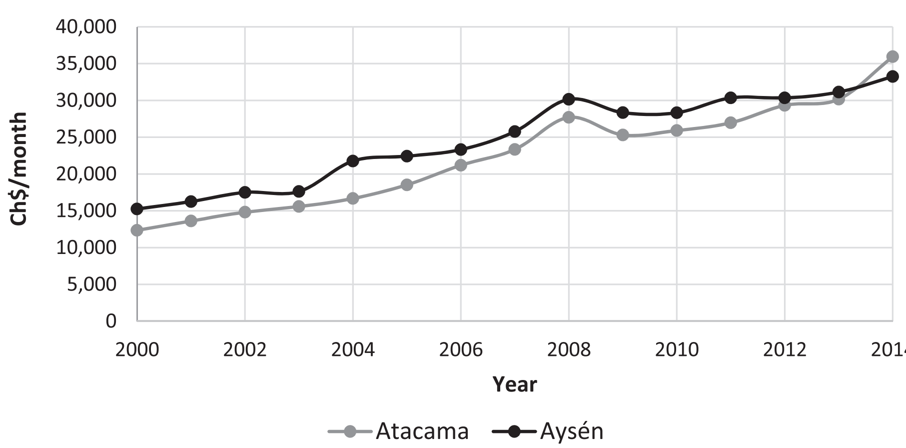

Fig. 5. Evolution of the price paid for 20 m^3/month including water and sewerage services.
Source: SISS (2014).

According to Eq. (4), the upper limit of water volume for the first block should be 6.5 and 5.5 m^3/month/household in Atacama and Aysén regions, respectively. This difference between the two regions is because the average household size in Atacama is 3.5 people per household while in Aysén is 3.0 people/household (INE, 2012). These upper limits of water volume are the maximum quantity of water that might be subsidized by the central government in the both regions. These figures involve a significant

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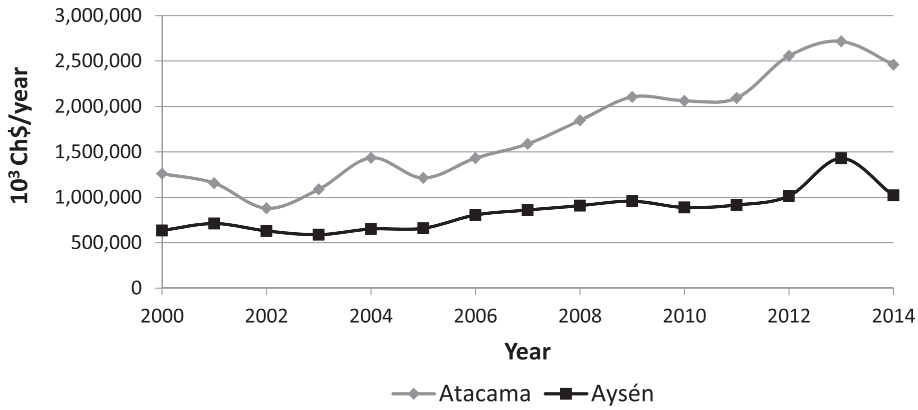

Fig. 6. Evolution of the spending to subsidize water and sewerage services.
Source: SISS (2014).

Table 1
Main parameters to establish unitary water price in Atacama and Aysén regions.

Parameter	Atacama region	Aysén region
T_o (Ch$/m^3)	803.23	726.61
V_{FB} (m^3/month*household)	6.3 ≈ 6.5	5.4 ≈ 5.5
V_T (m^3/month*household)	12.77	10.25
TH	85,018	24,628
HWOS	61,514	15,318
HWS	23,504	9310

Source: INE (2012) and SISS (2014).

reduction of the volume of water subsidized compared up to the current 15 m^3/month*household that might be subsidized nowadays. The total volume of water consumed (V_T) in Atacama and Aysén regions is on average 12.77 and 10.25 m^3/month/household and their standard deviation is 10.25 and 8.36, respectively. According to this data, it makes no sense to subsidize 15 m^3/month/household. If the volume of water that might be subsidized is not reduced, the customers have no incentive to reduce water consumption. In other words, we propose to reduce the maximum volume of water that might be subsidized with the aim of showing citizens that water is a valuable resource and therefore, should be used sustainably. Moreover, the maximum volume of water that might be subsidized would be different for each Chilean region according their population characteristics.

According to Eq. (3), the unit water price for the first block is 15% of the current water price (T_o). Hence, as is shown in Table 2, the unit water price for the first block is 682.7 Ch$/m^3 for Atacama region and 617.6 Ch$/m^3 for Aysén region. While these figures are derived from the current water price, somehow they reflect the value of the water in both regions. Estimates of the unit water price for the second block (T_2) for both regions would depend on their water scarcity factors (*SF*). Following the experience of California (Western Municipal Water District) that introduced a drought factor in the equation to set water tariffs (Barr, 2011), the *SF* value should be estimated by each water company based in the availability of water for domestic use. Nevertheless, the *SF* value proposed by each water company must be approved by the regulator.

Table 2
Unit price proposed for the first and second blocks (Ch$/m^3) for Atacama and Aysén regions according five scarcity factor (SF) scenarios.

		Atacama region	Aysén region
Unit price for the first block (Ch$/m^3)		682.745	617.618
Unit price for the second block (Ch$/m^3)	SF = 0.00	1553.2	1805.78
	SF = 0.25	1754	1987.43
	SF = 0.50	1954.8	2169.08
	SF = 0.75	2155.6	2350.7
	SF = 1.00	2356.4	2532.4

For the case studies developed in this paper, it should be noted that the region of Atacama is an extremely arid area and therefore its *SF* should be the maximum, i.e. its *SF* should be one. On the other hand, Aysén region is a water abundant area which does not face water scarcity problems. Hence, for this region the *SF* should be zero. Table 2 shows the unit water price proposed for the second block for both regions considering 5 scenarios according *SF* values: (i) there is no water scarcity (*SF*=0.00); (ii) water scarcity is low (*SF*=0.25); (iii) water scarcity is moderate (*SF*=0.50); (iv) water scarcity is high (*SF*=0.75); and (v) water scarcity is extremely high (*SF*=1.00). According to current water scarcity conditions in both regions, unit water prices for the second block in Atacama and Aysén regions that should be implemented are 2356.4 and 1805.78, respectively. As a result, the variable water rates proposed for Atacama and Aysén regions are illustrated in Fig. 7.

Table 2 evidences that when water scarcity is ignored, the unit price of water in the Aysén region should be larger than in the Atacama region. This is because the percentage of households with subsidies to drinking water supply is higher in Aysén than in Atacama (see Fig. 7) and according to Eq. (2), the revenue from the proposed water rate should be equal to the current revenue that water utilities obtain plus the expenses that the central government spends to pay the subsidies. By contrast, when differences of water scarcity which regions face are integrated into the water rate proposed, the results illustrated that for the second block, the unit water price in Atacama is around 30% higher than in Aysén. According to Eq. (8) the integration of a *SF* equal to one in the water rate in Atacama would generate a revenue of around 310 million of Ch$/month which should be aimed to design and implement a program of measures for water conservation in the region or to finance investments in alternative water sources such as a desalinization plant.[8]

Table 3 shows the current bills for different water consumption levels and those resulting from the proposed water rate for both regions analyzed. In both cases, the estimation takes into account only the variable charge since this study focused on the volumetric component of the tariff. It is illustrated that the proposed water rate

[8] This investment has been analyzed but it is not clear how to finance it because of its significant impacts on water tariffs.

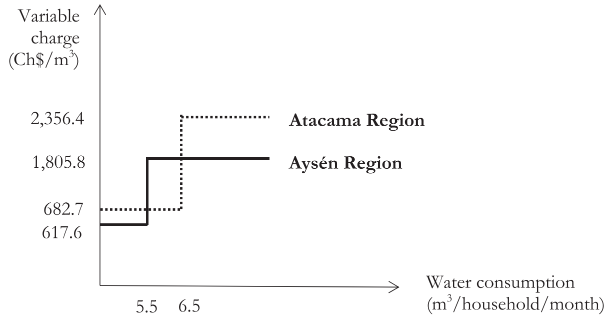

Fig. 7. Variable rate proposed for the Atacama and Aysén regions.

is an incentive for households to reduce water consumption. Whether water consumption is maintained in the first block, this is about 5 m3/month, households could reduce by about 15% its water bill. This fact improves water affordability since the subsidy to access to drinking water does not cover the 100% of the water bill but the payment shares from 15 to 85 per cent of the water bill. Hence, with the proposed water rate, the poorest households have to pay less for accessing water services. On the contrary, those households whose water consumption involves first and second block, the percent raise of the water bill is larger as water consumption increases. This is due to the fact that the proposed water rate strongly penalizes excessive water consumption.

From a policy point of view, it should be highlighted that in water-scarce areas, water pricing is a useful tool to incentivize water consumption reductions so as to improve the sustainability of the urban water cycle. The proposed water rate is a useful demand management policy since its implementation would lead to a decrease of water consumption mainly in the regions most affected by water scarcity problems. From a social point of view, the implementation of the proposed water rate contributes to improve the equity. The cross-subsidy proposed that large consumers subsidize low consumers who usually are low-income households. 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.

6. Conclusions

Water pricing is a useful economic policy instrument to affect the environmentally, socially, and economically efficient use of water. A well-designed water rate structure should deal with multiple objectives such as promotion of economic efficiency, equity, environmental and financial sustainability, public and political acceptability, etc. Hence, policy makers face the challenge of setting water tariffs taking all of these objectives into account.

This study proposes a water rate structure that integrates the environmental criteria (water scarcity) and at the same time improves the social concerns (equity and affordability). The proposal focuses on the variable component of the tariff and follows an increasing block tariff strategy. The suggested unit price of the water considers that consumption in the first block is subsidized while the volumetric rate in the second pricing block covers the operational costs, the subsidies provided to customers in the first block and measures for water conservation.

An empirical application is developed for two regions in Chile which have different characteristics: (i) the Atacama region which is an extremely arid area and; (ii) the Aysén region which has abundant water resources. The results for these case studies provide the following primary conclusions: (i) the volume of water that currently is subsidized is too high since it is larger than the average water consumption in Chilean households; (ii) the volume of water to be subsidized should be different for each region according to their characteristics; (iii) when a water scarcity value is integrated into the water rate, the unit water price for the second block in Atacama is approximately 30% higher than in the Aysén region; (iv) the proposed cross-subsidy implies that in both regions large consumers pay for low consumers which create incentives for those who generate the greatest external cost to reduce water consumption and; (v) whenever water consumption is maintained in the first block, households could reduce its water bill by about 15%. On the contrary, in households whose water consumption involves first and second block, the percent rise of the water bill is larger as water consumption increases.

As has been illustrated in the empirical application developed in this study, the main advantages of the proposed water rate can be summarized as follows: (i) the maximum volume of supplied water that can be subsidized should not be uniform throughout the country and ought to depend on the characteristics of the population in each region; (ii) considers a cross-subsidy since high water users pay for low users who usually are low-income households and hence, equity between users is improved; (iii) the expenses needed to finance the subsidies to low-income households are obtained from the water bills and therefore, the central government can reallocate funds towards other social needs; (iv) the revenue obtained by the water utilities is unaffected; and (v) the introduction of a scarcity factor to estimate the unit water price for the second block generates extra revenue which should be used to implement water conservation measures of supply augmentation alternatives which are extremely needed in water-scarce regions.

From a policy perspective, it should be highlighted that with water becoming increasingly scarce in many regions as a result of a growing population, rising incomes, and increasing water pollution and climate change, water pricing is increasingly becoming an important policy tool to manage scarce resources more efficiently. Thus, there has been a growing public and political acceptance of water prices as a valid instrument to recover water provision costs, at the same time insuring continuity of water provision. However, there is a growing concern of the affordability of the different water pricing mechanisms. In this context, several countries have adopted increasing block tariffs (IBTs), adjusting its design to minimize unintended distributive effects and insure affordability and access (OECD, 2003). Hence, the political acceptance of this tariff scheme

Table 3
Current and proposed variable bills for Atacama and Aysén regions.

Volume of water (m^3/month *household)	Atacama region		Aysén region	
	Current bill (Ch$/month)	Proposed bill (Ch$/month)	Current bill (Ch$/month)	Proposed bill (Ch$/month)
5	4016	3436	3633	3088
10	8032	12,685	7266	11,523
15	12,048	24,467	10,899	20,552
20	16,065	36,249	14,532	29,581

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has increased, and we do not foresee higher political obstacles than those present with other water pricing models that incorporate conservation reductions. Additionally, a growing number of people support the idea that higher water consumers should pay higher water prices for their excess consumption.

Additionally, in the case of those countries that have implemented water pricing policies, such as Chile, the implementation of the proposed water rate would not require major legal reforms. Moreover, water authorities would obtain an extra revenue to implement a program of water conservation measures which is essential to improve the sustainability in water-scarce regions. This means that the proposed water rate involves an internalization of the water waste costs. From a social point of view, our proposal would contribute to improve equity. In addition, the authorities which currently are paying the subsidies for water and sanitation services would liberate funds which might be allocated to other social projects.

However, there are difficulties associated with the implementation of this water pricing framework. The most important of these is the need to quantify individual household consumption in order to allocate the consumption to the relevant block, and allow customers to be charged at the rates applicable to their consumption levels and to be billed accurately. Thus a clear obstacle to implement the proposed water tariff is the lack of adequate water metering in both developing and developed countries. For example, there are cases where metering is performed collectively for condominiums, such as in France. In this case, the incentive to reduce consumption in water scarce areas reduces. In fact, free rider problems may present itself, where individual consumers increase their consumption and the cost is born by all families of the condominiums.

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