Challenges to Water Pricing in Developing Countries:

The Case of Lima, Peru

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Abstract:

Water pricing can be understood as an important root of water quantity and water quality problems in developing countries – but also as a possible solution to them. This paper proposes an analytical framework to understand challenges related to pricing water supply and sanitation. The framework rests on three criteria: efficiency, cost-recovery and affordability. It highlights that the actual effects of water pricing do not only depend on its design but also on the institutional and technical environment it is embedded in. The framework is used to identify and analyze challenges to water pricing for the case of water supply and sanitation system in Lima, Peru.

Keywords:

Water pricing, developing countries, efficiency, affordability, cost-recovery, Peru

1 Introduction

Water supply is subject to important problems in many developing countries throughout the world. Particularly arid and semi-arid areas are facing severe water scarcity. Moreover, water supplied often does not met minimum quality standards. These basic problems are aggravated by deficiencies in water supply and sanitation infrastructure. For example, significant water losses in the network may contribute to water scarcity. Lacking wastewater treatment may be one source of water pollution. Moreover, consumption patterns of at least some (wealthier) parts of society may foster an excessive use of the scarce resource water.

Inappropriate water prices can be understood as a decisive root of many of these problems – and reforming water prices may be one possible solution to them. Water pricing provides revenues to water suppliers, which these can reinvest in the maintenance, improvement and extension of water supply and sanitation infrastructure. Water prices also set incentives to save water and may thus promote a sustainable use of water (Rogers et al. 2002, p. 2; OECD 2010).

However, the design and the implementation of water prices are subject to substantial challenges. In general, prices have been found to be very low in most developing countries (see, e.g., Briscoe 1997). This observation can be attributed to a variety of reasons. Pricing has to meet multiple, possibly conflicting criteria and policy objectives (OECD 2009). Pricing systems may be subject to institutional constraints. These may include legal restrictions, informational problems or underlying informal rules, such as the perception of water as a basic right (e.g., Dinar and Saleth 2005; le Blanc 2008). Moreover, the pricing system will also be influenced by political considerations related to the water sector. For example, politicians may tend to favour low-price systems in order to be re-elected (for an overview, see Dinar 2000).

To organize and better understand the challenges surrounding water pricing, this article proposes an analytical framework. This framework is based on a set of three criteria, which are decisive when it comes to water pricing: efficiency, cost recovery and affordability. Furthermore, the framework emphasizes that different dimensions have to be taken into account in order to assess the performance of water pricing system with respect to these criteria. These dimensions include the design of the water price itself – but also the institutional as well as the technical environment into which the water price is embedded.

The framework is applied in this paper to evaluate the performance of the existing water pricing system in Lima, the capital of Peru. Lima, one of the largest megacities in Latin America, is facing severe problems of water quantity. Water availability is generally low due to Lima's location in the desert. Precipitation is virtually nonexistent. The groundwater table is continuously lowering. The city primarily depends on water from glaciers and precipitation in the Andes, which is transported to Lima by three minor rivers. Climate change is likely to cause significant impacts on these sources. In fact, Peru is considered as one of the countries most strongly affected by climate change worldwide (Rosenberger 2006). Water scarcity is coupled with a high demand for water. First of all, this is due to the large population of the city. It currently amounts to some eight to nine million inhabitants and is expected to grow by two percent annually. Moreover, per-capita consumption of water is very high. Estimates range from 150 to 260 litres per person and day. These problems are deteriorated by shortcomings in Lima's water supply and sanitation infrastructure. 10 percent of Lima's population, or roughly one million inhabitants, are not connected to the network. Some 30 to 40 percent of the water entering the network is lost on the way to the customer. Only about 15 percent of the wastewater is treated, and hardly any of it is reused (SUNASS 2007). These problems illustrate that substantial investments in infrastructure are needed in the future. Moreover, behavioural changes are needed in order to reduce per-capita water consumption of Lima's inhabitants. This article examines to what extent the current water pricing system does effectively address these issues. In this context, it considers the wide array of criteria and restrictions guiding decisions in the water sector.

The paper is organized as follows. Section 2 introduces the analytical framework. It presents the evaluation criteria as well as the relevant dimensions of water pricing. Section 3 describes and evaluates the current water pricing system in Lima using the analytical framework. Section 4 concludes and derives policy recommendations.

2 Analytical Framework

This section first of all presents the criteria which are important when it comes to evaluating water pricing systems. Subsequently, it introduces the different dimensions of a water pricing system which have to be taken into account in order to be able to assess the performance of the system with respect to the different criteria.

2.1 Criteria

This paper focuses on three criteria which are particularly important with respect to water pricing: efficiency, cost recovery and affordability.[1]

[1] In fact, there are many more criteria which may be considered, such as equity, fairness, transparency, simplicity or administrative ease (for an overview, see e.g., Rogers et al. 2002, p. 6).

The criterion of *efficiency* refers to the welfare of the society as a whole. Welfare computes as the difference between benefits and costs of water use. The efficiency of water consumption rests on two questions (Bithas 2008, p. 223): (1) Is the aggregate quantity of water consumed by a society optimal? (2) Is this aggregate quantity of water consumption allocated optimally to different possible users? (1) In economic terms, the aggregate optimum is attained when marginal costs of water consumption equal the marginal benefits. In this case, the cost of consuming one more unit of water would exceed the corresponding benefits. In order to determine the optimal level of overall consumption, the full value and the full cost of water supply should be taken into account. The full value includes direct and indirect benefits to water users and third parties as well as intrinsic values. The full cost of water includes operation and maintenance costs, capital costs, opportunity costs and external environmental costs of water supply. In an ideal setting, these refer to the costs and benefits of present users as well as of future generations (Rogers et al. 1998). Therefore, an efficient water price should be set equal to the full cost of the marginal unit of water supplied. (2) Allocation of water between different users is optimal when the marginal benefit of the last unit water consumed by each user is equal for all users. In this case, allocating yet another unit of water from one user to another would result in welfare losses to the former which would not be compensated by welfare gains to the latter user. An efficient allocation of water can be achieved by implementing a uniform price for all users. In this case, each user will consume water as long as his marginal benefits are higher than the price. Eventually, such mechanism provides for marginal benefits to be equalized across all users.

The criterion of *cost recovery* addresses the needs of the water supplier. Firstly, the revenues resulting from water pricing should be sufficient to pay the costs of operating and maintaining the infrastructure for water supply and sanitation. Secondly, the revenues should also be available to recover the capital costs of investments, including the depreciation charges and interest rates for loans. Finally, water prices should also provide a return on capital at risk and a cash reserve for unexpected events (Whittington 2003, p. 63). Cost recovery requires that the water price be equal to the average cost of water supply. With a large amount of fixed costs (which is typical for water supply where large initial investments in infrastructure are needed), it may well turn out that average costs are higher than marginal costs (which refer to variable costs only). Thus, there may be a conflict between efficient and cost-recovering water pricing. The efficient price may be too low to recover the costs of the water supplier.

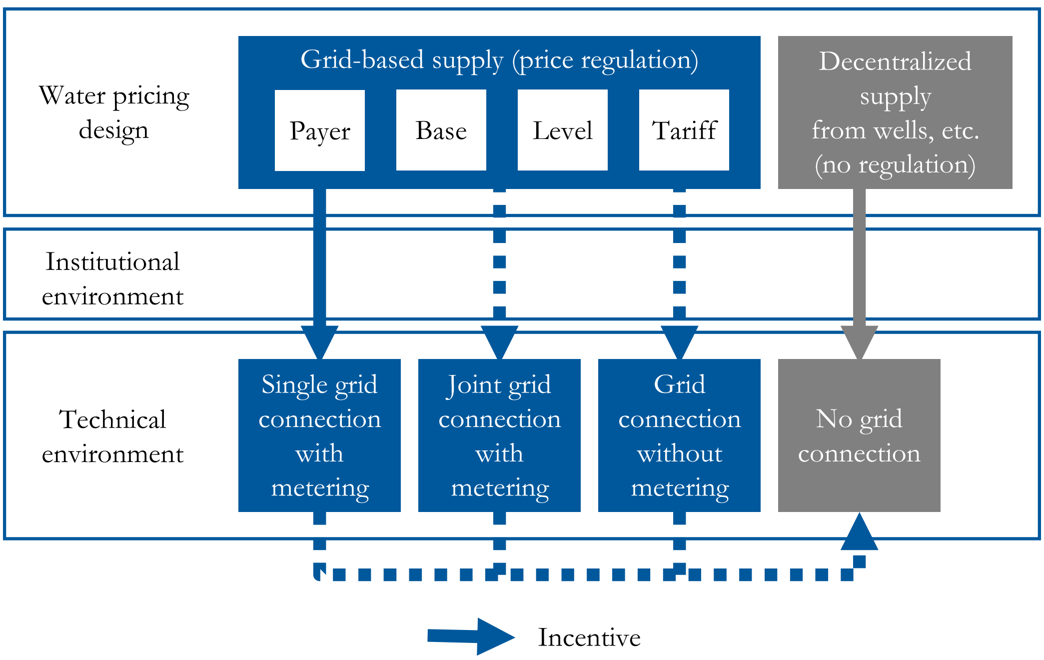
Finally, the criterion of *affordability* focuses on the need of individual water consumers. Affordability means that each potential water user should be able to afford a subsistence amount of water irrespectively of his income. This criterion may be interpreted such that water prices should be below the full cost of water supply. It may also imply that the water price should be differentiated with respect to income. That is, poorer consumers should pay less for water than consumers with more resources. The price may also be differentiated with respect to some proxies to individual income, such as the level of water consumption or the average income of a neighbourhood. Alternatively, a water price could be accompanied by additional policy instruments, such as direct water subsidies for the poor. Mostly, affordable water price will violate the criterion of efficiency requiring uniform pricing at full cost: the average level of the price is too low and/or the incentives to use water are heterogeneous across water users. Addressing affordability may also produce conflicts with cost recovery when the average level of the water price is below the operation, maintenance and capital costs borne by the water supplier.

This brief presentation illustrates that different criteria may have quite different implications for the optimal design of a water price. It will be highlighted in the following, however, that the actual performance of a water pricing system does not only depend on the design of the price but also its institutional and technical environment.

2.2 Dimensions of the Water Pricing System

In order to understand the effects of water pricing, it is necessary to apply a broad perspective which considers three important dimensions: the design of the water price, its institutional environment and its technical environment. These three dimensions are understood in this paper as the water pricing system (see Figure 1). That is, this system includes the proper water price but also goes beyond it.

Figure 1: Dimensions of the water pricing system



Of course, *water price design* is the dimension which first of all determines the effects of water pricing in reality. In this respect, it is useful to distinguish between grid-based water supply to customers connected to the network and decentralized water supply from wells or water tankers by private water vendors. Usually, only grid-based supply is subject to price regulation by the government. In contrast, decentralized water supply by vendors is often pretty close to a free, liberalized water market. Consequently, a discussion and evaluation of water price design is usually only carried out for grid-based supply where there are available means of government intervention.

Four elements characterize the design of a water price. The first element is the definition of payer, i.e. the party that is obliged to actually pay for water. This could be, for example, the consumer of water or the discharger of wastewater but also the landlord of a rented house (so not the actual water user). The second component of water price design is the assessment base. It determines what the price has to be paid for. The assessment base may the quantity of water consumed, the quantity of wastewater discharged or the contamination of wastewater. Moreover, simpler measures such as a fixed price per grid connection or a price depending on the continuity of supply may also be applied. Thirdly, the average level of the water price is decisive. It can be determined on the basis of very different concepts, e.g. marginal costs versus average costs, full costs versus less than full costs, short-term versus long-term costs, any several more. Finally, the tariff determines how this average water price is actually imposed on different groups of customers. The tariff may be fixed, i.e. irrespective of water consumption, or variable, i.e. depending on water consumption. There may be a single-part tariff composed of a fixed or a variable charge or a two-part tariff including both types of charges. The tariff may be uniform, i.e. all consumers have to pay the same price per unit of water, or differentiated.

Next to water price design, the *institutional environment* is a second important dimension determining the actual effects of water pricing. This environment includes, for example, the complex set of legal rules into which water price are embedded. Consumers' decisions on water consumption may not only be guided by the price but also by regulation on water technologies, for example. That is, the entire effect of the policy mix has to be assessed. Moreover, informational capacities and restrictions (and the underlying transaction costs) may have an impact on how customers actually react to water prices. On the one hand, informational problems can be experienced by water users. Two questions are noteworthy in this respect: Are water users actually aware of the price the pay? This may not be the case when water is billed on an annual basis only or when water costs are included in the monthly rent. Are water users actually aware of available technologies to save water and their corresponding costs and benefits?

On the other hand, information may also be a constraint for the water supplier. Here, the question is whether the water supplier is actually capable of monitoring and enforcing water prices in reality? Otherwise, water customers may have an incentive to cheat. All these institutional constraints and conditions determine how water prices perform in reality.

Finally, the *technical environment* also has an impact on how effective water prices actually are. The corresponding incentives can only be passed on directly and perfectly to water users which dispose of an individual, metered connection to the network. Otherwise, i.e. when there is a joint connection for multiple users and/or not metering, incentives are distorted. This is because in this case it is technically impossible to impose the price on the correct amount of water units used by each individual customer. Rather, the distribution of water costs has to be based on rough proxies to individual consumption. For example, the water bill for a joint connection may be equally divided by all users.

What is more, prices set for grid-based water supply do not have a direct effect on decentralized water supply of course. Here, the incentive to use water only depends on the market prices demanded by water vendors. However, there may be an indirect link between both kinds of water supply when customers connected to the network sell water to other users not connected. In this case, the regulated grid-based price establishes a bottom line for decentralized water pricing. These considerations show that the different characteristics of the technical environment may have an important impact on the effects of water pricing as well.

3 The Case Study: Water Pricing in Lima, Peru

This section first of all presents the different dimensions of the existing water price system in Lima. Subsequently, the system is evaluated using the analytical framework derived in the previous section. Thus, it examines the efficiency, cost recovery and affordability of Lima's water pricing system. The presentation and discussion of the Lima case study is based on an extensive document analysis. Moreover, multiple interviews were carried out in Lima with representatives of the regulatory authority SUNASS, the water supplier SEDAPAL, several non-governmental and development cooperation organizations as well as scientists.

3.1 Description

3.1.1 Water Price Design

Generally, the design of the water price which may be imposed by Lima's public water supplier SEDAPAL for grid-based supply is determined by the state regulatory authority SUNASS. The *payers* of water prices in Lima are the consumers of potable water. The *assessment base* is the consumption of potable water in cubic metres for customers with a metered connection. For customers without a meter the assessment base is an assigned amount of cubic meters per connection which depends on the category of the customer and the continuity of water supply. Moreover, the assignation is higher for domestic customers living in wealthier districts than for those in neighbourhoods with a relatively low level of average income (see Table 1).

Table 1: Assessment base assigned to water customers without meters in m^3 per month in 2009

Category	Up to 3 hours water supply per day	4 to 6 hours water supply per day	7 to 24 hours water supply per day
Social	4	7	12
Domestic			
Districts I	17	30	
Districts II	15	21	
Commercial	15	18	
Industrial	27		
State	34		
	Districts		
I	Provincia de Lima: Barranco, Breña, Cercado de Lima, Chorrillos, Cieneguilla, Jesús María, La Molina, La Victoria, Lince, Los Olivos, Magdalena del Mar, Miraflores, Pueble Libre, Rimac, San Borja, San Isidro, San Luis, San Miguel, Santiago de Surco, Surqillo Provincia de Callao: Bellavista, Callao, La Perla, La Punta		
II	Provincia de Lima: Ancón, Ate, Carabayllo, Comas, Chaclacayo, El Agustino, Independencia, Lurigancho, Lurín, Pachacámac, Puente Piedra, Pucusana, San Martín de Porres, San Juan de Lurigancho, San Juan de Miraflores, Santa Anita, Surco Viejo, Villa Maria del Triunfo, Villa El Salvador, Santa Rosa Provincia de Callao: Carmen de la Legua, Ventanilla		

Source: (SUNASS 2006b, p. 324569)

The *level* of the water price refers to the average cost of water supply and sanitation. Costs considered include investment costs, financing costs, operation and maintenance costs and taxes. However, the level of these costs is not based on real-world figures but rather on theoretical cost functions which would characterize an efficient model firm. Aguas Andinas, the water supplier of Chile's capital Santiago de Chile, serves as a benchmark for this model firm (SUNASS 2006a).

The *tariff* chosen to distribute this average price level to water users is depicted in Table 2. It is a two-part tariff including a fixed charge, which is irrespective of consumption, and a variable charge per unit of consumption. The variable charge is differentiated with respect to different user classes and categories: residential (social customers, e.g. public standpipes or hospitals, and regular domestic customers) and non-residential (commercial, industrial and state customers) users. Except for domestic customers, a uniform tariff applies for each category. Domestic customers are facing an increasing block tariff. The tariff is progressive since per cubic metre prices increase with each block of consumption. If customers consume 21 to 30 cubic meters, the tariff of the second rank applies only to the consumption exceeding 20 cubic metres. If customers consume 31 to 50 cubic metres, the tariff of the second rank applies to entire first 30 cubic metres and the tariff of the third rank to any consumption exceeding 30 cubic metres. For the ranks 51 to 80 cubic metres and more than 80 cubic metres, the tariff refers to the entire consumption of water. A special sanitation tariff applies to customers who have an own well at their disposal but are connected to the sanitation network (SUNASS 2006b). The by far most important tariff category is that of domestic customers. It accounts for more than 90 percent of the connections and 75 percent of the billed water volume (SEDAPAL 2007, p. 20).

Table 2: Water tariff in Lima in 2009

				Price in PEN
Fixed Charge				4.444
Variable Charge	Class	Category	Range in m^3	Price in PEN/m^3
	Residential	Social	>0	1.311
		Domestic	0-20	1.311
			21-30	1.735
			31-50	2.675
			51-80	2.675
			>80	4.005
	Non-residential	Comercial	>0	5.291
		Industrial	>0	5.291
		State	>0	2.675
		Use of sanitation only		3.082

Source: (SUNASS 2008b)

Water users without grid connection mainly buy water from private water tankers. Prices required by water tankers are not regulated by the government. Rather, they are the result of free competition between water tankers. Moreover, they depend on the prices required at private and public wells and standpipes, which are in competition with each other as well. A 2003 study estimates that prices at which water tankers sold water varied from 5.65 PEN per cubic metre in the southern districts of Lima to 7.41 PEN per cubic metres in the north (FOVIDA 2003). The average price amounted to around 6.81 PEN. Thus, the price of decentralized water supply is significantly higher than that of grid-based supply.

3.1.2 Institutional Environment

One major institutional restriction is the availability and awareness of information related to water pricing in Lima. This holds true for water users as well as the water supplier. Expert interviews revealed that many water users do not seem to be aware of the actual scarcity of water in Lima – and the sense of pricing as an indicator of the related costs and a means to stimulate water saving. This is particularly true for the numerous poor immigrants from the mountain range and rainforest areas which have experienced abundance of water and developed an according use of water. However, the lack of awareness can also be observed for wealthier inhabitants living in Lima for generations. It is often unknown to them where the potable water actually comes from and to where wastewater is discharged. Moreover, many water users in Lima may not be aware of the benefits of water supply. They do not understand, for example, that insufficient water supply and sanitation is directly related to diseases, such as diarrhoea. Finally, water consumers often assume that connection to the grid and individual metering will increase their water-related costs per se – even though this is not necessarily true. This is an important reason why water users may reject being connected to the network or getting a water meter installed (see, e.g., APDES 2007). Informational restrictions are also faced by the water supplier SEDAPAL. Stakeholders often argue that the company lacks sufficient resources to actually monitor and enforce water prices in the entire city. This task is particularly costly due to the city's size and constant growth. In addition, corruption is also often cited by representatives of different institutions as a factor distorting the actual enforcement of water pricing in Lima.

Apart from informational restrictions, general perceptions of water users may hamper the effects of water prices in Lima. In this respect, a strong refusal of any type of government intervention (including governmentally supplied and priced water) can be observed. This attitude is particularly common among immigrants from other parts of Peru and can be explained historically. In post-Colombian times, Lima has always been the capital of a centralized Peru. Peru's political, economic and social elites were based in Lima. All of the countries resources went to the capital or abroad. In turn, Lima was oriented to the west, to the Pacific Ocean rather than to country's inland. Thus, Peru in fact was divided into Lima and the rest of Peru. For this reason, many immigrants coming to Lima believe that they have a right to a share of Lima's resources, including land and water. However, they do not expect the government to allocate this share to them since they have never received any support from it. They do not consider themselves as citizens with rights and duties. They rather see themselves as "conquerors" or "invaders" that have come to regain their share in Lima's wealth. They "conquer" water by establishing illegal connections to the network. And they are not willing to be connected to the network and pay an additional charge to the government (the water supplier SEDAPAL is considered a synonym) who has already taken all resources from them (for an extensive discussion of these developments, see Matos Mar 2004).

3.1.3 Technical Environment

This section specifies the characteristics of the technical environment illustrated in Figure 1 for Lima. 90 percent of Lima's water users are connected to the water grid while ten percent depend on decentralized supply from water tankers. 70 percent of the grid connections are actually metered while the rest is billed on the basis of assigned consumption (SUNASS 2007). There seems to be no reliable data on the share of joint connections. Nevertheless, this share must be significant as the estimated number of supplied households (1.7 million) is substantially higher than the number of domestic connections (950,000) (SUNASS 2008a).

3.2 Evaluation

This section evaluates Lima's water pricing system with respect to the criteria efficiency, cost recovery and affordability. As before, it distinguishes between the three dimensions which may have an effect on the performance of water pricing: water price design, institutional environment and technical environment.

3.2.1 Water Price Design

Level below full cost of water supply

Regarding the *efficiency* of the level, it is first of all positive that water prices are set with respect to efficient levels of operation, maintenance and investment costs – not to real costs. Thereby, the water supplier has a strong incentive to optimize the use of resources employed for water supply and sanitation. Nevertheless, it is still to low in terms of efficiency as it does not consider opportunity costs and external environmental costs. The scarcity cost of water – i.e. the value of the actual resource, not the costs of processing it – is not taken into account. Moreover, the price should also reflect costs from discharging untreated wastewaters into the Pacific Ocean. Such costs may be incurred by local fisherman, for example, when pollution results in reduced catches. A further component of the water price should be expenditures which are necessary to maintain water catchments upstream in the Andes, e.g. to reduce deforestation and soil erosion. Such measures may be key to reducing the impacts of climate change on water supply (see, e.g., GEA 2008). Yet, estimating these costs correctly may be a challenging task for decision-makers as they require a profound understanding of ecological, technical and economic interrelations. To summarize, the insufficient level of the water price results in incentives to save water which are too low from the point of view of efficiency. As a consequence, too much water is used for residential and non-residential water supply in Lima today – compared to other possible uses today and in the future.

The level of the water price does also not allow SEDAPAL to *recover its costs*. Experts estimate that the current price is only sufficient to cover operation and maintenance costs. Investments are mostly funded by the government or foreign organizations. A cost-recovering water price may need to be up to two times higher. The reason for this insufficiency is of course the theoretical model employed by SUNASS which assumes efficient cost functions to determine the average price level. This approach may be desirable for efficiency but it impairs cost recovery. Beyond this conflict of criteria, it may be questionable, however, whether cost functions of a private water supplier in Chile are a suitable benchmark for a public supplier in Peru.

Of course, a low level improves the *affordability* of water pricing for water consumers in Lima. Thus, one underlying reason for the low price level may be that the government – which eventually also guides the decisions of the regulatory authority SUNASS – attaches more importance to affordability than to other criteria. This is particularly likely as water prices are a politically very sensitive issue in Lima – as throughout the entire developing world.

No differentiation of assessment base

The water price in Lima is imposed on water consumption. It is meant to cover the costs of potable water supply and sanitation. Theoretically, *cost recovery* is possible with this assessment base (as well as with any other) if the price level is chosen appropriately. However, the lacking differentiation of the assessment base impairs the *efficiency* of water pricing. Producers of wastewater do not face the correct level of sanitation costs which would correspond to their quantity and contamination of wastewater. Rather, sanitation costs are borne by all water consumers in equal shares depending on their water consumption. This implies that the water price is too low for users producing relatively dirty wastewaters and too high for relatively clean users. Moreover, water prices based on water consumption only do not set any incentive to pretreat wastewater before discharge.

The suboptimal choice of the assessment base is also likely to compromise the *affordability* of water supply. Poor residential consumers can be assumed to produce less dirty wastewaters than industrial consumers, for example. When wastewater treatment costs are equally borne by all water users, this fact implies that poor residential consumers subsidize industrial customers. If the water price considered the quantity and contamination of wastewater, poor water users would probably pay a lower price than today.

Differentiation of the tariff

The tariff for Lima's most important user category, domestic customers, is differentiated by consumption ranges. The main rationale behind this so-called increasing block tariff is usually *affordability* (Boland and Whittington 2000). Users with high consumption pay a price beyond the average cost of water supply and sanitation. Users with low consumption are charged below average cost. This mechanism may indeed promote affordability as water demand is usually found to be a function of income. Empirical estimates for Lima suggest that a ten percent increase in income may result in a one to five percent higher demand for water (Yepes and Ringskog 2001, pp. 23-24; Ortiz and Bendezú 2006, p. 26; SUNASS 2006a, p. 41).

Yet, the differentiation of the tariff – between user categories as well as between consumption ranges – clearly violates *efficiency*. The marginal price of water is not equal for all water consumers. In terms of social welfare, the incentive to save water is not sufficiently high for consumers facing a relatively low tariff (because either their consumption is low or they belong to a preferred user category). The opposite is true for users facing a relatively high tariff. Thus, tariff differentiation produces a trade-off between higher affordability and lower efficiency.

In theory, the structure of the tariff is neutral with respect to *cost recovery*. An increasing block tariff can be designed such that the average cost of water supply and sanitation lies somewhere between the lowest and highest price and is covered by the average revenues per unit of water. In reality, however, this requirement may pose informational problems for the regulatory authority. In order to get the design right, the authority needs a very good understanding of the characteristics of water demand. In order to determine the first block, it has to find out about the subsistence level of water demand and the price which would allow poor consumers to afford this level. Moreover, it has to know about the water quantity consumed in any other block to calculate corresponding price which eventually cover overall costs. More importantly, determining the first block may also be politically challenging. Stakeholder pressure may result in a quantity that is too large and in a price that is too low (Boland and Whittington 2000). If this block becomes very large and cheap it may not be possible (or politically feasible) anymore to recover the corresponding subsidies by larger prices on other blocks. Thus, cost recovery may be impaired. This case can actually be observed in Lima. In fact, blocks have been designed such that 85 percent of the water consumers receive a subsidy while only 15 actually pay for it. These numbers contrast with the figure that only 20 percent of Lima's population are considered as poor (SUNASS 2006a, p. 121). Under such circumstances, cost recovery may not be safeguarded in reality.

3.2.2 Institutional Environment

Institutional constraints and conditions appear to quite important for the actual effects of water pricing in Lima. On the one hand side, informational deficits and water-related perceptions on part of water users result in substantial resistance against water pricing. On the other hand side, the water supplier SEDAPAL seems to be incapable of perfectly monitoring and enforcing water prices in Lima. As a result, evasion of water pricing is a serious issue in Lima. Four types of evasion may be exemplary: (1) Water users may establish unauthorized connections directly to the water network. In fact experts estimate that illegal withdrawals may account for up to 50 percent of the water losses within the grid. (2) Water users without metering, which pay a flat rate based on an assigned amount of water, may supply water to third parties without connection to the network. (3) Water meters may be manipulated or destroyed. (4) Commercial and industrial users may register as residential customers in order to be eligible for a lower water price.

Evasion of water pricing is first of negative for *cost recovery*. If some units of water are not billed at all or below the correct price, real-world pricing does not correspond to the calculation which underlies the determination of the price level and tariff and is meant to provide for cost recovery. Moreover, if at least some units of water can be obtained without pricing, the overall incentive to save water is reduced as well. Thus, price evasion also impairs *efficiency*. In contrast, one may assume that price evasion improves the *affordability* of water. However, allowing for price evasion deliberately would question the credibility and integrity of the entire pricing system – and may result in a break-down of the pricing system. Moreover, there is no control on whether it is actually the poorest the benefit most from price evasion.

3.2.3 Technical environment

Insufficient coverage of grid connection

The lack of connecting all water users to the public water network results in the existence of two parallel water pricing systems: one for grid-based supply with relatively low prices and another for decentralized supply with relatively high prices. This price discrimination clearly violates *efficiency*, which would call for uniform pricing. In terms of efficiency, grid-based water users consume too much while water consumption in neighbourhoods not connected to the network is suboptimally low. This price discrimination is also likely to impair the *affordability* of water pricing. It is predominantly the poor living in Lima's peri-urban settlements, which are not connected to the network and pay the highest prices for water. The insufficient coverage of grid connection hardly affects the *cost recovery* of the water supplier as it depends on revenues from grid-based supply only. An indirect effect may be possible, though, given the assumption that water users depending on decentralized water supply may have a higher incentive than grid-based users to withdraw water illegally from the water network.

Joint connections

With joint connections, the water bill for one connection is usually divided equally by all water users depending on the connection. This distorts the *efficiency* of the incentive set by the water price. A water user is not charged for his actual consumption but for the average consumption of all users. This implies that the incentive to use an additional unit of water does not correspond to the full marginal price of that unit but only to the price divided by the number of co-users of the connection. Thus, the level of consumption of one user will be too high in terms of efficiency as he can partly externalize water costs to other users.

The existence of joint connections may also have detrimental effects on *affordability* of an increasing block tariff. The more water users depend on one connection, the higher is the overall level of consumption for that connection. Therefore, joint connections are likely to be subject to a higher unit price than connections with a single user. When single connections are more common in wealthier districts and joint connections usually supply poor customers, the following effect may occur: Poor water users may end up subsidizing the water consumption of wealthier customers. Thus, the intended effect of an increasing block tariff with respect to affordability is in fact reversed. In the setting of joint connections, it is thus a major shortcoming of increasing block tariffs that they do not consider the number of persons depending on one connection (see, e.g., Boland and Whittington 2000).

In theory, *cost recovery* should be possible with joint connections whenever the price level is chosen properly. In reality, however, an enforcement problem may impair the actual level of cost recovery. When joint connection is established for an entire building, single users within that building may not be disconnected from the network individually. In this case, it is impossible to sanction users which have not paid their bill.

Insufficient coverage of metering

In the absence of metering, consumers are assigned a fixed amount of water consumption. This amount is multiplied with the corresponding tariff and results in a flat rate to be paid irrespectively of actual consumption. Such flat rate impairs *efficiency*. The marginal incentive to save water is zero. Thus, customers can use a arbitrary quantity of water for whatever purpose without having to face any additional cost.

The impact on *cost recovery* may be ambiguous. If actual water consumption is higher than the assigned amount of consumption, cost recovery is impaired. Otherwise, it may be improved. Similarly, the effect regarding *affordability* is unclear. If consumption is below the assigned amount, the per-unit price increases, and water becomes less affordable. The reverse is true when the assignation of consumption is chosen too high. However, this latter effect is less likely to occur in Lima since water customers in poorer districts receive a lower assignation of consumption than those in wealthier areas.

4 Conclusion

In this paper, an analytical framework is proposed to evaluate water pricing systems in developing countries. The framework rests on three evaluation criteria: (1) efficiency, addressing the welfare of the entire society, (2) cost recovery, addressing the needs of the water supplier and (3) affordability, addressing the needs of individual water users. To assess the performance of a water pricing system, it is highlighted that three dimensions of this system should be considered: (1) the design of the water pricing (including the payer, the assessment base, the level and the tariff), (2) the institutional environment (referring, for example, to legal and informational restrictions) and (3) the technical environment (considering, for example, the coverage of grid connection and metering).

The framework is employed in this paper to evaluate the case study of the water pricing system in Lima, Peru. This analysis identifies several challenges which are summarized in Table 3.

Table 3: Overview of challenges to water pricing in Lima

Dimension	Challenge	Efficiency	Cost recovery	Affordability
Water price design	Level below full cost	-	-	+
	No differentiation of assessment base	-	o	-
	Differentiation of tariff	-	o/-	+
Institutional environment	Evasion of pricing	-	-	o/+
Technical environment	Insufficient coverage of grid connection	-	o	-
	Joint connections	-	o/-	-
	Insufficient coverage of metering	-	+/-	+/-

The analysis has shown that several modifications in Lima's water pricing system would be necessary to improve its overall performance. First of all, modifications of the water price design are required. In order to increase efficiency and cost recovery, the price level should be increased. Indeed, such increase would challenge the affordability of water pricing. However, the affordability should be improved not by choosing a low average price level but by designing the tariff differentiation more properly. Here, price subsidies should be targeted to those users that are actually poor. Moreover, the price differentiation should be linked more directly to income in order to avoid the adverse effects of increasing block tariffs in the presence of joint connections. Such differentiation may pose challenges regarding the necessary information on income, of course. However, such information seems to be available in Lima from databases of the Ministry of Finance and Economy. A corresponding modification has already been envisaged by the regulatory agency SUNASS (SUNASS 2008a). A further necessity with respect to water price design is the differentiation of the assessment base of water prices with respect to potable water consumption, wastewater production and wastewater generation. The implementation of such differentiation will be challenging for residential customers were metering would be tedious. However, it should be possible for large industrial customers which are responsible for wastewaters with major pollutant loads. A final requirement regarding water price design is the implementation of some kind of price regulation for decentralized water supply. This improvement would help to increase the overall efficiency of water use and the affordability of water for users not connected to the network.

Moreover, the analysis has also revealed that measures should not only address the design of the water price but also certain features of the institutional and technical environment. Measures should include, for example, information and awareness campaigns which highlight the scarcity of water and the benefits of regular water supply and metering. Such activities may help to reduce the opposition against and promote the enforcement of water prices. Moreover, policies and investments are necessary to improve the technical infrastructure – e.g. the coverage of grid connection, the coverage of metering and the installation of water saving and water treatment technologies. Such measures are likely to improve the overall performance and may even substitute tedious modifications of policy design. For example, regulation of decentralized supply would not be necessary if all water users were connected to the water network. Similarly, if all users had individual, metered connections the disadvantages of increasing block tariffs with respect to affordability could be reduced – and a more complex tariff considering income directly would not be needed. Most likely, however, a successful reform has to be based on a mixture of changes in water price design and advances regarding the institutional and technical environment.

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