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Estimating the benefits of efficient water pricing in France[☆]

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Abstract

The purpose of this paper is to evaluate the pricing of French water utilities. An econometric model describing both water supply and demand is specified and estimated on utilities located in the Bordeaux area. Based on the estimated technology and demand parameters, we simulate marginal-cost pricing (first-best pricing) and social surplus variations. We find a significant difference between observed marginal prices and marginal costs. We show that the optimal pricing scheme is characterized, first by higher marginal prices and second by a lower fixed charge. However, moving towards efficient prices does not result in important direct welfare effects.

JEL classification: C33; D82; Q25

Keywords: Water utility; Marginal-cost pricing; GMM estimation; Panel data; Simulation; Welfare effects

1. Introduction

During the last 10 years, policy decision-makers have become more and more concerned with regulation of water utilities (WUies hereafter). In France, even if water services are often delegated to private operators, local communities still remain legally responsible for

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water supply. In this context, one of the most important tasks of regulatory authorities is to determine the appropriate pricing scheme for the services provided by utilities. In France, water pricing schemes have been recently affected by legal decisions of public authorities. The January 1992 Water Law has attempted, first to reduce water waste and second, to promote equity between users. It has prohibited the use of flat tariffs, ruling out both entirely non-volumetric pricing schemes and tariffs combining a fixed charge covering a given volume of consumption with volumetric charges on the remainder. Since then, water price has significantly increased and the water bill has begun to gain in importance for consumers.

The efficiency of water pricing is also an important concern in most developed countries. In England and Wales, the economic regulator (OFWAT) requires companies to publish their long run marginal costs. In Portugal, the 1994 Decree-Law also requires newly privatized water services to price water at a charge equivalent to the long run marginal cost. But if there is now a consensus on the importance of efficiency criteria in water pricing determination, it is surprising to note that only a few recent studies have evaluated the pricing of WUies.[1] It is also interesting to see that, while the economics literature is quite consistent in its criticisms of water pricing by WUies, only few studies have estimated the magnitude of the gains to be expected from moving to efficient prices. Moreover, estimates of welfare gains vary from one study to another. Swallow and Marin (1988) show that moving toward efficient prices will result in an increase of welfare within 2% of the actual surplus. But Renzetti (1992b) finds that a move to seasonally differentiated pricing raises the aggregated surplus by approximately 4%. This situation contrasts strongly with the exhaustive analysis of the potential welfare gains to be achieved from reforming the pricing practices of other types of public utilities.[2]

The purpose of this paper is to answer the three following questions. First, are French WUies pricing schemes efficient? If not, what are the characteristics of efficient pricing? Last, what are the efficiency gains to be expected from moving from current pricing practices to optimal water prices? To this end, WUies cost and demand functions are estimated on a panel of local communities located in the Bordeaux area. The estimated cost and demand functions are used to evaluate the current water pricing. Then, efficient prices are simulated by equalizing the marginal cost of water supply to the price. Finally, welfare gains from reforming water pricing are computed. These simulations (by distinguishing the fixed charge and the marginal price) allow us to measure the impact of water pricing changes on the various economic agents (consumers, utilities and the State) which had not been done yet. Moreover, the French water sector has not been deeply studied although the French delegation system may be of interest for other countries. It is in particular more and more important for developing countries where implementation of such delegation schemes is recommended by international organizations like the World Bank. In terms of methodology,

[1] See Kim (1995) and Renzetti (1999) for water pricing analysis in North America. To our knowledge, there is no economic evaluation of water pricing in France, but a study by Sage (1999) that deals with yardstick competition with an application to the water sector. As price regulation is carried out in France by local communities, it is difficult to collect the information on prices and costs required to evaluate the efficiency of pricing schemes.

[2] See, for example, Mitchell (1978) for the telecommunication industry and Dimopoulos (1981) and Protti and McRae (1980) for the electric power industry. Efficiency gains from reforming public utilities pricing usually vary from 4 to 6%.

the paper is innovating as we use a GMM method adapted to panel data in order to jointly estimate a system of equations (cost and demand). Some previous studies evaluating water pricing efficiency have already been published but, to our knowledge, none of them use panel data and appropriate methods. The estimation methods (in some cases, OLS on separated equations) can be questioned.

The remainder of the paper proceeds as follows. In Section 2, general principles of water pricing and the potential sources of inefficiency are examined. The organization of water industry and pricing practices in France are briefly described. Section 3 presents the cost and demand model and its specification. An econometric method is developed for estimating the system of simultaneous equations using generalized method of moments (GMM) adapted to panel data. We derive the estimated parameters and discuss estimates of returns to scale and elasticities of demand. In Section 4, we analyze the current pricing of WUies by comparing marginal costs and current marginal prices. These estimates are then used to simulate first-best optimal pricing by solving a supply–demand system in prices and quantities. Finally, we evaluate the welfare variations resulting from a move to efficient pricing and we discuss issues related to fixed charge determination. Section 5 gives some conclusions and policy implications of our work.

2. Municipal water pricing and inefficiencies

2.1. General principles of water pricing

Designing efficient water rates is a crucial issue for water utilities and local communities. The first objective of a water utility pricing scheme is to generate revenues covering costs.[3] But any pricing rate must also realize two other functions: a pricing rate allocates costs between users and it has to provide incentives for efficient use and water conservation. Applying these criteria to determine the best rate structure is not an easy task. First, some of the criteria may directly conflict and require to make tradeoffs among them. The balance between revenue stability and efficiency of price is an example of such a tradeoff. Moreover, as water services involve high capital investments, a lot of expenses are fixed costs which do not vary with the quantity of water consumed. This makes the allocation of costs among users more difficult to achieve.

2.1.1. First-best water pricing

The theoretical literature on public sector pricing prescribes the form of efficient prices for a variety of circumstances. In the simplest formulation, maximizing social welfare leads a public utility to use marginal-cost pricing (MCP). Maximizing aggregate net surplus leads to the well-known *price equal to social marginal-cost* rule:

$$P = \frac{\partial C(Q)}{\partial Q} + \lambda, \tag{1}$$

[3] As recognized by the EU-Water Framework Directive in 2000.

where Q is the volume produced by the water utility, $C(Q)$, with $C' > 0$ and $C'' > 0$, its cost function, and λ is the marginal shadow price of water. This shadow price is positive when water is scarce or when water withdrawals have environmental impacts. If the price does not reflect the social marginal-cost, consumers do not receive an appropriate information about the societal cost of a marginal increase of demand. Notice that the list of assumptions required for using this result is quite impressive. Among others, the demand for output must be stable, known with certainty and it must depend on no price but its own. Furthermore, the public utility must be indifferent to the distributional consequences of its decisions and also to the possibility that its pricing may not be financially self-sustaining.

MCP deserves a certain number of criticisms and gives rise to at least a certain number of practical difficulties. First, the absence of a budget constraint may provide managers with inappropriate incentives for cost reduction. This is one of the reasons why average cost pricing (ACP) has been imposed on many regulated industries. Second, MCP does not reveal whether it is worth incurring the fixed costs, Coase (1946). MCP requires that the public authority decides for consumers whether they are ready or not to pay for covering total costs. Unfortunately, in many cases, the public authority may lack information to correctly implement this decision. Third, MCP implies that the public utility runs a deficit if it operates under increasing returns to scale. One of the earliest criticisms of MCP is related to the distortion implied by this deficit. In the absence of lump-sum transfers, the benevolent authority must resort to distortionary taxes. Therefore, optimal pricing in the presence of a cost of public funds requires the price to diverge from the marginal-cost. An alternative solution is to use two-part tariffs with a marginal price corresponding to the marginal-cost and a fixed charge allowing to recover the deficit. Last, implementation of MCP can also generate considerable administrative costs which may counter-balance the efficiency gains. For example, MCP requires the installation of sophisticated meters capable of determining not only the total consumption level of each water user but also the time at which water consumption takes place.

2.1.2. Second-best water pricing

All these difficulties can help understand why historically the “revenue-recovery principle” has been the primary rule in the design of water prices and why the price usually used by water utilities corresponds to the average cost (ACP):

$$P = \frac{C(Q)}{Q}. \tag{2}$$

The broadest criticism of such a price scheme is directed at the objective which underlies the entire process of rate-setting. There is little recognition of the role played by prices to signal resource scarcity. Consumer demands are viewed as exogenously determined and, as a result, there is no attempt to maximize the surplus from consumption through the choice of appropriate prices. Furthermore, since consumer demand is exogenous, no attempt is made to measure the market’s valuation of water. Without this information, decisions regarding a system’s capacity or the pricing of output are unlikely to yield to a social optimum.

In a second-best world where the budget of the water utility must be balanced, an alternative to ACP is “Ramsey–Boiteux” pricing:

$$\frac{P - \partial C(Q)/\partial Q}{P} = \frac{\mu}{1+\mu}\frac{1}{\varepsilon}, \tag{3}$$

where ε is the price elasticity of the water demand and $\mu/(1+\mu)$ a term reflecting the cost of the budget constraint. "Ramsey–Boiteux" pricing ensures the maximal economic welfare under a budget constraint. Implementing this pricing however requires a perfect knowledge of marginal-cost and price elasticity.

Last, the new theory of regulation has provided different models that help to define incentive pricing mechanisms. First, Baron and Myerson (1982) consider a firm with private information on its costs. The firm can use this private information strategically in order to benefit from more important subsidies from the public authority. In order to solve this problem of adverse selection, the regulator (the principal) can use a mechanism inducing revelation by the firm (the agent) of its private information. The second type of models (Laffont and Tirole, 1986), considers a more general framework where moral hazard is added (the firm does not exert the maximum effort to reduce its costs) but where the principal can observe ex post (with audit) information on costs that he doesn't know ex ante. The main lesson of this literature is that second-best pricing must tradeoff information rent extraction and production efficiency.

2.2. An evaluation of French water practices

2.2.1. The French water sector

The water and wastewater industry in France is organized on a municipal basis. French local communities have been responsible for water supply, treatment and sanitation since 1790. But local communities really started to organize water delivery since the middle of the 19th century. There are approximately 13,500 water services in France (for 36,851 local communities). Most of them serve a single municipality: only 2000 water services serve more than one municipality.

French local communities can either directly manage water services or delegate it to a private firm.[4] In case of private management, the relationship between the local municipality and the firm can take different forms: management contracts, affermage (lease contract) where the municipality remains the owner of assets, and concession where the private operator is responsible for financing all new investments over the period of delegation. Typically, all these contracts specify the nature of expected services and the water pricing schemes (including price updating formula). Affermage is the most common form of contract; contract length can vary from 7 to 12 years. The private firm has the responsibility for operation and maintenance of the water utility, it collects tariff revenues from users and pays a special additional charge to the local community, which is included in the water rate determined by the contract. Whatever the type of management chosen by local communities (public versus delegated), water services must have the characteristics of a public service: equal access for all consumers, continuity, and adaptability to the general interest.

[4] The private sector participation in the French water industry started in 1853 with the founding of the Générale des Eaux (renamed Vivendi Environnement in 1999, and Veolia Environnement in 2003). The delegation of water services is now governed by the "Sapin Law", 23 January 1993.

The participation of the private sector has progressively increased in France during the 20th century. For the water service, the market share (in terms of customers) of the private sector was 17% in 1938 and 44% in 1964 (Owen, 1998). According to the French Ministry of Environment, it is now 79%. Private sector participation in sewage service is less prominent with an estimated market share of 53% in 2000. The main characteristic of the private sector is its oligopolistic form with three major companies: Générale des Eaux (Veolia Environnement), Lyonnaise des Eaux (ONDEO-SUEZ group) and SAUR (Bouygues group). They represent the quasi-totality (98%) of the private market (other private companies operate at a local level but their weight remains small).

There is no centralized public authority in charge of the regulation of the water industry in France. Economic regulation of delegated services results in fact from two elements. First, a national legislative framework governs both the form of the private sector participation, and the conduct of the delegation bidding process. The Sapin Law (1993) and the Barnier and Mazeaud Laws (1995) are the main legislative texts defining these relationships between local communities and private firms. The second form of regulation is directly carried out by local communities via the content of the delegation contract. The delegation contract sets the price and also describes the obligations of the private operator (both in terms of service and economic information that must be given each year to the local community). Water price for the first delegation year is computed from financial forecasts. For the following years, a rate revision rule based on input price index changes is used. The main sanction in case of non-respect of delegation rules is the non-renewal of the delegation contract.

Environmental regulation takes place both at the national level through the Ministry of Environment and at the European level with the growing importance of European Commission regulation.[5] For WUies, stringent quality standards must be respected. At a regional level, river basin Water Agencies in France have adopted a resource conservation policy based on effluent emission and extraction charges for industrial and domestic users.

2.2.2. *Structure of French water prices*

The first component of the price paid by final users corresponds to the supply process (involving extraction of water, treatment and distribution to customers). It represents, in 2000, 42% of the price paid by a user consuming 120 m^3 per year,[6] see Table 1. The second part of the price corresponds to sanitation service: used water is collected in sewage and pumped to treatment facilities where it is treated before being discharged into rivers, estuaries or sea. This second component represents 31% of the water price in 2000. The last part corresponds to taxes and fees (27% of the total price): River Basin Agency fees charged by the six French Water Agencies,[7] National Fund for the Development of Water Supply System fee and value added tax (VAT) at 5.5%.

[5] At the European level, two important European Commission directives deal with the quality of surface water for the production of drinkable water (16 June 1975), and with the quality of water for human consumption (15 July 1980).

[6] In France, the average water consumption of a representative household is around 120 m^3 per year.

[7] The Basin Agency Fees include abstraction and pollution charges. Abstraction charges vary by location of user and type of resource (ground water or surface water). Pollution charges are based on pollution emitted by users. The number and the type of pollutants considered for taxation vary across Water Agencies.

Table 1
Recent trend in average water price in France

	1995 (€/m^3)	1996 (€/m^3)	1997 (€/m^3)	1998 (€/m^3)	1999 (€/m^3)	2000 (€/m^3)	Δ1995–2000
Water	1.01	1.04	1.07	1.08	1.10	1.11	10.6%
Sanitation	0.71	0.78	0.78	0.80	0.82	0.83	17.5%
Taxes	0.57	0.66	0.66	0.68	0.70	0.71	23.2%
Total	2.29	2.48	2.51	2.56	2.62	2.65	15.9%

Source: DGCCRF (2000). *Notes*: The first column of each year corresponds to the average price in €/m^3 for 120 m^3. Taxes include French Water Agency fees, National Fund for the Development of Water Supply System fee and value added tax.

Concerning the pricing policy, using a two-part tariff is compulsory since 1994, with a fixed charge corresponding more or less to provisions for capital stock renewal and debt service, and a marginal price corresponding to operating expenses.[8] Denoting the fixed charge by FC and the marginal price by P, the two-part tariff for an annual water consumption of q is $\mathrm{FC} + Pq$. The fixed charge may be rewritten as:

$$\mathrm{FC} = (\mathrm{FC}_{\mathrm{w}}^{\mathrm{d}} + \mathrm{FC}_{\mathrm{s}}^{\mathrm{d}} + \mathrm{FC}_{\mathrm{w}}^{\mathrm{lc}} + \mathrm{FC}_{\mathrm{s}}^{\mathrm{lc}})(1 + \mathrm{VAT}) \tag{4}$$

where $\mathrm{FC}_i^{\mathrm{d}}$, and $\mathrm{FC}_i^{\mathrm{lc}}$ $i = \mathrm{w, s}$ are parts of the fixed charge paid respectively to delegated firm and local community for water service $i = \mathrm{w}$ and sanitation service $i = \mathrm{s}$. The term VAT denotes the VAT paid by users. The marginal price of water may be written as

$$P = (P_{\mathrm{w}}^{\mathrm{d}} + P_{\mathrm{s}}^{\mathrm{d}} + P_{\mathrm{w}}^{\mathrm{lc}} + P_{\mathrm{s}}^{\mathrm{lc}})(1 + \mathrm{VAT}) + \mathrm{TAX}. \tag{5}$$

TAX denotes the Basin Agency Fees paid for abstraction and pollution by users to the Water Agencies. Water price in France has increased during the first half of the 1990s, largely due to the implementation of the European Urban Waste Water Treatment Directive. According to the French Finance Ministry, water price has risen by 46.3% over the period 1991–1996. The nominal increase of water price has been reduced to 15.9% from 1995 to 2000, see Table 1.

2.2.3. *Some possible sources of prices inefficiencies*

2.2.3.1. Average costs. Prices are derived from an accounting system that emphasizes historical rather than economic costs and they are based on artificial unit costs. The water price is in general set such as the expected revenues from water sales cover the forecasted expenses. This is very close to an average-cost pricing. Moreover, the accounting observed cost may not correspond to the true economic cost. This is for example the case when a single operator manage water services for different local communities. The allocation of joint costs (general administrative expenses) to each service can be used by the private operator either to subsidy a given local community or to artificially increase accounting costs. This may explain why consolidate profits of the operator can appear positive whereas declared profits at the local community level are sometimes negative. The marginal costs of

[8] Some utilities use more complex pricing like block-rate-structures where the unit charge may decrease with the amount consumed (decreasing block-rate-structure) or may increase (increasing block-rate-structure).

supply and factors that may be expected to influence them are neglected in the rate-setting exercise. It follows that marginal-cost pricing still remains in France the exception.[9]

2.2.3.2. Social value of water. In order to be efficient, the marginal price of water faced by consumers must be equal to the marginal social cost, Eq. (1). It is clear that the full economic cost of water and the cost of the water utilities may not coincide for two main reasons. First, unless water is purchased from a regional wholesaler, it is typically assigned no value. Thus, the price faced by consumers represents more the cost of treating, storing and delivering water rather than the value of water itself. Second, prices may reflect the costs of delivery but they may not incorporate the social cost of water treatment once consumption has taken place. This is especially the case when sewage treatment is administered by a separate utility or municipal department. Last, the social value of water should be represented by the River Basin Agency fees. However, theses fees are computed in order to balance Water Agencies' budgets. They may significantly differ from environmental social marginal damages.

2.2.3.3. Weak enforcement of economic regulation by local communities. As mentioned previously, the economic regulation of delegated services is directly carried out by local communities. Local communities must ensure that users interests are protected. In term of price efficiency, this creates a number of problems. First, due to information asymmetry, local communities are not always in a good position to exercise an efficient control of water service providers. Due to long periods of water service delegation, some communities lack technical expertise to evaluate the delegation contract. This is especially true for small communities with limited financial resources. Second, the main sanction available (non-renewal of the contract) may not be credible. A recent survey by GEA-ENGREF (2003) has shown that renegotiation of delegation contract in 2001 has resulted in a change of private operator in only 11% of cases. Third, ex ante competition between private operators, via the bidding process for the delegation contract, is quite limited. The GEA-ENGREF survey has shown that around one-third of local communities get a bidding offer from only one private company.

2.2.3.4. Non-discriminatory pricing. Price differences across consumer groups are not tied to differences in the marginal-cost of service. Factors such as distance from the supply center and the period of consumption do not directly enter the pricing scheme. Therefore, whether an individual's consumption occurs when excess capacity exists or when aggregate consumption is constrained by system capacity is irrelevant to the price of output for most WUies.

3. Specification and estimation of the model

In order to analyze current water pricing practices of French water utilities, we first have to characterize the structure of costs and water demand.

[9] The "Canal de Provence" Company is one of the few water utility implementing marginal cost pricing for all user types. This situation differs from other European countries such as England and Wales where the economic regulator requires all water utilities to submit estimates of their marginal costs of providing water services.

Two limitations of our analysis should be pointed out. First, as we do not have any cost information on sanitation service, we only consider pricing practices for water supply. It follows that cross-subsidy effects between water and sanitation services delegated to the same private firm cannot be considered here. However, such cross-subsidy effects are likely to be of limited importance. According to the French Administrative code for local communities ("Code des Communes"), water supply and sanitation are viewed as distinct public services and following article L. 322-5 of this code, the budgets for each service must be balanced.[10] This should rule out any transfer from one budget to another. Moreover, in the case of delegated management, it is not possible to set a unique contract for both water supply and sanitation services. Hence, the expenses and revenues of each service are well identified and they can be analyzed independently. Second, as the level of taxes (basin agency fees) may not coincide with the social marginal value of water, the resulting price faced by final users may not correspond to the full economic cost. This issue, although important, is not addressed here as we only consider pricing of water services delegated to private firms. However, the recent and very important increase of taxes in France[11] has substantially reduced the gap between the marginal social value of water and its price.

3.1. Cost and demand specifications

A water utility sells to final customers a water volume Q, with a network rate of return r defined as the ratio of water sold to final customers to water injected into the distribution network. Water losses are a typical feature of water networks. As losses represent in France 25% on an average, they must be taken into account when estimating a water cost function. This is especially true as water utilities can use losses as an adjustment tool for production decisions. The production process uses four inputs: labor L, electricity E, material M, and capital K. We assume that the production technology adapts slowly to technological innovations and that, for a given network, the technology is the same for all production units. Since WUies face a different production and network environment, our specification takes into account the characteristics of the served area such as the number of metered connections (denoted by the number of customers n) and the size of service (represented by the length of network Leng that is the proxy variable of the water utility capital K). We assume that a water utility minimizes its operating expenses $w_{\mathrm{L}}L + w_{\mathrm{E}}E + w_{\mathrm{M}}M$, conditional to Leng (the quasi-fixed input) and other technical variables. The utility's short-run variable cost function can then be defined as

$$\mathrm{VC} = \mathrm{VC}(w, Q; r, n, \mathrm{Leng}), \tag{6}$$

[10] The French Law introduces however, some flexibility for small services. According to the Barnier Law "the local communities with less than 3000 inhabitants may set a unique budget for the water supply and sanitation services if the two services follow the same rules in terms of VAT and if the type of management chosen by the local community is the same." However, "the budget and the water bills have to make clear the allocation between the operations related to water supply and those related to sanitation."

[11] Taxes represent now more than 25% of the price. This price component has registered during the last decade the fastest increase (+256% for Basin Agency Fees and +115% for other taxes from 1991 to 1998).

where VC are (minimal) variable costs and $w = (w_L, w_E, w_M)'$ is the vector of variable input prices. We use the well-known translog approximation first introduced by Christensen et al. (1973) to represent the variable cost function.

This is a second-order Taylor expansion around the mean of observations, hence all right-hand side variables must be normalized by their sample mean, White (1980). Moreover, we impose the symmetry of the Hessian matrix as well as linear homogeneity in input prices by dividing variable cost and input unit prices by the price of a given input.[12] As Garcia and Thomas (2001) have shown that homotheticity of cost cannot be rejected, we impose homotheticity by restricting parameters associated with cross-products between outputs and input prices to be zero. Thus, the translog variable cost function is:

$$\begin{aligned}\ln\left(\frac{\mathrm{VC}}{w_L}\right) &= \alpha_{c1} + \sum_j \alpha_j \ln\left(\frac{w_j}{w_L}\right) + \alpha_Q \ln(Q) + \alpha_r \ln(r) \\ &\quad + \sum_k \alpha_k \ln(A_k) + \frac{1}{2}\sum_j \sum_{j'} \alpha_{jj'} \ln\left(\frac{w_j}{w_L}\right) \ln\left(\frac{w_{j'}}{w_L}\right) \\ &\quad + \frac{1}{2}\alpha_{QQ}(\ln(Q))^2 + \frac{1}{2}\sum_k \sum_{k'} \alpha_{lm} \ln(A_k) \ln(A_{k'}) \\ &\quad + \sum_j \sum_k \alpha_{jk} \ln\left(\frac{w_j}{w_L}\right) \ln(A_k) + \sum_l \alpha_{Qk} \ln(Q) \ln(A_k), \end{aligned} \tag{7}$$

where subscripts running are $j, j' = E, M; k, k' = 1, 2$, with $A_1 =$ Leng and $A_2 = n$. Using Shephard's lemma and denoting S_j the cost share of input j, we can write:

$$S_j = \frac{w_j x_j}{\mathrm{VC}} = \frac{\partial \ln(\mathrm{VC}/w_L)}{\partial \ln(\omega_j/w_L)} = \alpha_j + \sum_{j'} \alpha_{jj'} \ln\left(\frac{w_{j'}}{w_L}\right) + \sum_k \alpha_{jk} \ln(A_k). \tag{8}$$

Water is used by domestic consumers as a final good. As a result of a utility maximization program, domestic water demand is determined by a set of variables, including the marginal price of water P^D faced by the average domestic user and some characteristics X^D of the representative user such as age, housing size or income. Water is also used by industrial users. Industrial water use is a typical example of a producer's derived demand for an input (Renzetti, 1992a or Reynaud, 2003). Firm's cost minimization results in input demands, including water demand. We assume that water is separable from other inputs. Due to data limitation, this assumption cannot be tested here. Reynaud (2003) shows however on a sample of industrial firms located in France that this assumption is satisfied. Hence, the water demand of a representative industrial user depends on the marginal price P^I and on some characteristics X^I of the representative industrial such as the number of employees or the type of activity. Considering that a final user of water may either be a domestic user or an industrial one, the aggregated water demand per consumer in a given local community is:[13]

[12] This is equivalent to imposing a set of restrictions on cost function $\sum_j \alpha_j = 1$, $\sum_j \alpha_{jj'} = \sum_{j'} \alpha_{jj'} = 0$, $\sum_i \alpha_{jk} = 0$.

[13] As we do not observe water consumption of domestic and industrial users, only an aggregate water demand can be estimated.

$$\frac{Q}{n} = f(P^{\mathrm{D}}, X^{\mathrm{D}}, P^{\mathrm{I}}, X^{\mathrm{I}}, X^{\mathrm{LC}}), \tag{9}$$

where X^{LC} represents a vector of variables characterizing each local community. This vector may for example include the proportion of industrial users located in each local community or the level of rainfall. Estimating (9) requires to specify the form of the demand function. For simplicity, we consider here a log–log form. Moreover, we use a single marginal price P in the demand function:[14]

$$\ln\left(\frac{Q}{n}\right) = \alpha_{\mathrm{c2}} + \alpha_{\mathrm{P}} \ln(P) + \sum_k \alpha_k \ln(X_k), \tag{10}$$

where $X = (X^{\mathrm{D}}, X^{\mathrm{I}}, X^{\mathrm{LC}})$. It follows that the estimated coefficients of the log–log demand function can be directly interpreted as elasticities.

3.2. Econometric methodology

It is possible to separately estimate the translog cost function and the demand function, but it would lead to an efficiency loss. Typically, water pricing is based on an equilibrium between water supply and demand, and the endogenous variables (price and quantity) are simultaneously determined by a set of exogenous factors. By adding an error term to each equation, it is expected that the nature of simultaneity is translated into the correlation between these disturbances.[15] This is why we employ a full-information method by estimating the system of equations consisting of the variable cost equation, and all but one cost share equations (we drop the labor cost share[16]) and the demand equation.

The error term of each equation is assumed to be independently and identically distributed. As we have panel data, it consists of an unobservable individual specific effect and the usual independently and identically distributed error term. We write the above system in a more compact way as follows:

$$Y = R\beta + \varepsilon, \tag{11}$$

where Y is the ($MHT \times 1$) vector of dependent variables, M the number of equations in the cost system, H the number of utilities, T the number of period and K the number of parameters. R is the $MHT \times K$ matrix of regressors, β the parameter vector and ε is a $MHT \times 1$ error vector.

As discussed later, some variables in the left-hand side term of the system are considered as endogenous. We choose to use the Generalized Method of Moments (GMM, see Hansen, 1982) to estimate the parameter vector β with panel data. Following Cornwell et al. (1992), it is based on L orthogonality conditions: $E[A'(Y - R\beta)] = 0$, where A is a $MHT \times L$ matrix of valid instruments. For equation m, we choose the instruments of Hausman and Taylor

[14] Domestic and industrial users face different average water prices, mostly because of important differences in fixed charges. Nevertheless, the marginal prices are not significantly different.

[15] This correlation may also result from the fact that the endogenous variables have common unobserved determinants.

[16] As $\sum_i S_i = 1$, one of the cost shares is dropped to avoid singularity of the variance–covariance matrix of errors.

(1981):[17] $A_{\mathrm{m}} = [WX_{\mathrm{m}}, X_{(1)\mathrm{m}}, Z_{(1)\mathrm{m}}]$, where $WX = \{X_{it} - \bar{X}_i\}$ for all i and t, and X the matrix of time-varying (exogenous and endogenous) variables, $X_{(1)}$ the matrix of time-varying exogenous variables and $Z_{(1)}$ the matrix of time-invariant exogenous regressors.

The moment conditions are approximated by their empirical counterpart and the general GMM criterion to be minimized is:

$$\left(\frac{1}{HT}A'(Y - R\beta)\right)' V \left(\frac{1}{HT}A'(Y - R\beta)\right), \tag{12}$$

where V is an arbitrary positive definite weighting matrix ($L \times L$). The expression for the efficient GMM is achieved by replacing this weighting matrix by the inverse of the variance–covariance matrix of the set of orthogonality conditions: $V = \Phi^{-1}$ with $\Phi = E[A'(Y - R\beta)(Y - R\beta)'A] = E[A'\Sigma A]$.

Our estimation typically proceeds in two steps: first we estimate the parameter β with a unit variance–covariance matrix for error terms (instrumental-variable method), and then we minimize the GMM criterion above where Σ is replaced by its first-stage estimate. This produces heteroskedasticity-consistent parameter estimates. The GMM estimator of the system (11) is:

$$\hat{\beta}_{\mathrm{SGMM}} = (R'A\hat{\Phi}^{-1}A'R)^{-1}R'A\hat{\Phi}^{-1}A'Y, \tag{13}$$

where

$$\hat{\Phi} = \frac{1}{H}\sum_{h=1}^{H} A'_h \hat{\Sigma} A_h,$$

with

$$\hat{\Sigma} = \frac{1}{H}\sum_{h=1}^{H} \hat{\varepsilon}_{h,\mathrm{IV}} \hat{\varepsilon}'_{h,\mathrm{IV}}$$

and $\hat{\varepsilon}_{h,\mathrm{IV}}$ is the first-step instrumental-variable residual.

The GMM criterion is distributed as a χ^2 with $L - K$ degrees of freedom under the null hypothesis that moment conditions are valid. This is the Hansen specification test, where there are $L - K$ over-identifying restrictions that are not necessary to identify β, but convey information that is used to check the model specification. In particular, if the designed instrument set contains endogenous variables (correlated with the individual effect and/or the time-varying error term), the Hansen test detects departure from the null hypothesis, and the instruments matrix has to be modified accordingly.

3.3. Data description

We use a panel data sample of 50 WUies in the Bordeaux area of period 1995–1998 corresponding to a total number of 200 observations. All utilities are privately operated,

[17] There exist more efficient instrument-variable procedures, see Amemiya and MaCurdy (1986) and Breusch et al. (1989). However, the number of overidentifying restrictions is already important. Adding more instruments may lead to biased estimates in the case of small samples.

i.e., delegated to private companies (Générale des Eaux-Veolia Environnement, Lyonnaise des Eaux, Electricité Services Gironde, SOGEDO, SAUR-CISE). Descriptive statistics for cost and demand variables used are presented in the Appendix A.

3.3.1. Cost function

The main source of data comes from financial and technical reports made available by the Gironde Local Administration for Agriculture and Forest (DDAF, 1995, 1996, 1997, 1998). These reports contain information on total operating and maintenance costs, water volumes produced, electricity and labor inputs, as well as technical data on networks. The other sources of data are a mail survey we directed toward local communities, and financial and internal reports provided by Electricité Services Gironde company marketing services. From this additional source, data on input costs and network features were complemented.

Water utility variable cost is the sum of labor L, electricity E, materials and other expenses M. The fixed costs or capital expenditures CE are the expenses related to investments. They take into account the economic value of the facilities plus their costs of financing. The volume produced and sold to final customers, Q, is the sum of volumes charged to customers in the community, and volumes sold to other communities. Labor input is defined as total hours worked per year. The unit labor price w_{L} (including employer contribution to social security and pension benefit programs) is obtained by dividing wage expenses by total worked hours. The unit price of electricity w_{E} is defined as the ratio of total electric power expenditures divided by the total quantity of electricity used. Material expenses consist of different categories of heterogeneous costs obtained by consolidating financial accounts like stocking, maintenance work, and subcontracting. Because of data limitations and the problem of heterogeneity of this input, we choose to construct a price index for input materials w_{M} as a unit cost per cubic meter delivered.

The cost model includes technical variables such as the number of customers n and the network rate of return r defined as the ratio of the water volume sold to final customers and the volume delivered at the entry of distribution network, but also network length Leng representing the existing capital.

3.3.2. Water demand

Estimating water demand requires an important amount of data. Specific water variables for years 1995–1998 were found in the water authority's technical reports. Other socio-economic variables for 1995–1998 comes from the Institut National de la Statistique et des Etudes Economiques (INSEE). Last, variables describing housing characteristics are obtained from the 1990 French census.

The explained variable Q/n (m^3) is the water consumption per customer in a local community. The variable P (€/m^3) is the marginal price of water service paid by the average user. It includes the marginal price of water delivery, the marginal price of sanitation and the various taxes paid by the final user. Variables characterizing domestic users, X^{D}, are the average taxable income I from 1995 to 1998 (€ per fiscal household), the number of dependents per fiscal household $\mathrm{Size}^{\mathrm{D}}$ from 1995 to 1998, the proportion of housing not equipped with a bath or a toilet (%) in 1990, and the proportion in 1990 of housing built after 1982, $H82$ (%). Industrial users are characterized by X^{I} which includes for each year the average number of employees Size^{I} and the proportion of firms operating in the electricity, gas, water and construction sector Sect. Local community characteristics, X^{LC}, include the proportion of industrial users Prop and the level of summer rainfall Rain (in mm).

3.4. Discussion of estimation results

Some exogeneity assumptions are required in order to construct orthogonality conditions for the GMM criterion. There are several sources of potential endogeneity in our system of equations. First, the assumption that WUies take input prices and output levels as fixed may not be verified. In particular, the water volume sold is endogenous in the demand equation. Second, as the material unit price is computed as a function of the water output, it may also be endogenous. The assumption of endogeneity of water price is usually made for the demand equation because the price results from a negotiation process between the municipal council and the operator (the outcome of this process depends on several cost and demand variables). For these reasons, we assume that water sold to customers, material price and water marginal price are endogenous variables.

The matrix of instruments consists of time-varying regressors centered by the Within transformation (WX_{m}) for each equation, of $X_{(1)\text{m}}$ containing all time-varying regressors but the endogenous variables cited above (Q, ω_{M}, P), and their associated cross-products, $X_{(2)\text{m}}$. The matrix of instruments also contains $Z_{(1)\text{m}}$, the vector of exogenous time invarying. There are 30 parameters to be estimated with 56 instruments. We check for the validity of moment conditions with the Hansen test statistic, which equals 11.0138 with 26 degrees of freedom. The P-value of the test is 0.9955: our instruments are neither correlated with the individual specific error term nor with the time varying error term. Hence, the model seems to be well specified. Estimated parameters are presented in Table 2.[18]

The price-elasticity of water demand given by α_{P} is -0.2542. This low value is consistent with what is found in the empirical literature on residential and industrial water demand, see Nauges and Reynaud (2001) and Renzetti (1992a). The income-elasticity is positive but not significantly different from 0. Another point of interest is given by the coefficient associated to $H82$. The positive sign for $H82$ means that local communities with a high proportion of recent housing use relatively more water, all other things being equal. A possible explanation may be that new housing are more often equipped with water-consuming equipment such as a swimming pool or air conditioning. As expected, the sign associated to Prop is positive and significantly different from zero: the higher the proportion of industrial users is, the higher is the consumption per user.

We now consider how the number of customers and the size of the network affect the variable cost function. Considering both customer and network sizes allows to distinguish between returns to density and returns to scale (see Roberts, 1986 for a definition in a model of electricity costs). The elasticity of density (DENS)[19] measures the cost savings

[18] We also have separately estimated the cost and the demand functions. We get similar results but less efficient parameter estimates.

[19] DENS is computed as the inverse of elasticity of cost with respect to output: $\text{DENS} = 1/\varepsilon_Q$. Returns to density are increasing (economies of density), constant or decreasing when DENS is greater than 1, equal to 1 or less than 1, respectively.

Table 2
Parameter estimates

Parameter	Variable	Estimate	Standard error
Cost parameters			
α_{c1}	Const1	8.4399***	0.0161
α_{E}	w_E	0.0952***	0.0016
α_{M}	w_M	0.4510***	0.0056
α_{Q}	Q	0.7263***	0.0485
α_{r}	r	−0.6723***	0.0476
α_{1}	Leng	−0.1380***	0.0224
α_{2}	n	0.3902***	0.0531
α_{EE}	$w_E \times w_E$	0.0436***	0.0023
α_{MM}	$w_M \times w_M$	0.1949***	0.0045
α_{EM}	$w_E \times w_M$	−0.0402***	0.0023
α_{QQ}	$Q \times Q$	−0.0026	0.2508
α_{11}	Leng × Leng	0.3321***	0.0643
α_{22}	$n \times n$	0.0184	0.2546
α_{12}	Leng × n	−0.3284***	0.0835
α_{E1}	w_E × Leng	0.0317***	0.0033
α_{E2}	$w_E \times n$	−0.0295***	0.0035
α_{M1}	w_M × Leng	0.0843***	0.0108
α_{M2}	$w_M \times n$	−0.0636***	0.0114
α_{Q1}	Q × Leng	0.0692	0.0748
α_{Q2}	$Q \times n$	0.0930	0.2408
Demand parameters			
α_{c2}	Const2	4.4993***	0.2675
α_{I}	I	0.0271	0.0423
α_{P}	P	−0.2542***	0.0528
α_{D}	Size^{D}	0.0599**	0.0277
α_{I}	Size^{I}	0.1808***	0.0262
α_{Sect}	Sect	0.0570***	0.0160
α_{Bath}	Bath	−0.0514	0.0300
α_{Prop}	Prop	0.3244***	0.0402
α_{H82}	H82	0.0459*	0.0270
α_{Rain}	Rain	−0.0003	0.0060

Notes: $H = 50$, $T = 4$. See Appendix A for definition of variables. $\bar{R}^2$ for VC, Q/n, S_E and S_M are 0.9592, 0.2561, 0.4594 and 0.6696, respectively.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

that result from an increase of production when we hold the number of customers and the network size constant (i.e., the demand per user increases). We define the elasticity of scale (SCE)[20] as the proportional increase of water volume and number of users made possible

[20] SCE is computed as the inverse of the sum of the elasticities of cost with respect to output and cost with respect to number of users multiplied by one minus the elasticity of cost with respect of network length: SCE $= (1-\varepsilon_{\text{Leng}})/(\varepsilon_Q+\varepsilon_n)$. Even if long-term considerations are directly embodied in computation of SCE, these returns to scale are equivalent to long-term ones only if the current level of capital is optimal or if the production technology is homothetic (Panzar, 1989). Returns to scale are increasing (economies of scale), constant or decreasing when SCE is greater than 1, equal to 1 or less than 1, respectively.

Table 3
Estimates of returns to scale

Length (km)	Number of WUies	Estimate	Standard error
[9–76]	64	1.049	0.020
]76–166[	80	1.015	0.012
[166–889]	56	0.985	0.024

Notes: All elasticities are computed at the variables sub-sample mean. Standard errors are computed using the delta method (Kmenta, 1986).

by a proportional increase of all inputs (including the capital represented by the length of the network).

At the sample mean, we find returns to density significantly different from 1 at a 5% level (DENS = 1.3769 with a standard error of 0.0920). Existence of economies of density for the average service means that an increase of demand per user will result in a decrease of its average cost. At the sample mean, returns to scale are not significantly different from 1 (SCE = 1.0193 with a standard error of 0.0117). This result contradicts the general opinion viewing water production and distribution as a perfect example of natural monopoly. However, the results are more ambiguous when we take into account the size of WUies. We have computed the elasticities of scale for three types of utilities ranked according to the network length and we find significant economies of scale (1.049) for the smallest utilities. Our results are reported in Table 3. Water services are local monopolies and there is an upper limit to the extension of network allowing increasing returns to scale.

4. An evaluation of French WUies pricing

4.1. Empirical comparison of costs and prices

We first turn to the question of efficiency of current WUies water pricing. Recall that we only deal with the water price of the operator excluding the sanitation price and the local community part. Table 4 gives some interesting information on current pricing: the

Table 4
Evaluation of WUies water pricing

	Number of WUies	Average marginal price (€/m^3)	Average marginal cost (€/m^3)	Average fixed charge (€ per user)	Average capital expenditure (€ per user)
Network length					
[9–76]	64	0.39	0.37	29.55	19.26
]76–166[	80	0.35	0.39	25.98	13.30
[166–889[	56	0.31	0.48	21.41	16.57
Number of users					
[257–1500]	75	0.35	0.40	23.52	21.75
]1500–2500[	46	0.37	0.41	24.71	14.00
[2500–17210[	79	0.35	0.42	28.71	12.02
Total	200	0.35	0.41	25.85	16.12

marginal water price and fixed charge paid by users to WUies, an estimate of marginal cost and the level of capital expenditures per user for different classes of network length and number of users. The analysis is made according to the size of the WU considered. Several remarks can be drawn from Table 4.

First, the structure of WU costs depends on the size of the water service. Small WUies (those with a small network or serving a limited number of users) have low marginal costs but high per capita capital expenditures. On the contrary, large WUies exhibit higher marginal costs and lower capital expenditures per capita. Hence, the trend seems to be a marginal-cost increase and a per user capital expenditure decrease with the size of WUies.

Second, pricing depends on the size of the WU considered. WUies with a small network (length smaller than 76 km) price water above their marginal cost. Remember that small WUies operate under increasing returns to scale. Hence, marginal-cost pricing would result in a deficit that would have to be covered with very high fixed charges. Such a pricing may be in contradiction with some social objectives of local communities. For other WUies, the marginal price of water is lower than the marginal cost. These utilities have constant or decreasing returns to scale, see Table 3. This seems to be an evidence that most of the French water utilities use average-cost pricing. Last, the difference between marginal price and cost increases with the size of WUies.

Third, WU pricing is in most cases inefficient: the marginal price differs from the marginal cost. On an average, WUies tend to price water under their marginal cost. The average marginal price on the whole sample is € 0.35 with a standard deviation of 0.16. The average marginal cost is estimated at € 0.41 with a standard deviation of 0.10. The gap between the marginal price and the marginal cost of water service is quite low but significantly different from zero.[21] This result may be explained by the constant nature (on average) of returns to scale implying that average and marginal costs are very close, and by the utilities' practice of average-cost pricing.

Moreover, this difference could be related to the level of the fixed charge. The average fixed charge (€ 25.85 per user) is more than one half the average capital expenditures (€ 16.12 per user). An interpretation of this result may be that WUies try to secure their revenues through fixed charges. By recovering some variable costs through fixed charges, they reduce financial risks which may derive from the volatility of water consumption. A consequence of these water pricing practices is under-pricing of water. In the long-run, as residential water uses increasingly take, at least in part, some characteristics of a luxury service,[22] under-pricing of the service will provide an environmentally-damaging and economically-misleading signal to consumers.

We have answered the first question addressed in the introduction of this paper. The pricing system of WUies is not socially efficient although the price is close to the estimated marginal cost. Two questions still remain. First, what is efficient pricing? Second, what are the welfare gains to be expected from reforming the pricing of French WUies? We discuss these two points in the last section of the paper.

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[21] The null hypothesis of an average marginal price equal to the average marginal cost is rejected at a 1% level of significance. The Student's t-test statistic, equal to 4.21, is greater than $t_{200,0.99} = 2.34$.

[22] In 1997, only 7% of domestic water use in France corresponds to direct human consumption, see Maresca et al. (1997).

4.2. Moving toward efficient water prices

Our objective is to define for each WU the optimal pricing scheme. A pricing scheme is summarized here by a marginal price $P_w^{d^*}$ and a fixed charge $F_w^{d^*}$ paid by users to the WU. As mentioned previously, the optimal marginal price is equal to the marginal cost. The computation of the optimal fixed charge is less straightforward as it cannot rely on efficiency considerations. From the social planner's point of view, a fixed charge is just a monetary transfer from customers to WUies. It follows that the social planner must arbitrate between social and/or redistributive considerations, such as access to water for poorest households, and recovering of WUies long-term costs for determining the level of the fixed charge. We discuss this point in the second paragraph of this section but we first compute the optimal marginal price.

4.2.1. Characterization of efficient marginal prices

The optimal marginal price paid by users to the water utility is obtained by equaling the marginal price to the marginal (private) cost.[23] It follows that $\{P_w^{d^*}, Q^*\}$, where Q^* is the optimal water consumption, is solution of the system:

$$\begin{cases} Q = Q(P, X^{\mathrm{D}}), \\ P_w^d = MC(Q, X^{\mathrm{S}}). \end{cases} \tag{14}$$

X^{D} represents the vector of other variables in the demand and X^{S} represents the other variables in the costs. The demand function in system (14) is non-linear with respect to marginal price. The approximation of the cost function by a translog form is a non-linear function of water distributed, so that the marginal-cost function is non-linear as well. It follows that the system (14) is non-linear with respect to (P_w^d, Q). Finding solutions to this system requires a numerical procedure. Simulations of optimal prices and quantities are realized using the NLSYS procedure of GAUSS.

Columns 1–4 of Table 5 report the observed prices and corresponding predicted quantities (marked with a superscript '0'), versus the simulated first-best equilibrium prices and quantities (marked with a superscript '$*$'). Examination of these results reveals that the new pricing rule leads to a 8.5% increase of the marginal price, from €0.35 to €0.38. The optimal price is smaller than the observed price only for WUies with network length less than 76 km on average. When we have a closer look at the price changes with respect to the size of WUies, we can note that the first-best marginal price increases with the size of the service. Moreover, the larger the water service is the more important the gap between actual and simulated prices. This suggests that the largest WUies are farther away from the efficient pricing.

Concerning the water quantities consumed, it is not surprising to observe that the quantities associated to simulated first-best prices are lower than the actual quantities since the

[23] The total marginal water price paid by a user (P^*) includes the marginal price paid to the delegated water utility (P_w^d), to the local community (P_w^{lc}) and to the state (TAX and VAT), see Eq. (5). As mentioned previously, the level of taxes has significantly increased in France during the last 10 years. The deviation between taxes and scarcity rent is assumed to be negligible.

Table 5
Simulation of WUies efficient water pricing

	P_{w}^{d0} (€/m^3)	P_{w}^{d*} (€/m^3)	Q^0/n (m^3)	Q^*/n (m^3)	S^0 (€ per user)	S^* (€ per user)	Π^0 (€ per user)	Π^* (€ per user)	Efficiency gain (€ per user)
Network length									
[9–76]	0.39	0.32	131.5	132.7	91.04	99.90	−11.98	−20.66	0.19
]76–166[	0.35	0.39	132.6	132.3	100.79	95.31	−14.40	−8.54	0.38
[166–889[	0.31	0.42	137.3	135.5	107.06	94.09	−12.11	1.27	0.40
Number of users									
[257–1500]	0.35	0.36	130.8	130.6	103.91	108.61	−21.56	−26.00	0.26
]1500–2500[	0.37	0.38	135.0	135.5	83.30	86.09	−2.93	−5.34	0.38
[2500–17210[	0.35	0.39	135.4	134.3	104.55	90.95	−10.70	3.31	0.36
Total	0.35	0.38	133.6	133.1	99.38	96.44	−12.98	−9.67	0.33

Notes: S denotes the net surplus of the average user, Π net profit of a WU. Superscript ‘$*$’ indicates simulated first-best variables and superscript ‘0’ indicates observed and predicted variables.

Table 6
Welfare changes from moving to WUies efficient pricing

	User (€ per user)	WU (€ per user)	Local communities (€ per user)	State (€ per user)	Resource (€ per user)	Total (€ per user)
Scenario 1	−2.99	3.32	0.07	−0.69	1.15	0.71
Scenario 2	0.51	0	−0.11	−0.69	1.15	0.71

Note: Total corresponds to the sum of surplus changes.

marginal price increases on average. First-best marginal pricing results in a 0.4% decrease of water consumption per user.

4.2.2. Welfare efficiency gain

Moving to MCP results in a welfare efficiency gain. If the marginal price differs from the marginal cost then consumers do not receive an appropriate signal about the cost of a marginal increase of demand.

Columns 5–9 in Table 5 give a measure of efficiency gains to be expected from first-best pricing. As it is common practice in applied analysis, we estimate approximated surplus variations using Marshallian demands.[24] Several comments can be drawn from Table 5. First, the estimated profit per user at the observed price level is negative (€ −12.98 per user on average). This could be surprising but most of financial accounts published by WUies report negative profits. From our computations, the main result is that welfare gains resulting from moving to efficient prices are small. On average, they are equal to € 0.33 per user which corresponds to less than 0.4% of the initial net welfare. This result contrasts with previous studies. Swallow and Marin (1988) have shown that efficient prices would result in a welfare increase of 2%. In Renzetti (1992b), moving to seasonally differentiated pricing raises aggregated surplus by approximately 4%. Three explanations may be advocated. First, as the aggregated water demand function is very inelastic, changes in water prices only result in small modifications of water consumption. Second, the small level of efficiency gains could also be related to the return to scale of the WUies (constant on an average) and the fact that utilities use average-cost pricing. The third explanation is that efficient prices are computed considering only the delegated part of the water service, $P_{\mathrm{w}}^{\mathrm{d}}$. We should also take into account the sanitation part of the price in order to derive true optimal prices. However, the small welfare gains to be expected from moving toward efficient prices does not mean that water pricing efficiency must be neglected by public authorities. First, moving to efficient prices results in a decrease of water consumption. The yearly aggregate water consumption per user goes from 133.6 to 133.1 m^3. The pricing reform allows to save 0.4% of the actual water consumption. This amount of resource becomes available for alternative uses (recreative use, environmental purposes for example). Priced at the market price, the value of this water represents € 1.15 per user and per year (see Table 6). Second, the new pricing scheme gives more incentives to water conservation. Since marginal price increases on average from

[24] An exact measure of welfare changes would require using Hicksian demand curve. Hausman (1981) shows however that in the case of a single good it is possible to compute exact surplus variations using Marshallian demands. Moreover, as we do not observe Hicksian demands directly, computation of exact welfare measures still remains more complicated.

€ 0.35 to € 0.38, reduction of water consumption becomes more valuable. This should favor in the long run consumer's investments in low water-consumptive equipment.

4.2.3. Fixed charge, welfare and redistribution

We now turn to the computation of optimal fixed charges $F_{\mathrm{w}}^{\mathrm{d}^*}$. From the social planner point of view,[25] a fixed charge is just a monetary transfer from customers to WUies and to the State.[26] Here, we consider two possible scenarios. In the first scenario, we assume that $F_{\mathrm{w}}^{\mathrm{d}}$ remains constant before and after the marginal price changes. In the second scenario, we assume that all efficiency gains resulting from moving to efficient WUies prices are redistributed to consumers. So, the fixed charge paid to a given WU is computed in order to keep its profits constant before and after the pricing reform. $F_{\mathrm{w}}^{\mathrm{d}^*}$ is solution of:

$$(P_{\mathrm{w}}^{\mathrm{d}^*} Q^* + nF_{\mathrm{w}}^{\mathrm{d}^*}) - (\mathrm{VC}(Q^*, X) + \mathrm{CE}) = (P_{\mathrm{w}}^{\mathrm{d}^0} Q^0 + nF_{\mathrm{w}}^{\mathrm{d}^0}) - (\mathrm{VC}(Q^0, X) + \mathrm{CE}), \tag{15}$$

where CE represents capital expenditures, $P_{\mathrm{w}}^{\mathrm{d}^0}$ and $F_{\mathrm{w}}^{\mathrm{d}^0}$ are the observed marginal price and the fixed charge, Q^0 the estimation of water demand given the observed marginal price. Eq. (15) states that the net profit after a price reform for a given WU (left hand-side term) is equal to the net profit prior reform (right hand-side term).

We can now estimate the welfare changes resulting from first-best pricing. As mentioned previously, any modification of water pricing also modifies local communities and public authorities (Water Agency and State) revenue. A change in water price results in modifying water consumption and so revenue from taxation. A change in water price induces a modification of local communities revenue corresponding to: $(P_{\mathrm{w}}^{\mathrm{lc}} + P_{\mathrm{s}}^{\mathrm{lc}}) \times (Q^* - Q^0)$. Public authority revenue change includes modifications both of VAT and Water Agency charges revenue: $\mathrm{VAT}\ (P^* Q^* - P^0 Q^0) + \mathrm{TAX}(Q^* - Q^0) + \mathrm{VAT} \times n \times (F_{\mathrm{w}}^{\mathrm{d}^*} - F_{\mathrm{w}}^{\mathrm{d}^0})$. Changes in surplus and revenues collected are presented in Table 6. The resource gain in column 5 comes from the decrease in water consumption due to the marginal price increase. This water, available for alternative uses, is valued at its market price P^*.

In scenario 1, the fixed charge (equal on average to € 25.85 per user) remains constant before and after the marginal price reform. The marginal price increase is mainly borne by consumers. Under scenario 1, the net profit of WUies increases significantly (€ 3.32 per user corresponding to a 25% increase) whereas user's surplus decreases (€ −2.99 per user corresponding to a 3% reduction). Under scenario 2, the fixed charge goes down from € 25.85 per user to € 22.54 per user on average. The consumer' s surplus increase is equal to € 0.51 per user on average. Thus, the redistributive effects of water pricing seem to be more important than the efficiency effects. An optimal regulation of WUies should focus not only on the level of the marginal price but also on the computation of the fixed charge.

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[25] We consider here a utilitarist social planner maximizing the aggregate surplus of WUies and users.

[26] Remember that the fixed charge, FC, paid by a final user is: $\mathrm{FC} = (\mathrm{FC}_{\mathrm{w}}^{\mathrm{d}} + \mathrm{FC}_{\mathrm{s}}^{\mathrm{d}} + \mathrm{FC}_{\mathrm{w}}^{\mathrm{lc}} + \mathrm{FC}_{\mathrm{s}}^{\mathrm{lc}})(1 + \mathrm{VAT})$. Hence, any change in $F_{\mathrm{w}}^{\mathrm{d}}$ modifies the tax revenue collected by the State.

5. Conclusion

There is a large consensus for considering efficient water pricing as a prerequisite of any efficient water resource policy. Many countries are now engaged in some form of pricing reform.[27] However, welfare gains to be expected from moving toward efficient prices have rarely been estimated. This is the main point addressed in this paper where we discuss the effects of moving from actual French WUies pricing to marginal-cost pricing.

WUies pricing analysis requires to jointly take into account water supply and demand. In this paper, the production technology of WUies is modeled along a translog cost function and water demand is specified by a logarithmic form representing both domestic and industrial users. A consistent and efficient econometric method is used to estimate the supply–demand system of simultaneous equations. We compute elasticities related to demands and costs. We find low demand price-elasticity (−0.25) and income-elasticity (0.03) in accordance with previous estimations of the empirical literature. This seems to indicate that different price policies would not necessarily result in strong variations in water consumption and social surplus. On the supply side, we find that scale economies only exist for the smallest WUies. As we have shown, this result has direct implications on the marginal price and the level of the fixed charge.

Next, we evaluate the efficiency of current WUies pricing. This objective is achieved by estimating the marginal costs of water supply. We have shown that observed marginal prices and marginal costs are significantly different. The average marginal price on the whole sample is €0.35 and the average marginal-cost is estimated at €0.41. It follows that the current water pricing results in social welfare losses.

As the current pricing of WUies is not efficient, the next step of our analysis was to characterize the optimal pricing policy of WUies and to estimate the welfare gains to be expected from moving toward this optimal pricing. Achieving this objective requires to solve a supply–demand system where marginal price is equalized to marginal cost. Two results should be highlighted.

First, optimal pricing is characterized by an increase in marginal prices (from €0.35 to €0.38 on average). Second, efficiency gains from moving to efficient prices are almost negligible (roughly 0.4% of initial surplus). Nevertheless, two arguments may be given in favor of moving towards more efficient prices. First, we have only considered in this study the delegated part of the water supply service. The inclusion of other price components (wastewater service) in price changes may lead to more substantial welfare gains. Second, the new pricing encourages water savings. As the marginal price of water increases, any reduction of water consumption becomes more valuable. In the long-run, this should favor consumer's investment in low water-consumptive equipment.

Finally, we would like to mention that the distributional effects of the fixed charge are much more important than the effects of moving toward an efficient pricing. For example, the pricing when all efficient gains are given to users (scenario 2) is more compatible with some social objectives of local communities as the fixed charge decrease favors the poorest

[27] See, for example, Dinar and Subramanian (1997) who survey water pricing reform in 22 selected countries or OECD (1999) for pricing analysis in 17 OECD countries.

consumers. The high level of fixed charges set by the WUies seems to be an easy way for them to capture users surplus.

The setting-up of an independent water regulation authority (as OFWAT in UK) could be an interesting way to promote more pricing efficiency in the French water sector. But implementing such a regulatory authority in charge of information, refereeing and supervising relationships between operators and local communities would require to solve some very important problems. First, as water services are by the law local services, French local communities are directly responsible for these services. It follows that the regulatory authority would have to supervise a large number of delegation contracts and prices. The administrative costs of such a regulation authority may be very high. Second, problems may arise due to asymmetric information. When water supply cost parameters are unknown (adverse selection), the private operator has a strategic interest to overestimate its costs and consequently the production choices can be affected, see Garcia and Thomas (2003). The issue of moral hazard when effort of the operator is not observed by the local community has also to be accounted for. These problems have a significant impact on the contract-based relationship between both parties. A report by the Haut conseil du Secteur public (1999) recommended the creation of a future regulation authority of water and urban services in charge of elaborating technical standards, investments financing, prices index rules .... In June 2001, the French government proposed a law including the setting-up of such a regulation authority ("Haut Conseil du Service Public de l'Eau et de l'Assainissement"). The negotiations have been very grim, and progressively the prerogatives of this authority have been cut down. Finally, since the general elections in 2002, the project has been given up. Even if the direct welfare gains to be expected from moving towards more efficient water prices are small, such a regulation authority may be useful for the French water sector.

Appendix A. Descriptive statistics in the sample, 200 observations

Variable	Data	Mean	Standard deviation	Minimum	Maximum
Cost variables					
VC	Panel	221125	252010	20544	1558779
CE	Panel	42209	61738	0	387023
S_L	Panel	0.452	0.153	0.167	0.673
S_E	Panel	0.097	0.036	0.016	0.299
S_M	Panel	0.451	0.148	0.096	0.756
ω_L	Panel	29.85	1.51	24.18	33.81
ω_E	Panel	0.07	0.03	0.02	0.26
ω_M	Panel	0.19	0.07	0.04	0.41
n	Panel	3012	3213	257	17210
r	Panel	0.746	0.078	0.489	0.901
Leng	CS	154.18	160.97	8.66	889.40
Q	Panel	415520	507629	31755	3177604

Variable	Data	Mean	Standard deviation	Minimum	Maximum
Demand variables					
n^{D}	Panel	2585	2726	232	14720
n^{I}	Panel	426	524	21	2605
Prop	Panel	13.7	4.08	5.70	26.3
P	Panel	13.59	4.38	4.09	26.57
I	Panel	82.55	15.46	56.95	176.31
$\mathrm{Size}^{\mathrm{D}}$	Panel	0.52	0.21	0.28	2.24
Bath	CS	9.56	3.71	2.41	17.81
$H49$	CS	45.93	18.51	11.02	83.09
Rain	Panel	166.07	77.94	31.00	406.00
$\mathrm{Size}^{\mathrm{I}}$	Panel	3.02	1.68	1.29	10.48
Sect	Panel	0.25	0.13	0.04	0.70

CS: cross-sectional, panel: panel data, VC: total variable costs (€), CE: capital expenditures (€); S_{L}: cost share of labor input (%), S_{E}: cost share of electricity input (%); S_{M}: cost share of material input (%), w_{L}: unit labor price (€/h); w_{E}: unit electricity price (€/kWh), w_{M}: unit material price (€/m^3); n: total number of customers, r: water rate of return (%); Leng: network length (km); Q: water volume sold to final customers (m^3); n^{D}: number of domestic customers, n^{I}: number of industrial customers; Prop: proportion of industrial users (%); P: marginal price (€/m^3), I: average income (€ 10^3 per household); $\mathrm{Size}^{\mathrm{D}}$: number of dependents per household; Bath: proportion of home not equipped with bath or toilets (%); $H49$: proportion of housing built before 1949 (%); Rain: summer rainfall (mm), $\mathrm{Size}^{\mathrm{I}}$: number of employees; Sect: proportion of firms operating in electricity, gas, water and construction sectors.

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