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Economic tools for water resource management

For a long time, water policy in France gave priority to the building of major supply facilities and to the co-financing of investments for the preservation of water quality and the securing of supplies. Since the end of the 1980s, the recurrent episodes of drought and associated restrictions on use have brought the debate on the management of water demand to the fore, with particular focus on economic tools such as prices and taxes on water abstraction. While in the past, the sensitivity of the actors to the level and nature of management tools was very low, research works have since showed the major role of economic tools in the management of water demand. Beyond the identification of the elasticity of demand to price and income, new research has covered the modes of access of households to drinking water, in particular through the arbitration between several sources, as well as the policies for the social pricing scheme for drinking water. We present here an overview of the results on the role of economic tools in the management of the residential uses of water.

Nature and origin of the economic tools

The economic tools used in water management have a budgetary objective, first and foremost: financing operations of development, distribution, depollution and so on. They also have an ecological objective of guaranteeing the preservation of water quality and maintaining water abstraction at a level compatible with the natural availability of the resource. In the vast majority of industrialised countries and also developing countries, the complexity of water policy partly lies in the fact that the quality of the resources required for economic activities is heterogeneous and that the actors involved in water management are numerous and operate at different scales.

However, several key principles dictate how taxes and prices are calculated. They must not lead to the exclusion of certain agents from the market; they must not be individualized (no differentiation based on income or corporate name, for example); their level must result from consultations with all the actors concerned at the relevant local level. Due in particular to an implicit criterion of acceptability requiring sufficient legibility by users, there is sometimes a large gap between the economic tool used in practice and its optimal theoretical form as recommended by economic theory. So sophisticated price fixing and taxations taking account of the users' heterogeneity may be preferable from an economic viewpoint, but in practice, it is impossible to implement.

The question of the sensitivity of economic agents to the level (and nature) of management tools is essential on several accounts. First, economic theory provides precise rules as regards the specification of taxes or tariffs to be applied in the case of locally managed natural resources (case study of the drinking water distribution service as a local natural monopoly, of the industrial plant as a source of occasional pollution, of the irrigator as a source of nonpoint source pollution), and these rules include the sensitivity of uses to the instruments. Second, the ex-ante or a posteriori assessment of the performance of policies for resource management is precisely based on the comparison between the budgets dedicated to water policy on the one hand, and convergence towards the environmental objective on the other hand. Any reduction in uses or pollutant emissions must be compared with the revenues from the application of policy tools.

A very important distinction must be made in the empirical identification of the elasticity of uses regarding the economic tools, between the cost of access to the resource and the marginal cost of its use (including through deterioration in quality). For instance, residential households may turn out to be more sensitive to the fixed costs of connection to a drinking water supply network than to the marginal price of a cubic metre; industrial companies may integrate into their economic calculation the (subsidized) cost of the investment in depollution facilities rather than the savings made on pollution charges; a farmer may pay for irrigation water at an all-inclusive tariff or one that is proportional to surface area. Last, in certain cases, access to the resource is conditioned by statutory obligations, themselves leading to indirect costs (for instance, retrofitting of installations). Consequently, an analysis of decisions about use of the natural resource will have to take into account the whole costs, indirectly or directly linked to the volumes used, but also, in some cases, the possibilities of substitution for other supply sources.

Surveys on the role of economic tools in the management of water demand are by far the most numerous for residential uses. Industrial or agricultural use is generally studied within the economics of production, which places the industrial company or the irrigator in a position to choose a combination of their factors in order to obtain the minimum operating cost for a given level of production. We are therefore presenting research results about the domestic sector, which has the advantage of being characterized by a highly diversified pricing scheme.

Estimation of the demand for drinking water

Be they domestic or industrial uses, the share of water in expenditure (budgetary or running costs) is usually very low, lower than 5% in developed countries. This does not mean that the actors will be insensitive to any variation of the unit cost of access to the resource, but implies that the effects on household welfare or firms' financial health will most probably be limited, even for high levels (taxes, prices). The economic modelling of the impact of the latter in terms of use most often results from the specification of a demand equation derived from an economic calculation (maximisation of household welfare, minimisation of the cost to industrial companies for a given level of production). A fundamental element in this equation consists in integrating the possibility of substituting other resources (consumer goods, production factors) for water according to their relative prices. But these possibilities of immediate substitution are extremely limited for the households' or industrialists' most common uses (sanitary, electrical appliances, industrial cooling and so on). Consequently, numerous studies considered (particularly in the case of households) that the simultaneous modelling of water uses with that of other goods was pointless, leading to relatively simple functional forms (see frame 1).

In the determination of the residential level of consumption according to water price, an important question concerns the definition of the explained variables (consumption) and explanatory variables (price). Should we predict the average annual or seasonal consumption of the household or the consumption per capita? Regarding the price, is the pertinent variable the average price (bill divided by the number of cubic meters consumed) or the marginal price (the cost of the last cubic meter excluding the fixed part of the tariff)? How do we calculate the price in the case of binomial tariffs or tariffs including several brackets?

In the wake of a series of mainly North-American works, the usual practice consists in explaining a household's annual consumption according to the average price and the socio-demographic variables of the household (including the house's equipment and characteristics). The possibility of an average endogenous price (because it depends on the fixed part divided by the priced volume) is taken into account by appropriate econometric methods (instrumental variables). It appears that, in spite of the low contribution of drinking water to household budget, households react to price variations even if the estimated price elasticity is relatively low (from -0.15 to -0.4). As regards income elasticity, this is modest (from 0.05 to 0.2). These simplified models of demand were extended in several directions. First, behaviour differences between households dependent on services managed by a local administration or delegated services, or faced with different climate conditions, were tested in several French samples. Next, we took into account the case of multi-brackets tariffs, which are based on "discrete-continuous" decision rules: choice of the consumption bracket then choice of the volume consumed within that bracket. Naturally these models are more interesting for regions experiencing major water shortages (Mediterranean Europe, Africa), insofar as a progressive block pricing scheme reinforces the signal about the scarcity of resources.

Access to water and social pricing scheme

The still-insufficient development of network infrastructures due to difficult implementation of sustainable public-private partnerships, the low incomes of part of the population or even the limited potentialities of the resource are all factors in difficult access to drinking water for some regions of the world or some categories of the population of industrialised countries.

Perhaps paradoxically, it is sometimes easier to accede to drinking water in many developing countries (in particular, Sub-Saharan Africa) than in the urban centres of the industrialised countries where populations are "captive" to their municipality's supply network. Of course, this apparent flexibility is shown by very heterogeneous tariffs and often extremely high ones for some supply modes. For example, a survey on drinking water in Senegal (Briand - Nauges-Travers forthcoming) concerns the choice determinants of supply at public drinking fountains (with a daily payment) and/or through a private connection (bimonthly payment). Use of the first mode may be also motivated by precautionary storage because of the (frequent) water cuts. The opportunity cost for the time passed at the public drinking fountains for water, the probability of failure of the public network or the socio-economic factors are all factors influencing households' choice. In Africa, since most often women are in charge of water collection, a clear arbitration is shown in the management of their time with other activities (children upbringing and so on). However, a review of the surveys on water consumption in developing countries points out that the price elasticity of demand in these countries is relatively close to that estimated in the industrialised countries, since it was estimated at between -0.3 and -0.6 from individual data concerning countries from Africa, Latin America or Asia (Nauges - Whittington 2008).

For the very poor populations, the policies of access to drinking water have been the subject of numerous experiments, including in Europe (case study in Belgian Flanders). In Côte d'Ivoire, for instance, a system of social pricing has existed for 20 years within the delegation contract with the operator SODECI. For several decades, a tax deducted from all consumption in the network has allowed subsidized access (connection fees) for disadvantaged populations of the urban centres, according to observable technical criteria (numbers of water taps and so on). The solidarity fund supplied in this way allows the use of a "social" tariff corresponding to a minimum volume of drinking water according to the criteria of the World Health Organisation. For the sake of legibility of the tariff and easy management, the tariff is progressive and has a limited number of brackets and is identical for all the urban municipalities of the country. A survey (Diakité-Semenov-Thomas, 2009) compared the existing tariff with an optimum simulated tariff (pricing scheme maximizing social welfare with the constraint of an existing first "social" bracket). Econometric estimations from data from Ivorian municipalities on drinking water consumption, on the basis of the current social pricing scheme with brackets, allowed the calibration of the simulation model and the calculation of the welfare measures for various options. Two are of particular interest: a) approximation per threshold (simplification) of the optimum tariff with the same number of brackets as the present tariff; b) imposing a pure progressive tariff for all the segments of consumption. The results of the simulation show that the present tariff is sub-optimal but that the welfare losses for households remained limited. Moreover, some regions are heavily penalized by the imposition of the present homogenous tariff while others profit from it: thus, there is a real subsidizing of the consumption of disadvantaged municipalities by well-off municipalities. In this application, the municipality of Abidjan profits both from upper average income and from more advantageous conditions for access to the resource.

By comparison with the optimum calculated tariff, limiting the number of brackets or imposing a progressive tariff over the whole range of consumption has a negative effect (up to -5% of expenditure on drinking water) in terms of welfare for most of the regions (except for the "favoured" municipalities mentioned above). The present tariff, used identically in all the urban municipalities of Côte d'Ivoire, is sub-optimal but is a better response to the legibility requirement (simplicity) of the declared tariff (see frame 2). An interesting possibility would consist in using the optimal tariff with a first "social" bracket of 106 m^3 per year, but offering the very poor households the first 8 m^3 free, corresponding to the difference between the present tariff and the optimum one.

Conclusion

At present, water economists agree on a moderate sensitivity of water demand in relation to its price. However, the empirical research on drinking water in the industrialized countries suffers from limited access to individual data. Surveys carried out directly at the household level would help explain the heterogeneity of behaviours and particularly understand better consumers' level of information (on the price and quality of the water distributed), the role of socio-demographic factors, habitat characteristics but also behavioural factors (for instance, the sensitivity to environmental problems) on the consumption level but, above all, on the households' choice as regards buying and using water consuming equipment.

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Frame 1 –Estimation of the drinking water demand by households

In the case of simple tariffs, the demand for drinking water (just one bracket) is specified through a function f(.) as follows: Q = f(p, R, X), where Q is the consumption per capita, p the price of the goods consumed (including the average or marginal price of water), R the disposable income and X a vector of characteristics (composition of the household, climate, quality of untreated water, etc.). The demand function f(.) may be parametric or non-parametric, and may only depend on the drinking water price (restriction on vector p). We get the price and income-elasticities with the following formula by deriving the demand function:

$\varepsilon_{Q|p} = \partial f / \partial p \times (p / Q)$ (Q varies by $\varepsilon_{Q|p}$ % following a price variation of 1%),

$\varepsilon_{Q|R} = \partial f / \partial R \times (R / Q)$ (Q varies by $\varepsilon_{Q|R}$ % following an income variation of 1%).

In the case of pricing schemes per brackets, the mechanism of the selection by households of the optimum bracket of consumption is specified jointly with the conditional demands (one per bracket).Various methods of estimation are necessary (Full Information Maximum Likelihood, semi-parametric methods).

Survey	Period	Geographic location	Price-elasticity
Nauges-Thomas 2000	1988-1993	Moselle	-0.21
Nauges-Reynaud 2001	1990-1993	Gironde-Moselle	-0.08 and -0.22
Reynaud-Thomas 2006	1990-1994	Gironde	from -0.05 to -0.13
Blundell-Nauges 2001	1997	Cyprus	from -0.19 to -0.31
Garcia-Reynaud 2004	1995-1998	Gironde	-0.25
Martinez-Espineira-Nauges 2004	1991-1999	Spain (Sevilla)	-0.10
Nauges-Thomas 2002	1988-1993	Gironde	from -0.26 to -0.40

Frame 2: An example of social pricing

The social pricing scheme is supposed to come from an optimisation programme by the public decision-maker trying to jointly maximise the consumers' welfare (by offering a first bracket of the tariff with a uniform price) and the network operator's profit. The solution is a non linear form of pricing depending on the parameters of the demand function, the opportunity cost for the public funds and the structure of the production costs. Up to the level q_{min}, consumers pay for a "social" set price.
$T_{min} = p_{min} \times q_{min}$, these last two terms being the solution of the programme of the public decider.

$$[p_{min} - c(q_{min})] / p_{min} = - \alpha / \varepsilon_{Q|p} (q),$$

$$Q(T_{min}, P_{min}/q_{min}, q_{min}) = Q[P(p_{min}, q_{min}), p_{min}, q_{min}],$$

where Q(P,p,q) is the total demand for water, P the total payment (P = T + pxq), T the fixed fee of the tariff.
The generalised demand Q is a measurement of the number of consumers willing to pay for the total tariff P and buy more than q units at price p. Income distribution intervenes in the population of consumers.

Beyond q_{min}, the volumes are invoiced according to a non linear tariff p(q) following a monopoly price rule (Ramsey rule), the solution of:

$$[p(q) - c(q)] / p(q) = - \alpha / \varepsilon_{q|p} (q), \quad q > q_{min}.$$

where $\alpha = \lambda/(1+\lambda)$, λ is the opportunity cost of the public funds, p(q) the optimum tariff, c(q) the marginal production cost and $\varepsilon_{Q|p} (q)$ the price-elasticity of the total demand.

Simulation consists in resolving numerically the equations originating from the decision-maker's programme to find solutions in p_{min}, q_{min} and p(q). From the estimated functions of cost and demand, the empirical income distribution and α fixed at 1, we find T_{min} = 66.25 dollars US / year and q_{min} = 106 m3 / year. As regards the price p(q) it varies from 0.10 to 0.77 dollars US according to the volume consumed beyond q_{min} .

For further information

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