A Fair Tariff System for Water Management

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Abstract Access to water will be one of the most challenging problems in the next years. It involves many aspects and in this paper we consider the possibility of designing a fair tariff system in order to have also a good evaluation of the amount of water that a community will need in a given period. Here, we analyze the situation in Italy, taking into account the law and the consequent organization of the water management.

Particular emphasis is devoted to the truthfulness and implementation aspects.

Key Words: Tariff system, Implementation, Contested garment.

1   Introduction

Water management is going to assume increasing relevance in the near future; in the recent past it was thought of as a problem related to developing or tropical countries, but now we are realizing that situations which appeared classical only for those countries are going to become usual also in other countries. The available water quantity will reduce of about one third in the next 20 years. Access to water is fuelling competitions and conflicts among countries depending on the same water basin, so that 2003 was declared by United Nations Organization the year of water, in order to promote the analysis of the related problems.

We can mention the European situation in summers 2002 and 2003, referring in particular to Italy, where quite all the regions suffered for the scarcity of water.

The Italian southern regions are afflicted by water management problems from a very long time, due to different reasons that lead to a very dramatic

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situation: low level of rains, permeability of the ground, limited number of natural or artificial basins, old and bad maintained water networks. Some of these reasons are natural, so that they can be hardly tackled, some others are historical and cultural and, finally, some others are political. For example some aqueducts have a water loss larger than fifty percent.

On the other hand the Italian northern regions, thanks to their geographical position at the feet of the Alps, and the central regions, located close to the Apennines, never suffered of water problems in the past. In fact the two mentioned mountain chains represented a very large reservoir of water, e.g. in the Po valley there are more that 50 main rivers, including the tributaries of the river Po.

In 2002 the climatic situation caused a lot of problems. From the beginning of the year there was a reduced amount of water that does not filled the lakes and other water reservoirs as it was usual; the summer was extremely hot, so that there was not only a high level of evaporation, losing other water from the reservoirs but also an increasing using of water, mainly for irrigation but also for home usage. Municipalities has forbidden to use water for not strictly necessary reasons, e.g. garden irrigation, car washing and so on, but it was not enough for compensating the scarcity of water.

The so-called *Legge Galli* (5/1/94 n. 36) [5], a set of technical and economic rules on water resources management, has two main targets: a new approach to the management operations in order to preserve the resources and a new tariff policy. In particular the Legge Galli states:

- the management of water has to be centralized, substituting the many small managers, public and private, each one in charge of part of the water system;

- the optimal size of the area managed, via the determination of suitable areas, each one corresponding to a *Ambito Territoriale Ottimale* or ATO;

- the separation of the programming and control of the water services, devolved to local authority, the *Autorità d'ambito* and the management of the service;

- the tariff policy has the aim of increasing the efficiency and the quality of the service and of reducing the management costs.

Referring to the tariff system the Legge Galli was improved by the technical annex of the Ministerial Act 1/8/1996 [2] according to which:

2

- the average tariff for the present year has to take into account the operating costs, the mortgage costs and investments of the preceding year and the inflation rate of the present year. In other words the tariff can be increased in order to fully cover the costs of the water system, but this increasing cannot be done in a single year;

- the quality of the water is a relevant parameter;

- the tariff should be reduced for special situations: low income users, critical areas, and small amount used.

This tariff system is referred as the *normalized tariff*.

A note of the Interministerial Committee for the Economic Programming (CIPE) specifies other targets:

- low income situations are very relevant for house usage;

- other categories can be identified only for relevant difference;

- water savings should be incentivated.

The geographical area we are dealing with, the ATO/6 (ATO n.6), includes 133 municipalities of the province of Alessandria and 14 municipalities of the province of Asti, with about 350.000 inhabitants, more than half concentrated in 5 main cities (Alessandria, Tortona, Acqui Terme, Novi Ligure and Ovada).

This is the scenario where our work started. Cooperating with the Autorità d'ambito, we studied the possibility to design a tariff system that may allow a reduction in water usage and mainly in water wasting.

Our proposal is a tariff system that respects the current directives and is based on the declaration of the users of their forecasted amount of water used each year, so we called it *declarative tariff*. The aim of this proposal is threefold: a fair tariff system, a reduction of water wasting and the possibility for the manager of obtaining good data about the total water requirement for each year.

The paper is organized as follows: in the next section we present the actual tariff system in the ATO/6; the third section is devoted to the proposed tariff system, analyzing its potential features; some final comments conclude.

2   Current Tariff System

As we said in the Introduction, the Italian Law gives some suggestions and rules for a fair water tariff system; in particular the tariff should balance

the quality standards for the users and the costs for the service, including financial costs and capital risk. Other interesting points are the incentivation of optimal use of the water, the reduction of water wasting and the environmental impact; finally the tariff should be socially sustainable.

The tariff system adopted in the area of ATO/6 (see [3] and [4]) already respects some of the requirements of the "Legge Galli"; in particular it takes into account:

- different categories of users;

- usage range;

- geographical and local characteristics.

More precisely, the current tariff system is strongly rooted in the so called *tariffa di riferimento* (reference tariff) that in the Ministerial Act 1/8/1996 is defined as "the tool that allows to obtain suitable levels of service, incentivates developing programs, reducing the costs for the users and increasing the efficiency of the management". The reference tariff is defined as:

$$T_n = (C + A + R)_{n-1}(1 + \Pi + K)$$

where:
T_n is the tariff for year n,
C are the operating costs,
A are the mortgage costs,
R are the capital costs,
Π is the programmed inflation rate for the year n,
K is the *limite di prezzo* (fare bound).

The reference tariff for the starting year, T_0, can be obtained as the weighted average of the costs of the previous managers that had in charge the water system in the area corresponding to the current ATO, including the rent fees for public water, cost of the water purchased from third parties, rent fees for the water system, costs arising from current laws and costs for current loans.

K represents a percentage that preserves the users from too high increases of the tariff in order to complete covering the managing costs. This percentage is necessary as the subsidization of the water costs in some areas of Italy was very high, also larger than 90%, so that for fulfilling the requirements of the new law it should be necessary a relevant increase of the tariff. For this reason the law fixes the maximal percentage of increasing according to the previous costs.

For the first year the value of K is defined as:

- $K = 25\%$ if the weighted average tariff per cu.mt. in 1995 was less than 1000 Italian Lire (about 0.52 euros);

- $K = 7.5\%$ if the weighted average tariff per cu.mt. in 1995 was greater than 1600 Italian Lire (about 0.83 euros);

- for values among 1001 and 1599 the value of K is computed by interpolation.

For the following years the value of K is defined as:

- $K = 10\%$ if the actual average tariff per cu.mt. in the previous year was less than 1100 Italian Lire (about 0.57 euros);

- $K = 5\%$ if the actual average tariff per cu.mt. in the previous year was greater than 1750 Italian Lire (about 0.90 euros);

- for values among 1101 and 1749 the value of K is computed by interpolation.

A note of the Interministerial Committee for Pricing (CIP) proposes the following limits for the usage ranges, referring to the average use of 150 liters per inhabitant per day stated by the Decree of the Council of Ministries n.47 of 4 March 1996:

- 50 cu.mts. per year for applying reduced tariffs;

- 150 cu.mts. per year for applying penalties for large use.

The tariff is the sum of two parts, one fixed, the rent fee, and one variable, that depends on the amount of water used, with increasing prices for cubic meter.

For the ATO/6, the tariff system for 2002 was the following:

- House users

    - *rent fee*: 24.00 euros per year
    - *reduced tariff* (up to 60 cu.mts. per year): 0.50 euros per cu.mt.
    - *basic tariff* (from 60 to 150 cu.mts. per year): 0.80 euros per cu.mt.
    - *first exceeding* (from 150 to 240 cu.mts. per year): 0.95 euros per cu.mt.
    - *second exceeding* (over 240 cu.mts. per year): 1.20 euros per cu.mt.

- Non house users

  - *rent fee*: 48.00 euros per year

  - *basic tariff* (up to 150 cu.mts. per year): 0.80 euros per cu.mt.

  - *first exceeding* (from 150 to 240 cu.mts. per year): 1.20 euros per cu.mt.

  - *second exceeding* (over 240 cu.mts. per year): 1.30 euros per cu.mt.

- Farm users

  - *rent fee*: 48.00 euros per year

  - *reduced tariff*: 0.50 euros per cu.mt.

- Public users

  - *rent fee*: 24.00 euros per year

  - *basic tariff*: 0.80 euros per cu.mt.

- Large users

  - the rent fee and the tariff are decided by agreements

3 Proposed Tariff System

The basic idea of the new tariff system is rooted in the advantages of the knowledge of the necessity of the users for the future; in fact water can be easily stored, also for long periods. So, this information could be used in order to reduce the difficulties arising in scarcity periods. The new tariff system refers mainly to house users but it can be tailored also for other kinds of users.

The main idea is that each user commits him for a forecasted amount of water at the beginning of each year, on the hypothesis that a larger declared amount corresponds to a higher basic tariff per cubic meter of water. At the end of the year penalties are assigned to those users that required a larger amount of water. The penalty system assigns larger penalties to users that made larger misevaluations.

Notations

We will make use of the following notations:

d	declared cubic meters
x	used cubic meters
p	standard price per cubic meter
p'	penalty price per cubic meter ($p' > p$)

The first idea for a declarative tariff is to ask the users for the forecasted amount of water needed for the following year, d, and then to apply the standard price, p, to the used quantity of water, x, up to the declared cubic meters, and the penalty price, p' to the quantity exceeding that amount, i.e.:

Tariff 1

$$\begin{array}{ll} px & \text{if } x \le d \\ pd + p'(x - d) & \text{if } x > d \end{array}$$

This tariff system incentivates the users to reducing water wasting, but fails in the truthfulness of the declaration; in fact the users may declare very large amount of water required in order to be sure to pay the standard price whatever the amount of water actually used.

The simplest idea for incentivating truthfulness is to ask the users for paying the whole declared amount at the standard price, i.e.:

Tariff 2

$$\begin{array}{ll} pd & \text{if } x \le d \\ pd + p'(x - d) & \text{if } x > d \end{array}$$

It is straightforward to check the truthfulness; in fact if the real used amount of water is larger that the declared one the penalty price is applied and on the opposite if it is smaller the whole declared amount is paid anyhow. On the other hand this tariff fails in reducing water wasting, as a user may think that the water up to the declared amount can be used for free.

We can try to reach both the aims introducing variable prices. More precisely we can define the standard price using an increasing function π that fixes the price per cubic meters up to the quantity d and the penalty price using an increasing function π' that is applied to the exceeding quantity of water, i.e.:

Tariff 3

$$\begin{array}{ll} \pi(d)x & \text{if } x \le d \\ \pi(d)d + \pi'(d)(x - d) & \text{if } x > d \end{array}$$

This third proposal seems good but we can consider the following example.

Example 1 *Let the standard price be expressed by $\pi(d) = 0.50 + 0.01d$ and the penalty price by $\pi'(d) = 0.70 + 0.015d$. If a user that needs 150 cu.mts. per year declares 150 the standard price is 2.00 euros and the penalty price is 2.95 euros so the final tariff is $2.00 \cdot 150 = 300.00$ euros; but if he declares*

148 *the standard price is* 1.98 *euros and the penalty price is* 2.92 *euros so the final tariff is* $1.98 \cdot 148 + 2.92 \cdot 2 = 298.88$ *euros.*

So, a user may have an advantage from non truthful declarations. To avoid these situations, and taking into account the first two tariffs, we can bind the prices when the actual usage is larger than the declaration, to the actual usage instead that to the declared one, i.e.:

Tariff 4

$$\begin{array}{ll} \pi(d)x & \text{if } x \le d \\ \pi(x)d + \pi'(x)(x-d) & \text{if } x > d \end{array}$$

Referring to Example 1 we can see when the declaration is 148 but the actual usage is 150 the standard price is 2.00 euros and the penalty price is 2.95 euros so the final tariff is $2.00 \cdot 148 + 2.95 \cdot 2 = 301.90$ euros.

It is possible to enforce the penalty for non truthful declaration applying the standard price $\pi(x)$ to the whole amount x and adding the penalty price for the exceeding part $(x - d)$, i.e.:

$$\pi(x)x + \pi'(x)(x-d) \qquad \text{if } x > d$$

Referring again to Example 1 the final tariff becomes $2.00 \cdot 150 + 2.95 \cdot 2 = 305.90$ euros.

It is trivial to check that Tariff 4 and the modified one penalize mistakes in the declarations; so, both tariffs match our purposes, limiting the water wasting due to the increasing costs and incentivating a good evaluation of the total water needed due to the increasing standard and penalty prices.

3.1 Variable Prices and the Italian Law

The idea of variable prices allows us to respect the Italian directives on reduced usages. In this case it is simpler to define the standard costs and the penalized costs instead of the prices per cubic meter. For example we can define the standard cost function C taking into account the ranges stated by the ATO/6 (see Section 2) as:

$$C(x) = \begin{cases} 0.50x & \text{if } x \le 60 \\ 30.00 + 0.80(x-60) & \text{if } 60 < x \le 150 \\ 102.00 + 0.95(x-150) & \text{if } 150 < x \le 240 \\ 187.50 + 1.20(x-240) & \text{if } x \ge 240 \end{cases}$$

In this case the function is piecewise linear, so each user has an advantage in declaring the upper bound of its range (the cost per cu.mt. is constant in each range), paying the penalties only if he exceed the upper bound.

Also the amount of the rent fee plays an important role, due to its influence on the price per cubic meter, especially for small amounts of water, but this is behind our purposes. For this reason we think that the rent fee, the reduced tariff for small usage and the limit for reduced tariff should be correlated in order that over the quantity fixed for the reduced tariff the cost per cubic meter should increase.

In the case of ATO/6 the average cost per cubic meter, including the rent fee, for reduced usage can be expressed as:

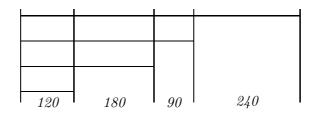$$\pi(x) = \frac{24.00}{x} + 0.50, \qquad \text{if } x \le 60$$

that leads to a reduction of the cost for increasing usage, until 0.90 euros per cu.mt. when the usage is 60 cubic meters. The cost of further water, up to 150 cubic meters is 0.80 euros per cu.mt. In other words the function $p(x)$ should assume its minimum for $x = 60$. This can be done modifying the rent fee, for example fixing is at 18.00 euros, or increasing the limit of reduced usage up to 80 cubic meters or changing the tariffs, for example decreasing the reduced tariff to 0.40 euros per cu.mt. or increasing the basic tariff to 0.90 euros per cu.mt.

4   Concluding Remarks

The results of the declarative tariff system were satisfactory, not only from a theoretic point of view, but also in the evaluation of the technical experts of ATO/6, compared with the current tariff system.

We made a comparison also with another game theoretic approach, the *Rabbi rule* or *contested garment* (see [8]); in this case the total monetary amount is assigned as claim to the highest user; next we can consider ranges of usage as the claims of the other users, via a linear approximation. The amount associated to each range is divided among the users that require that amount of water or a larger one. The procedure can be applied directly to the usage amount, without stating the ranges. We refer to the following example to make the procedure clearer.

Example 2 *Consider 4 users that require 40, 100, 130 and 210 cubic meters of water, respectively; let the total amount of money required for the current period be 630 euros, taking into account also the total amount of 480 cubic meters used. The amount of 630 is associated to 210 and correspondingly, using a linear approximation, the amount of 120 is associated to 40, the amount of 300 is associated to 100 and the amount of 390 is associated to 130.*

                    120   180   90   240

The four users pay 30, 90, 135 and 375 euros, respectively. If we compute the cost per cubic meter we get 0.75, 0.90, 1.04 and 1.78 euros, respectively.

This approach could make the cost per cubic meter too much depending on the amount needed. It should be clear that if we consider a reasonable number of users, those with lower amounts of water, or those in the first ranges have a very limited cost per cubic meter, while the users with higher amounts of water may be penalized by this tariff system, if their number is very low. A simple possibility is to use a non linear approximation.

Returning to our proposed tariff system we may remark that the high level of freedom in determining the parameters of the tariff allows matching many possible requirements and constraints, both technical and normative.

Another relevant question is the fixed tariff, i.e. the rent fee; the underlying idea is that the fixed costs of the water system should be equally paid by all the users. Nevertheless this approach does not take into account other features of the problem; for example the amount of the rent fee could be relevant for low income people, but could be a very small fraction for other users or it is possible that for very small water usage the rent fee is larger than the amount for water and in this case it is necessary to distinguish among people living alone that try to save water (and, consequently, money) and people that use the house only for short periods of the year. These particular situations can be in contrast with what we said in the previous section. This means that a deep analysis is necessary.

Again we suggest the instrument of game theory; it is possible to take into account the different requirements of the agents involved referring to bankruptcy approaches (see [7]) or to the class of "infrastructure cost games" that were successfully applied to railway infrastructures (see [5]) and to urban solid wastes consortia (see [6]).

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