Accounting for sustainability in the assessment of performance of water and sewage utilities

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Abstract. This paper assesses technical performance in the water and sewage industry in the Southern European region of Andalusia. The main contribution to the existing literature is that performance is assessed while accounting for sustainability in the management of water resources, which is measured by unaccounted-for water. In addition, the opportunity cost of *producing* sustainability is evaluated. As regards the methodology, *Data Envelopment Analysis* techniques and mathematical programming are used. The main results show that *producing* sustainability has a positive and increasing marginal cost. Furthermore, given the low cost of raw water in Spain in relation to the estimated opportunity cost of saving this natural resource, wasting water becomes a profitable strategy for utility managers from a private perspective. However, this managerial strategy has the social cost of wasting water in an area of Europe where the sustainable management of this natural resource is a really pressing need. Our conclusion is that environmental policy aimed at discouraging this wasteful behaviour is urgently needed. We advocate a schedule of taxes discriminating among utilities according to how sustainable their management of water is.

Keywords: water and sewage utilities; input-specific technical efficiency; sustainability; unaccounted-for water; Data Envelopment Analysis.

JEL Classification: C61; Q25; L20; L95.

1. Introduction

The sustainable management of natural resources constitutes a matter of concern at present that is receiving increasing attention from both policy decision-makers and academics. While politicians face the challenge of upholding longer-term sustainability, academics have the task of providing them with sound information to improve the design of their environmental policies. Outstandingly, the ever-increasing demand for water motivated by continuous demographic and economic growth, in addition to rising water scarcity in many areas of the world, are turning the efficient management of this natural resource into a high-priority. As recognised by the European Environment Agency (2005), achieving sustainable management of water resources is becoming a pressing need in some Southern European areas which are presently facing a worrying process of desertification, most likely due to climate change.

Furthermore, the European Commission is currently promoting the use of benchmarking techniques as a powerful instrument towards achieving a better knowledge of managerial practices in the European water and sewage industry (Commission of the European Communities, 2007). Benchmarking managerial practices acquires additional relevance in activities such as the water and sewage industry in which the low potential of competition and the existence of institutional regulations that restrict managerial decisions contribute to the existence of inefficient practices. As noted by the OECD (2004), benchmarking is a substitute for active competition in the water industry that can improve operational efficiency, as it provides managers and decision-makers with valuable information as a sound basis for making strategic choices.

The interest in assessing managerial performance in the water and sewage industry had already arisen in the eighties, leading to a growing literature which has, to date, produced a wealth of contributions (González-Gómez and García-Rubio, 2008 review the literature). Without aiming to be exhaustive, some papers have investigated the relative performance of public and privately-owned utilities (Kirkpatrick *et al.* 2006), the extent of scale and scope economies (Torres and Morrison-Paul, 2006), the convenience of vertically integrating the different services produced by water and sewage utilities (Garcia *et al.*, 2007) or the impact of changes in the regulatory framework on performance (Aubert and Reynaud, 2005).

In Europe, the maximum exponent of the application of benchmarking analyses on behalf of regulating authorities is the Office of Water Services (OFWAT), which has used these techniques to identify cost-efficient practices in the English and Welsh water and sewage industry, as a basis for establishing a regulated price for water. Moreover, the Instituto Regulador de Águas e Residuos (IRAR) and the Verening van Waterbedrijven in Nederlands (VEWIN) have benchmarked the Portuguese and Dutch water and sewage industries, respectively.

In spite of this broad literature, the vast majority of studies devoted to assessing performance in the water and sewage industry have focused on managerial performance, let us say, from a *private* perspective, thus ignoring other *social* dimensions of the management of water resources, such as sustainability. However, the urgent need of achieving sustainable management of this natural resource calls for fresh approaches to the assessment of the performance of water utilities.

In this context, our paper assesses performance in the water and sewage industry while accounting for sustainability in the management of water resources. An empirical application to a sample of utilities located in the Southern European region of Andalusia is carried out. Furthermore, the opportunity cost of *producing* sustainability is evaluated. In doing so, benchmarking techniques based on non-parametric *Data Envelopment Analysis* (*DEA*) and mathematical programming are used. Sustainability is measured through unaccounted-for water or water which gets lost along pipelines due to inadequate maintenance[1], the greater the unaccounted-for water the less sustainable. According to the European Environmental Agency (2001), the reduction of leakages is essential for water resource conservation and to achieve a favourable water balance at river basin level (see also European Community, 2006).

Our main findings are as follows. In the first place, accounting for sustainability displays a picture of performance somewhat different to that obtained from an assessment which omits sustainability. Secondly, *producing* sustainability saves raw water but also consumes productive resources such as labour and other operational costs endowed with an opportunity cost, the marginal cost of sustainability being increasing. In the third place, the opportunity cost of saving raw water by far exceeds the cost of acquiring this natural resource, making wasting water a profitable managerial strategy for Andalusian water and sewage

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[1] Several papers in this field of research have considered in some way a variable representing unaccounted-for water, Antonioli and Filippini (2001), Garcia and Thomas (2001), Coelli *et al.* (2003), Tupper and Resende (2004), Lin (2005) and Picazo-Tadeo *et al.* (2008), among them. However, none of these papers has the objective of assessing performance while accounting for sustainability.

utilities. Accordingly, our main conclusion is that environmental policy measures aimed at ending this squandering of water are required immediately. This paper advocates for a system of taxes on the use of raw water capable of discriminating among water utilities according to how sustainable their management of this natural resource is.

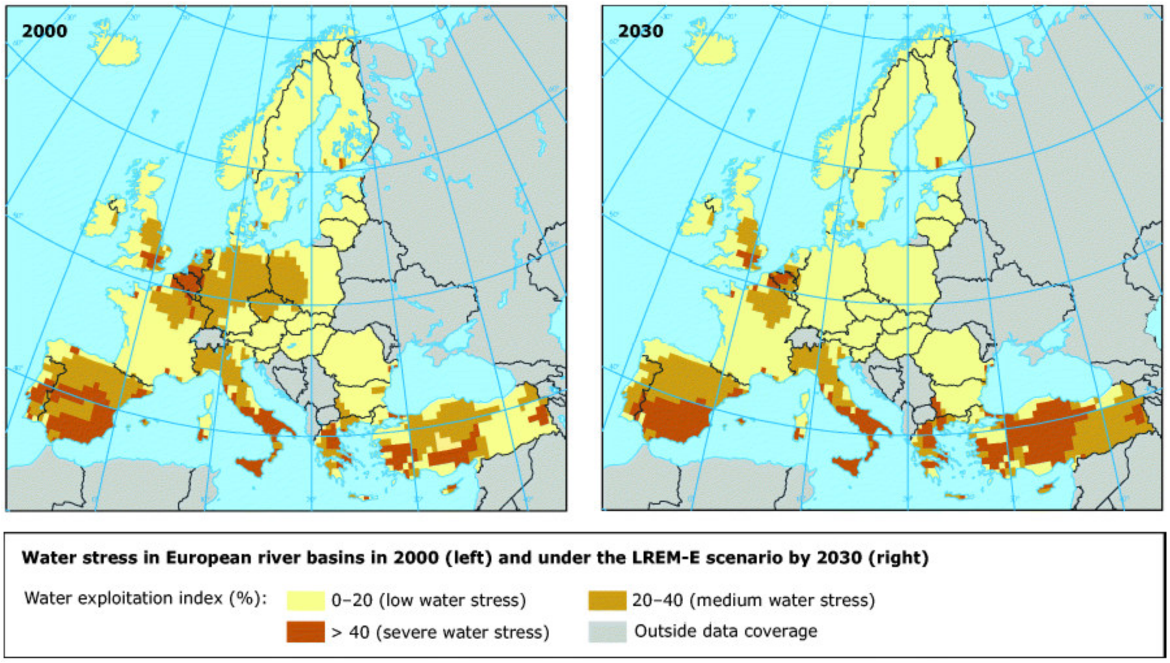
The rest of the paper is organised as follows. Section 2 briefly describes Andalusia and the problem of water scarcity faced by this Southern area of Europe. Section 3 deals with the data and methodological issues, while Section 4 describes the results and their policy implications. A final section summarises and highlights the main conclusions.

2. The management of water resources in Andalusia.

Andalusia is a European region located in the South of the Iberian Peninsula with a surface area of 87,268 km^2 and a population of slightly more than 8 million inhabitants. Along its 1,101 kilometres of coastline there is significant tourist activity which attracts visitors from all over the world, particularly from the centre and north of the European Union. The problem of water scarcity was detected some time ago and has become more pronounced over the years. The water resources available, estimated at around 5,600 hm^3 a year, are not enough to meet the increasing demand for water. In 2004, the *water deficit* amounted to somewhat more than 200 hm^3 and is forecast to reach 1,045 hm^3 by 2010 (Junta de Andalucía, 2004).

As is the case in other meridional European regions, Andalusian water resources are under great pressure (Figure 1), which does not look like decreasing in the next few decades (Henrichs *et al.*, 2002). In the water basin that covers the largest area of Andalusia, the Atlantic basin of the Guadalquivir, the water exploitation index –which measures total water abstraction per year as a percentage of long-term freshwater resources– stands at around 85% and is forecast to exceed 90% by 2030. The water stress problem in Andalusia is even more pronounced in the Mediterranean basins due to supply and demand factors.

Figure 1. Water stress in European river basins, 2000 and 2030.



Source: Reproduced from European Environment Agency (2007b; page 9).

The main factor affecting the availability of water resources in the region is climate change (Bates *et al.*, 2008). Andalusia suffers from two primary vulnerabilities on being a coastal region and being located in Southern Europe. It is therefore understandable that climate change –increase in average temperatures, decrease in rainfall, erosion, desertification and water salinity, among others– has a particularly marked impact on Andalusia. As a result, water scarcity problems become more serious, thus augmenting the negative impact on water quality and aquatic ecosystems (European Environment Agency, 2007a).

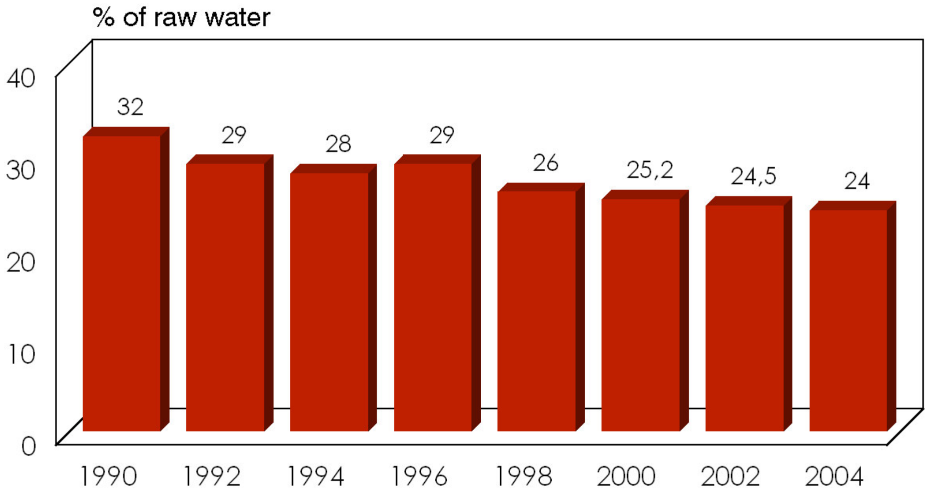
In relation to demand, although growth is markedly restricted, irrigation agriculture still uses around 80% of the region's available water resources. The rest is accounted for by urban demand, which has risen spectacularly over the last few decades. As a result, new urban and recreational uses are competing with traditional uses. Increasing water demand for urban uses is mainly determined by impressive urban development due, to a large extent, to an increasing influx of tourism and the arrival of many European citizens who establish their second residence on the Spanish Mediterranean coast. Moreover, the overexploitation of aquifers on the Andalusia coast has sparked a continuous rise in water salinization. According to the European Environment Agency (2007a), in the coastal areas, especially in Southern Europe, the reduced availability of surface water during dry periods and the reduced groundwater recharge will increase the pressure on groundwater considerably. Many of the groundwater bodies are already heavily abstracted and over-exploited and some will not be suitable as drinking water because of saline intrusion due to rising sea levels.

In a scenario of severe water scarcity such as that currently faced by Andalusia, protection and integrated sustainable management of water resources should be recognised as a pressing need. In fact, the Spanish government has recently changed the direction of its water policy –traditionally based on constructing water infrastructure to transfer resources from regions with surpluses to those with shortages– towards enhancing the management of water. Recent research supports this type of measure aimed at improving the management of water resources in Andalusia (Velázquez, 2006, 2007; Pulido-Velázquez *et al.*, 2008).

However, high levels of unaccounted-for water are commonly observed in Spanish water and sewage utilities.

According to estimates from the Asociación Española de Abastecimientos de Agua y Saneamientos (2006), the ratio of unaccounted-for water in Spain has dropped considerably since 1990. However, in 2004 the average was still 24% (Figure 2). Furthermore, there are marked differences among water basins, Andalusia being one of the Spanish regions that loses the most water from its pipeline network, with an average ratio of unaccounted-for water of between 26% and 30%, depending on the water basin. These figures contrast entirely with the 16% average observed in developed nations (Tynan and Kingdom, 2002) and also with the aim to use water efficiently and sustainably included in the *Water Framework Directive* of the European Commission (European Union, 2000), which establishes a desirable ratio of unaccounted-for water below 15%.

Figure 2. Unaccounted-for water in Spain, 1990-2004.



Source: Asociación Española de Abastecimientos de Agua y Saneamientos (2006)

Why do Andalusian water utilities, faced with a marked shortage of water, continue to register such a high level of unaccounted-for water? The answer to this question is not easy, but could be related to two circumstances: on the one hand, the incentives of the companies in charge of managing water resources and, on the other hand, a lack of an organism to monitor that certain levels of unaccounted-for water are not exceeded.

In Spain, city councils are responsible for providing urban water cycle services, although under the legislation currently in force, they can delegate management to private companies. The public sector is responsible for supplying 60% of the population of Andalusia with water, while private companies supply the remaining 40%. Concerning the incentives to manage water resources efficiently, publicly-managed water utilities, on the one hand, do not appear to consider controlling water losses as a priority, as this problem goes unnoticed by voters and, as a result, implies no electoral cost. On the other hand, it has been repeatedly pointed out that, given the low cost of water in Spain, tracing and repairing leakages can be very expensive for private water utilities. As a result, increasing raw water use to feed leaks may prove a cheaper managerial strategy (González-Gómez, 2005). In addition to this, Spain currently lacks a regulatory body to dictate what the objective should be in reference to unaccounted-for water and monitor whether or not it is being complied with.

In consequence, strategies followed by both public and private water and sewage utilities concerning the management of water, in addition to a lack of environmental regulations aimed at achieving sustainable management of this natural resource, might well be leading to squandering behaviour on behalf of the Andalusian water and sewage industry which, although profitable for utility managers, is manifestly contrary to the interests of society. Providing this hypothesis with empirical support is also one of the objectives of our research.

3. Data and Methodological Issues

3.1. Sample and Dataset: Modelling the Production Structure

In this paper we use a dataset belonging to a sample of Andalusian water and sewage utilities, with data from a comprehensive survey performed by the authors in 2001 and financed by the *Instituto del Agua de Andalucía*. The dataset includes figures on inputs, outputs and sustainability for 38 water utilities, which provide water services to one hundred and twenty-eight municipalities and more than four million inhabitants. This sample accounts for almost 60% of the 65 water and sewage utilities operating in the region.

One basic step when assessing performance is the modelling of the production structure and the selection of the variables representing outputs and inputs, which is not always an easy decision. In this paper, two outputs have been considered, namely, water delivered and sewage treated (both measured in m^3). Moreover, inputs are raw water (also in m^3), labour (number of workers), operational costs (measured in thousands of €) and, finally, delivery network (measured in kilometres). *Table 1* displays some descriptive statistics for the data.

Outputs are intended to account for the multi-output nature of water and sewage utilities, which can provide one or several of the services or stages that integrate the urban water cycle. While the first of such stages is the chemical treatment of water in order to make it suitable for urban consumption, the second involves distributing treated water to several urban users. In stages three and four sewage is respectively collected and treated to be returned to the environment minimising pollution or, even, to be reutilised for different purposes –such as cleaning cities or watering gardens. However, in our output set we only include water delivered and water treated because, in practice, there is a high correlation between the volume of water treated and water delivered, as well as between the volume of sewage collected and sewage treated. Correlations in our sample are 1 and 0.995, respectively, so including all four outputs in the model would not in fact capture any theoretical difference in these output categories. 20 out of the 38 water and sewage utilities in the sample deliver water and treat sewage, while the remaining 18 only deliver water.

Table 1. Sample description.

Variable	*Unit*	*Mean*	*Standard deviation*	*Maximum*	*Minimum*
Outputs					
Water delivered	Thousands of m^3	9,435	16,803	84,800	212
Treated sewage	Thousands of m^3	7,979	20,948	108,666	0
Inputs					
Raw water	Thousands of m^3	12,369	21,368	107,733	315
Labour	Number of workers	81	135	732	2
Operational costs	Thousands €	3.906	6.040	31.640	84
Delivery network	Kilometres	362	564	2,877	5
Sustainability					
Unaccounted-for water	Percentage	25.9	7.1	42.0	9.6

As regards production factors, the delivery network is intended to proxy input capital and is considered to be a fixed production factor. Conversely, labour, raw water and operational costs are considered to be variable inputs, as they can be adjusted in the short run. Finally, we also consider a measure of sustainability in the management of water resources on behalf of water and sewage utilities. Given the problem of water scarcity faced by the area of Europe where utilities in our sample are located, a sensible measure of sustainability is, as justified in the introduction, the ratio of unaccounted-for water, which has been computed as the quotient between water lost along pipelines, thus failing to reach final consumers, and raw water introduced into pipelines. Obviously, the greater the percentage of unaccounted-for water, the less sustainable management of water resources.

3.2. Methodological Issues

Once the production structure of water and sewage utilities has been modelled, performance can be assessed by using benchmarking techniques, through either econometric approaches or non-parametric methods based on *Data Envelopment Analysis* (*DEA*) (Charnes *et al.*, 1978). In this paper, our choice is to make use of *DEA* techniques and mathematical programming.

In essence, *DEA* allows us to compute for each productive unit in a sample, water and sewage utilities in our case, a measure of relative performance by comparing its observed behaviour, which is determined by input and output vectors, with best observed practices. An important advantage of *DEA* is that it allows a wide range of indicators of performance, each focusing on different aspects of production processes, to be easily computed. Emrouznejad *et al.* (2008)

review the empirical literature on *DEA*, while Thanassoulis (2000) highlights its usefulness for analysing performance in water utilities. Further details on this technique are in Cooper *et al.* (2007).

In order to formalise the main insights of the methodology, let us start by considering the general case of a productive process in which a vector $\boldsymbol{x}$ of $n = 1,\ldots,N$ inputs is used to produce a vector $\boldsymbol{y}$ of $m = 1,\ldots,M$ outputs, through a *technology* represented by:

$$T = \left[(\boldsymbol{x},\boldsymbol{y}) \,\middle|\, \boldsymbol{x} \text{ can produce } \boldsymbol{y} \right] \tag{1}$$

This technology describes all feasible relationships between inputs and outputs, and it is assumed to satisfy the standard properties initially proposed by Shephard (1970). In addition, let us consider that in the short-run $v = 1,\ldots,V$ inputs are variable, while the remaining $f = V+1, \ldots, N$ inputs are fixed, with $\boldsymbol{x}_v$ and $\boldsymbol{x}_f$ denoting, respectively, the vectors of variable and fixed inputs.

In the short-run, when fixed production factors cannot be adjusted, the technology can be modelled through the *restricted input requirement set*, which represents all vectors of variable inputs $\boldsymbol{x}_v$ that, conditional on the observed level of fixed inputs $\boldsymbol{x}_f$, produce at least an output vector **y**. Formally:

$$L(\boldsymbol{x}_f,\boldsymbol{y}) = \left[\boldsymbol{x}_v \,\middle|\, (\boldsymbol{x}_v,\boldsymbol{y}) \in T(\boldsymbol{x}_f) \right], \tag{2}$$

$T(\boldsymbol{x}_f)$ being the *short-run technology* representing all feasible productive plans for a given vector of fixed inputs $\boldsymbol{x}_f$.

Based on this characterisation of the technology, an assorted set of measures of performance can be computed. For the most part, papers focused on measuring technical performance in the water and sewage industry have computed Farrell-Debreu type measures (Farrell, 1957) based on radial or proportional contractions of all production factors necessary to achieve efficiency. Nonetheless, radial measures provide an inadequate basis for answering some of the key questions that motivate this paper. Alternatively, we compute Pareto-Koopmans type measures (Koopmans, 1951) as suggested by Färe and Lovell (1978), which provide scores of technical efficiency at input level. For positive inputs, this measure, known as the Russell measure, is defined as:

$$\text{Russell input efficiency}(\boldsymbol{x},\boldsymbol{y}) = Min\left[\sum\nolimits_{v=1}^{V}\frac{\vartheta_v}{V} \mid (\vartheta_1 x_1,\ldots,\vartheta_V x_V)\in L(\boldsymbol{x}_f,\boldsymbol{y});\, \vartheta_v \in (0,1]\right] \quad (3)$$

The Russell measure assesses the maximum attainable reduction of each variable input, namely variables ϑ_v, without worsening the level of outputs produced, thus providing a measure of technical performance in the use of that input. Furthermore, it should be noted that the Russell score itself, i.e. the arithmetic mean of maximum attainable input-specific contractions, is not a contraction factor for the input vector and that it does not directly provide the efficient projection onto the frontier.

Considering the set of inputs and outputs defined in Section 3.1 to model the production structure in the water and sewage industry, and using *DEA* on our sample of $k = 1,\ldots,38$ utilities, the input-specific measure of technical efficiency of expression (3) for utility k' is computed as the solution to the following programming problem:

$$\text{Russell input efficiency}\left(\boldsymbol{x}_v^{k'},\boldsymbol{x}_f^{k'},\boldsymbol{y}^{k'}\right)=Min_{\vartheta_v^{k'},\,z^k}\frac{1}{3}\sum\nolimits_{v=1}^{3}\vartheta_v^{k'}$$

subject to:

$$\begin{array}{lll}
\vartheta_v^{k'}x_v^{k'}\geq\sum\nolimits_{k=1}^{K}z^k x_v^k & v=\text{raw water, labour, operational costs} & (i)\\
x_f^{k'}=\sum\nolimits_{k=1}^{K}z^k x_f^k & f=\text{delivery network} & (ii)\ ,\qquad (4)\\
y_m^{k'}\leq\sum\nolimits_{k=1}^{K}z^k y_m^k & m=\text{water delivered, sewage treated} & (iii)\\
0<\vartheta_v^{k'}\leq 1 & v=\text{raw water, labour, operational costs} & (iv)\\
z^k\geq 0 & k=1,\ldots,38 & (v)
\end{array}$$

z^k being an intensity parameter that represents the weighting of utility *k* in the composition of the efficient production plan firm *k′* is compared with.

In order to introduce sustainability into our input-specific measures of technical efficiency, let us consider that each vector of outputs can be produced with different levels of sustainability, which is denoted by variable s. Furthermore, we assume that *producing* sustainability consumes resources endowed with an opportunity cost, i.e. resources that could otherwise be either devoted to producing marketable outputs or simply reduced. This is a reasonable assumption insofar as sustainability is measured through unaccounted-for water and tracing and repairing leakages requires utilities to incur in further costs stemming from the use of production factors such as labour and other operational costs. Obviously, as *producing* sustainability requires unaccounted-for water to be reduced, it also allows saving raw water thus reducing utility costs. Assessing the net impact of achieving more sustainable management of water resources on utility costs constitutes a highly interesting empirical aspect of this research.

The sustainability-corrected Russell measure of technical performance is defined, in the more general case, as:

$$\text{Sustainability-corrected Russell input efficiency}(\boldsymbol{x},\boldsymbol{y};s) = Min\left[\sum\nolimits_{v=1}^{V}\frac{\psi_v}{V} \mid (\psi_1 x_1,\dots,\psi_V x_V)\in L(\boldsymbol{x}_f,\boldsymbol{y};s);\ \psi_v\in(0,1]\right],\quad(5)$$

L($\boldsymbol{x}_f$,$\boldsymbol{y}$,*s*) being the *restricted input requirement set* representing all vectors of variable inputs that, conditional on the level of fixed inputs $\boldsymbol{x}_f$, produce at least a vector of output **y** and a level of sustainability s.

Sustainability-corrected input-specific measures of technical efficiency assess the maximum attainable reduction of each variable input without worsening the level of outputs produced while, at the same time, maintaining at least a level of sustainability s. For utility *k′* in our sample, these scores can be formally computed from the following program:

$$\text{Sustainability-corrected Russell input-oriented efficiency}\left(\boldsymbol{x}_v^{k'},\boldsymbol{x}_f^{k'},\boldsymbol{y}^{k'};s_{target}^{k'}\right) = Min_{\psi_v^{k'},z^k}\ \frac{1}{3}\sum\nolimits_{v=1}^{3}\psi_v^{k'}$$

$$\begin{array}{llll}
\text{subject to:} & & & \\
\psi_v^{k'}x_v^{k'} \geq \sum\nolimits_{k=1}^{K} z^k x_v^k & v=\text{raw water, labour, operational costs} & (i) & \\
x_f^{k'} = \sum\nolimits_{k=1}^{K} z^k x_f^k & f=\text{delivery network} & (ii) & (6)\\
y_m^{k'} \leq \sum\nolimits_{k=1}^{K} z^k y_m^k & m=\text{water delivered, sewage treated} & (iii) & \\
0<\psi_v^{k'}\leq 1 & v=\text{raw water, labour, operational costs} & (iv) & \\
z^k \geq 0 & k=1,\dots,38 & (v) & \\
\left(1-\dfrac{y_m^{k'}}{\psi_v^{k'}x_v^{k'}}\right)\leq s_{target}^{k'} & m=\text{water delivered};\ v=\text{raw water} & (vi) &
\end{array}$$

As compared to program (4), a further constraint concerning sustainability has now been added, namely restriction *(vi)*. This restriction assures that unaccounted-for water of utility *k′* at its projection onto the efficient frontier is equal to or lower than the targeted level, $s^{k'}_{target}$, which needs to be previously determined by the researcher. This target might be representing the objective of policy-makers or social preferences.

Let us go deeper into the economic intuition behind our measures of performance. On the one hand, when sustainability is omitted, the technical performance of each utility in the sample is assessed by comparing their productive plans either to a plan belonging to an observed efficient utility, i.e. a utility located on the technological frontier, or to the productive plan resulting from a linear combination of plans belonging to several efficient utilities, regardless of their level of sustainability. Conversely, when sustainability is accounted for in assessing performance, the efficiency of each utility in the sample is assessed by comparing their productive plans with an efficient productive plan which *produces* a level of sustainability equal to or greater than that previously targeted by the researcher. In other words, resources that could be decreased when performance is assessed omitting sustainability, must now be unavoidably dedicated to reduce unaccounted-for water.

Accordingly, the difference between both evaluations of performance, namely the assessment omitting unaccounted-for water and the assessment that considers this variable as a restriction, represents the opportunity cost of producing sustainability in terms of a lower potential of input reduction. Obviously, as *producing* sustainability allows utilities saving raw water potential reductions for this production factor are necessarily greater when sustainability is accounted for.

Finally, let us comment on the economic meaning of the equality restriction on fixed input delivery network, namely restriction *(ii)* in programs (4) and (6). It is well known that certain characteristics of the environment where utilities operate might influence the assessment of their performance. In particular, one feature that could influence our results is the difference in customer dispersion faced by the utilities in the sample. The reason is that leakages could be reasonably expected to increase as the length of the network increases, so utilities with a longer delivery network due to greater customer dispersion will incur, on equal terms, in greater amounts of unaccounted-for water. In order to control for this circumstance, in our empirical model the performance of each utility in the sample is always assessed by comparing its productive plan with a plan that makes use of the same delivery network length.

4. Results and Policy Implications

In order to assess the managerial performance of the water and sewage utilities in our sample, we solved programs (4) and (6). Performance accounting for sustainability has been assessed under two different scenarios in which unaccounted-for water is respectively restricted to be equal or less than 24% –which represents the Spanish average– and 23% of raw water for all utilities in the sample. While the first restriction affects 23 utilities, in the second restricted scenario one more utility is affected. In some of these restricted scenarios, no solution was found for utilities 4, 13, 16, 18, 25, 32 and 36 in our sample[2]. Results are in *Table 2*, where, in order make figures comparable across scenarios, all averages have been computed excluding utilities with no solution.

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[2] Considering further scenarios in which unaccounted-for water was restricted to the levels observed in other developed countries or to the 15% level recommended by the European Union would have been really interesting. However, tighter restrictions on unaccounted-for water led to an important increase in problems with no solution due to an insufficient number of productive units to shape the technological frontier, e.g. only 7 utilities in the sample present figures on unaccounted-for water below 20%.

Table 2. Input-specific technical efficiency and percentage of unaccounted-for water in observed and efficient scenarios. Averages.

			Scenario restricting unaccounted-for water to	
	Observed	*Unrestricted Scenario*	*equal or less than 24%*	*equal or less than 23%*
Russell score	-	0.800	0.809	0.813
Raw water	-	0.965	0.948	0.944
Labour	-	0.763	0.781	0.788
Operational costs	-	0.671	0.699	0.716
Unaccounted-for water	25.4% (1)	22.8%	21.5%	21.1%

(1) This percentage slightly differs from that presented in Table 1 because it has been computed excluding utilities with no solution in some of the restricted scenarios.

In the first place, our results show that important reductions of inputs are required to achieve technical efficiency. When sustainability is not considered as a restriction, average scores of technical performance are 0.763 and 0.671 for inputs labour and operational costs, suggesting a potential reduction of 23.7% and 32.9%, respectively. The average score of technical efficiency for raw water is 0.965, pointing to a much lower potential of reduction for this production factor of 3.5%. The assessment of technical efficiency accounting for sustainability displays, in the second place, a slightly different picture of performance. On the one hand, the potential to reduce labour and operational costs decreases to 21.9% and 30.1%, respectively, in the first restricted scenario, and to 21.2% and 28.4% in the second. On the other hand, potential reduction of raw water increases to 5.2%

and 5.6% in the first and second restricted scenarios, respectively, regarding the unrestricted scenario.

Let us go further into the economic meaning of these figures. They indicate that, *producing* sustainability consumes productive resources that otherwise could simply be reduced without worsening the quantity of service produced. Potential reductions of labour and, particularly, operational costs become noticeably affected because reducing leakages requires water utilities to incur in greater operational costs as well as to take more workers on to detect leakages and repair pipelines. Furthermore, given that sustainability is measured through unaccounted-for water, it is obvious that *producing* sustainability also saves the intermediate input raw water. These findings could alone provide utility managers and policy-makers with sound information, as they compare the technical performance of water and sewage utilities assessed from, let us say, a mere *private* perspective, to performance evaluated also including a social dimension of water management. One utility might happen to be a leader when its performance is evaluated from a private viewpoint, but drop significantly down the ranking when performance is assessed accounting for sustainability in the management of water resources.

Furthermore, provided that the cost of inputs labour and raw water is available at utility level, the scores of technical efficiency computed in both unrestricted and restricted scenarios can be used to estimate the opportunity cost of *producing* sustainability. In our sample, the average salary is 29.5 thousand € per worker, while the average cost of raw water is 0.029 € per m^3, which includes the charge that utilities pay to River Basin authorities for raw water and its transportation to the tanks from which it is treated and distributed to final customers. Results are in *Table 3*, where averages have been computed, once more, excluding utilities with no solution in some of the restricted scenarios.

Table 3. Estimated opportunity cost of reducing unaccounted-for water. Average per utility.

	Reducing unaccounted-for water to			
	equal or less than 24%		*equal or less than 23%*	
	thousand €	*%*	*thousand €*	*%*
Reduced cost of raw water	-4.4	-6.5	-5.8	-6.2
Increased cost of labour	19.9	29.3	29.3	31.3
Increased operational costs	52.4	77.2	70.0	74.9
Total opportunity cost	67.9	100.0	93.5	100.0

These figures show that, while reducing unaccounted-for water from an observed average of 25.4% to the 22.8% computed in the efficient scenario when sustainability is omitted (see the last raw in *Table 2*) might be achieved by merely improving efficiency, reducing leakages from this later figure to 21.5% observed in the first restricted scenario would imply, on average and per utility, increased cost of labour of 19.9 thousand € and increased operational costs of 52.4 thousand €. This increase in costs is only partially offset by an average reduction in the cost of raw water of 4.4 thousand €. As a result, the net opportunity cost of reducing unaccounted-for water below 24% for all utilities in the sample would amount to an average of 67.9 thousand € per utility. Similarly, the net opportunity cost of reducing the unaccounted-for water for all utilities below 23% reaches an average cost of 93.5 thousand €.

The cost of sustainability can also be measured in terms of € per m^3 of raw water saved by just dividing the total net cost from one scenario to another by the quantity of raw water saved. The results obtained show that reducing leakages from figures corresponding to the unrestricted scenario to those computed in the first restricted scenario would imply a cost of 0.628 € per m^3 of water saved. Likewise, the cost of reducing unaccounted-for water from figures in the unrestricted scenario to that in the second restricted scenario would lead to a cost of 0.634 € per m^3 of water saved. Finally, the cost of reducing leakages from averages computed in the less exigent restricted scenario to that corresponding to the more restricting one is 0.650 € per m^3 of water saved.

Table 4. Estimated opportunity cost of reducing unaccounted-for water. € per m^3 of water saved.

	Average
From the unrestricted efficient scenario to the first restricted efficient scenario	0.628
From the unrestricted efficient scenario to the second restricted efficient scenario	0.634
From the first restricted efficient scenario to the second restricted efficient scenario	0.650

Assessing the opportunity cost of *producing* sustainability on behalf of Andalusian water and sewage utilities leads to a relevant economic discussion which, in our view, has interesting policy implications. In the first place, our research shows that *producing* sustainability has an increasing marginal cost, which is not a surprising finding. A much more motivating discussion arises when the estimated opportunity cost of reducing unaccounted-for water is compared to the cost of raw water, which, as noted, reaches an average of 0.029 € per m^3. From this comparison it immediately follows that lacking the expenditure necessary to maintain pipelines and reduce unaccounted-for water proves a really profitable strategy for Andalusian utility managers. In other words, it becomes much more profitable to incur higher expenses derived from the use of raw water that will actually be lost along the pipelines, than maintaining and repairing delivery pipelines. In fact, in our sample we find a negative correlation of around 15% between the cost of raw water and the observed percentage of unaccounted-for water.

Obviously, although profitable from a private point of view, this managerial behaviour has the non-negligible *social* cost of wasting water in an area of Europe where the efficient management of this natural resource is a highly pressing need. Avoiding repairing leakages benefits utility managers and might even benefit final consumers, who will pay a lower price for water. However, society is greatly harmed as it assumes the environmental cost stemming from the wasteful use of an increasingly scarce natural resource.

Thus, our results here provide the arguments stated in Section 2 about the squandering behaviour in the management of water on behalf of the Spanish water and sewage industry with empirical support. In addition, results are in line with Garcia and Thomas (2001), who also stress how wasting water might prove to be a profitable strategy for French water utilities from a private view. The contribution of our research is, nonetheless, that the cost of reducing unaccounted-for water is assessed, which might provide policy-makers with sound information to improve the design of policies aimed at regulating the Andalusian water and sewage industry.

Concerning the policy implications of our research, the most outstanding conclusion is that environmental policy measures with the objective of discouraging the wasteful use of raw water by the Andalusian water and sewage industry are required without delay. The economic literature on the choice of adequate policy instruments for environmental management runs into hundreds of papers, the most standard instruments being command and control policies and environmental taxes. While, in our case, a control policy would imply establishing maximum allowed figures for unaccounted-for water, environmental taxes should be levied on the use of raw water. As compared to a tax schedule, the major strength of direct controls is that they can give society far greater assurance of achieving its objectives. However, an important weakness of instruments based on controls is that their enforcement cost can be much higher than the monitoring costs of a program of taxes.

Regardless of the multiple considerations involved in a policymaker's choice of environmental policy instruments, we believe that a fair understanding of the cost for utilities of reducing unaccounted-for water might be of great importance in designing effective environmental policies for the Andalusian water and sewage industry. Furthermore, we believe that the monitoring costs of an environmental regulation establishing a maximum figure for unaccounted-for water allowed would be quite elevated, mainly due to the lack of an already established organism in charge of controlling leakages and, also, the urgent need to improve the management of water resources. Conversely, a schedule of taxes on the use of raw water could achieve the same objective at a much lower cost.

However, the design of an *efficient* schedule of environmental taxes is not always an easy task. A linear tax on raw water consumption for all utilities regardless of their observed leakages, for instance, would comparatively damage utilities devoting greater efforts to reducing unaccounted-for water and, therefore, *producing* more sustainability. In contrast, a schedule of taxes capable of discriminating across utilities according to their, let us say, environmental behaviour, would be much more *efficient*, although it could also be seen as a costly policy.

Our view regarding this discussion is that benchmarking techniques might be of great help in designing a schedule of environmental taxes on the use of raw water capable of differentiating by utility according to how sustainable their management of this natural resource is. Actually, this schedule is advocated in this paper. Moreover, we believe that environmental taxes should be mainly supported by utilities, so that their implementation should be accompanied by measures conducive to avoiding levies being passed on in full to the prices paid by final consumers of water.

The economic impact of different water policies on the Spanish production system has been recently studied, in an input-output framework, by Llop (2008). In one of the scenarios analysed, this paper shows that a tax on the use of water combined with an enhancement in the technical management of this natural resource in the production sphere would significantly reduce intermediate water consumption. In the case that occupies this research, a tax on raw water consumption would help Andalusian water and sewage utilities to reduce leakages while, at the same time, encourages a more efficient management of water resources. Furthermore, the expected increase in the price of water for final consumers due to this environmental policy would act as a disincentive to consume water, thus reducing demand. However, given the low price of water in

Spain (Global Water Intelligence, 2008) and its reduced price elasticity of demand, which has been estimated at between 0.1 and 0.7 (Arbués *et al.*, 2003), this effect is expected to be small.

Finally, let us mention some potential limitations of our research. *DEA* is a deterministic approach to performance evaluation and tends to produce results that are sensitive to outliers and measurement errors, particularly if these observations are shaping a portion of the efficient frontier. However, we have tested that our estimates of performance do not depend on a reduced number of utilities repeatedly shaping the frontier, but rather on a set of ten to eleven utilities that envelop twice or more times the behaviour of other utilities in the sample. Furthermore, certain characteristics of input capital for which we have no information, such as the age of the delivery network, might also influence the assessment of performance. In spite of the lack of data about the quality of input capital, which is a common feature in efficiency analyses, we sincerely believe that our results are of interest for both the managers of utilities and policy-makers responsible for environmental legislation affecting the Andalusian water and sewage industry.

5. Summary and Conclusions

Assessing managerial performance in the water and sewage industry is a customary practice that makes valuable information available to both utility managers and policy-makers responsible for the regulation of this industry. Conventional analyses have mostly approached this issue from a *private* perspective ignoring that the management of water resources involves other *social* dimensions such as sustainability. Nonetheless, increasing water scarcity and the urgent need to achieve sustainable management of this natural resource calls for novel methods to assess performance in the water and sewage industry. In this paper, we use *Data Envelopment Analysis* techniques to assess the performance of a sample of water and sewage utilities located in Andalusia, a Southern European region, while accounting for sustainability in the management of water. Sustainability is measured by unaccounted-for water. Moreover, the opportunity cost of *producing* sustainability is assessed.

Our major results are the following. In the first place, we find that leakages could be significantly reduced just by improving managerial practices. Secondly, achieving additional reductions of unaccounted-for water requires utilities to incur in further use of productive resources, mainly labour and other operating expenses, the cost of which can be assessed in terms of opportunity. Once technical efficiency is attained, reducing leakages for all utilities in our sample below the Spanish average, which stands at 24%, would entail a cost of 0.628 € per m^3 of water saved. Assessing the cost of achieving further reductions shows that the marginal cost of *producing* sustainability is increasing. In the third place, comparing the opportunity cost of reducing unaccounted-for water with the cost of raw water –0.029 € per m^3, on average– demonstrates that wasting water resources is a highly profitable managerial strategy for Andalusian water utilities. However, this behaviour has a huge *social* cost in an area of Europe where, due to increasing water scarcity, attaining sustainable management of this natural resource is an urgent issue.

From the abovementioned results, our most important conclusion is that water policies aimed at avoiding the squandering of water resources by Andalusian water and sewage utilities are needed without delay. The design of effective environmental policies involves manifold considerations. However, our view is that estimating the cost for utilities of reducing unaccounted-for water might help policy-makers to design water policies capable of achieving this purpose. Here, we advocate for a system of taxes discriminating among water utilities according to how sustainable their management of water resources is. Benchmarking techniques and *Data Envelopment Analysis* are, as we show in this paper, suitable for assessing sustainability in the management of water at utility level.

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