

**EXPLANATORY FACTORS OF URBAN WATER
LEAKAGE RATES IN SOUTHERN SPAIN**

**FRANCISCO GONZÁLEZ-GÓMEZ
ROBERTO MARTÍNEZ-ESPIÑEIRA
MARIA A. GARCÍA-VALIÑAS
MIGUEL Á. GARCÍA RUBIO**

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Explanatory Factors of Urban Water Leakage Rates in Southern Spain

Francisco González-Gómez^{*}

Roberto Martínez-Espiñeira^{**}

Maria A. García-Valiñas^{***}

Miguel Á. García Rubio^{****}

ABSTRACT: The need of strategies leading to the sustainable management of water resources is an increasingly pressing issue, especially in regions that suffer greater water stress. Paradoxically, although there is awareness of this need, in many cities of the world, water losses remain high. This is a concern not only in developing countries, but also a challenge in developed countries. In this paper we analyze the case of Andalusia, the region with the greatest level of water stress in the European Union, which exhibits relatively high urban water losses. We pose the question of why the water losses are so high in some cities of Andalusia. In order to find an answer, we analyze data from 133 cities. We find that water loss volumes are related to the age of networks, the dispersion of population, population growth and the size of water reserves. The ideology of local governments and whether there is private participation in service management seem to exert no statistically significant effects.

keywords: urban water management; water losses; sustainable water use; sustainable cities.

JEL Classification: L95, Q25

^{*} Corresponding author: Departamento de Economía Aplicada. Facultad de Ciencias Políticas y Sociología. Universidad de Granada. C/Rector López Argüeta s/n. 18071. Granada. Spain. E-mail: fcojose@ugr.es

^{**} Department of Economics. Memorial University of Newfoundland. St John's. Newfoundland and Labrador A1A 5S7 Canada. E-mail: rmartinezesp@mun.ca. Tel:1-709-737-3676. Fax: 1-709-737-2094

^{***} Toulouse School of Economics, LERNA, Manufacture des Tabacs, 21 allée de Brienne, 31000 Toulouse. France. E-mail: mvalinas@toulouse.inra.fr

^{****} Departamento de Economía Aplicada. Facultad de Ciencias Económicas y Empresariales. Universidad de Granada. Campus de Cartuja s/n. 18071. Granada. Spain. E-mail: magrubio@ugr.es

1. INTRODUCTION

The impact of global climate change and the increasing demand pose serious challenges for water management. Throughout the World, climate change will affect daily life in many human settlements. In many regions, decreasing levels of average rainfall and rising temperatures will lead to lower water availability (Bates et al., 2008). Moreover, the rate of population growth will require that greater volumes of water be allocated to meet various human needs. According to United Nations (2009), world population rose between 1975 and 2009 from 4,061 to 6,829 million and in 2050 it is expected to exceed 9,000 million. In many regions, water stress will increase over time.

This situation highlights the need of a more efficient management of water resources throughout the world. Although in agriculture, which accounts for approximately 70% of the global water resources (Molden, 2007), there is a higher margin for saving water, it is also very important to improve the management of water resources in cities. Making and efficient use of water resources in urban areas will significantly contribute to the development of sustainable cities and regions (Satterthwaite, 1997; Alshuwaikhat and Nkwenti, 2002).

Undoubtedly, the reduction of water losses¹ is one of the main aspects to improve in management of water resources in urban areas. There are several negative impacts of water losses. For example, high volumes of water leakages means that supply firms incur higher costs, mainly because of the extra resources needed for the extraction and treatment of water that does not reach the service users. In addition, leaks can also risk of contamination of drinking water if the pressure distribution network is low, because pollutants can infiltrate through pipe breaks (Funk et al., 1999). It should be added that the paradox could occur, especially in regions with high water stress, that water is lost by the networks while the end user has to endure cuts in supply or changes in water pressure flowing through the networks, both inconvenient and unsafe practices (Cabrera et al., 1998). Finally, water leakages could even force the company to exploit lower quality raw water. This can lead to higher costs of purification and in the worst cases, a deterioration of the service that could endanger the health of the served population (Murray et al., 2006).

The issue of water losses is not equally pressing around the world. In developing countries water losses are estimated to reach 35%, while in developed countries are the estimate is 15% (Kingdom et al., 2006).² In any case, although water losses are greater in developing countries, they represent also a serious challenge for the

¹ In this paper we will refer interchangeably to “water loss” or “leakage”. This is because in the area of study most of the water losses are indeed due to leakages.

² Water losses data as a percent of system input volume.

developed world (Gurría, 2007). Spain is a clear example of developed country with water losses that are relatively high. On average, water leakages in Spain are around 25% (National Statistical Institute –INE–, 2009).

Most worrying is that there are many cities where the water loss rate far exceeds this very high average rate. This is particularly surprising in Andalusia, a region of southern Spain that exhibits the greatest levels of water stress in the European Union (European Environment Agency, 2009). The question we ask is why are there such high levels of water losses in some cities in southern Spain. Apart from the country's institutional factors, it would be desirable to identify which factors explain why water loss rates reach in some cases levels well above 25%. Applying regression analysis to data from 133 cities in the area we aim to find an answer to this question. Among the main conclusions we can highlight that the water losses are related to the age of networks, the dispersion of population, population growth and water reserves. Somewhat against expectations, the ideology of local governments and whether there is private participation in service management seem to have no statistically significant effects. We have no knowledge that, to date, similar research has been conducted, at least for the Spanish case. Those findings help policy makers to get an efficiency allocation of public funds.

The remainder of the paper is organised as follows. In the second section we review who is responsible for water management in cities and ultimately, for the control of water losses. The third section describes the context of the analysis. In the fourth section we present our hypotheses. In the fifth section, the methodology and the dataset are described and the results discussed. Finally, the sixth section is devoted to the summary and conclusions.

2. RESPONSIBILITY FOR WATER LOSSES IN SPANISH CITIES

The legal framework currently governing the administration of municipal services in Spain is given Bylaw 7/1985 Regulating the Basis of Local Government and Bylaw 57/2003 on measures to modernize local government. Article 25 of Bylaw 7/1985 reads that the municipality, *for the management of their interests and within the scope of their powers may promote any type of activities and provide any public services as to help meet the needs and aspirations of the neighborhood community*. The second paragraph of that article quotes that the municipality, among other services, must necessarily assume jurisdiction over the water supply service.

The municipality is charged with ensuring the supply of the water service and it also has the power to choose the type of administration. The local government has

jurisdiction to decide the legal form for the provision of water services. The aforementioned Bylaw 7/1985 and 57/2003 and the Royal Decree Law 2/2000, approving the revised text of the Law on Public Administration Contracts, establish different legal forms for municipal services. The options available to the local governments are to manage the service from the City Council itself or to outsource the service. In the latter case the management may be transferred to wholly public companies, to entirely private companies or to companies with mixed ownership.

Directly managing the service from the City Council itself implies that the council assumes all powers of decision and management, using their own staff and addressing their pay with funds from the municipal budget. The creation of publicly owned companies is a form of decentralized administration. This option means that management becomes subject to private law regulations aims at achieving management autonomy.

The local government also has the option of privatizing the management of the service. It should be noted that according to Spanish law, municipalities can only privatize the management of the water service as such, since the water supply infrastructure still belongs to the public administration. The company that holds the concession is responsible for the running of the service and the maintenance of the supply networks during the time arranged in the contract. At the end of the contract, the local government must decide once more how the service is to be managed.

The most widespread form of privatization in Spain is the concession. Concessions are formalized through a management contract of public services whereby the municipal administration, which remains legally charged with the service, entrusts its operation to a natural person or legal entity. Concessions are awarded through public competitions and they cannot be arranged with an indefinite term. In the case of water supply companies a limit of fifty years applies for contracts that include setting and operating works of public service, and twenty-five years for those that involve only the exploitation of a public service.

Another alternative to privatizing the management of water services is the creation of mixed public/private ventures (Warner and Bel 2008, Gonzalez-Gomez et al. 2009). In the mixed venture, equity participation is shared between public and private participation, but, in any case, the participation of the local entity must be sufficient to ensure an adequate achievement of the public purposes pursued. This legal figure can more easily combine the pursuit of public interests with the advantages afforded by the use of private management. The day-to-day management is performed by with the private partner who has more know-how of the industry, while policy decisions are made by the public partner.

Where the water service provision is made in house by a public agency, the responsibility for managing networks and therefore water leakage rests on the local government itself. In the event that the service is conducted by a public company, private or mixed responsibility is shared between the company and the local government, which must control the management of the service. In Spain there is no legal framework to set the amount of losses that the networks should have, nor are there regional or national administration bodies specialized in controlling the management of the water service. The responsibility for the management of networks is limited to the area of the city.³

3. BACKGROUND

Andalusia is a European region located in Southern Spain with an area of 87,268 km² and a population of around 8.2 million inhabitants. Its 1101 kilometer long coastline harbours strong levels of tourist activity, attracting visitors from different sources, particularly the central and northern European Union.

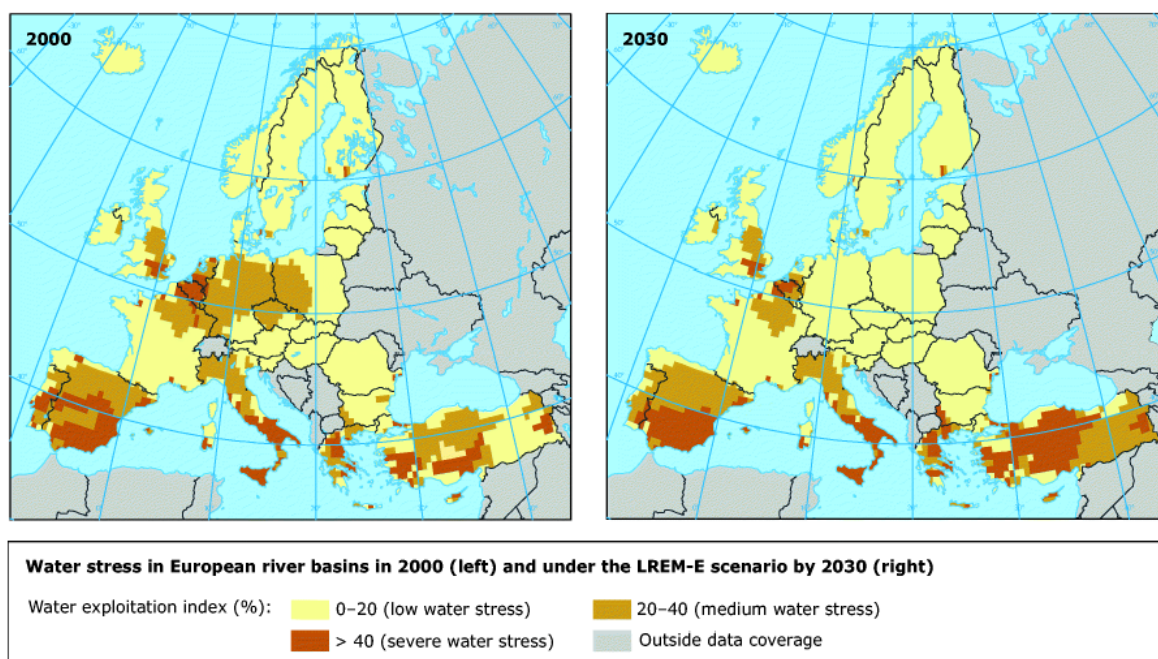
A water shortage problem has for long been detected in the region that has tended to become more pressing over the years. The available water resources, estimated at around 5,600 hm³ per year, are insufficient to meet the growing demand for water. In 2008 the water deficit was estimated at around 170 hm³ (Junta de Andalucía).⁴ As in other southern European regions, in Andalusia there is a high pressure on water resources (Fig. 1), which is unlikely to decline in coming decades (Henrichs et al., 2002). The southern river basins of Andalusia have an extremely high water exploitation index⁵ of 164%, the highest in the European Union (EEA, 2009).

³ In Spain, the pricing boards (Comisiones de Precios), dependent on the regional government, may request a leakage reduction plan when its rate is above 25%, otherwise they do not authorize the increase in water tariffs. However, Spanish municipalities can easily circumvent this control because of the complex and contradictory legal framework in this matter. Furthermore, these leakage reduction plans are not subject to any supervision or receive any advertising. In England OFWAT publishes since 1995 a biannual report on the evolution of the hydraulic efficiency of their supply systems (OFWAT, 2006), which undergo rigorous audits.

⁴ Junta de Andalucía. On-line consultation in December of 2009:
http://www.juntadeandalucia.es/medioambiente/site/web/menuitem.a5664a214f73c3df81d8899661525ea0/?vgnextoid=5dae28e8ba310110VgnVCM1000000624e50aRCRD&vgnnextchannel=b9bf1d00446a6010VgnVCM1000000624e50aRCRD&lr=lang_es

⁵ The Water Exploitation Index is an indicator of pressure on water resources which is calculated annually as the ratio of total freshwater abstraction to the total renewable resource.

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



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

In a scenario of severe water scarcity like that currently faced by Andalusia, protection and integrated sustainable management of water resources should be recognised as a really pressing need. In fact, in the last decade, the Spanish government has changed the orientation of its water policy, traditionally based on the creation of water infrastructure to store larger volumes of water and transferring resources from surplus areas to deficit areas, towards one based on promoting improvements in the management of this natural resource.

Paradoxically, however, in a region with such high water stress also high levels of water losses are commonly observed among the urban water and sewage utilities. According to data published by the National Statistical Institute⁶ in its *Survey on Water Supply and Sanitation*, water losses as a percent of system input volume were close to 23.5% in 2007, of which approximately two thirds were real losses and third apparent losses.⁷ The evolution of this indicator is also worrying, since in 1997 water losses were only 18.3% (Fig. 2). Both these figures provide a stark contrast to the average of 15% observed in developed countries (Kingdom et al., 2006) or to targeted rates of water losses encountered in other developed countries. For example, AWWA's Leak

Values above 40% indicate severe water stress and a clearly unsustainable use of the water resource (Raskin et al., 1997).

⁶ For further details, check www.ine.es.

⁷ Apparent losses is associated to unauthorised consumption and metering inaccuracies.

Detection and Accountability Committee (1996) recommended ten per cent of water leakage rates.⁸

Although water distribution systems typically allow a certain amount of losses, according to the system pressure or the size and type of pipe, which is not economical to repair (Wallace, 1987), it is apparent that the water losses in Andalusia, a region facing an extraordinarily high level of water stress, are inordinately high. In the following sections we attempt to provide explanations for why water losses are so high in several Andalusian cities.

Fig. 2: Water loss in Andalusian water management urban as a percent of system input volume. 1997-2007.



Source: Instituto Nacional de Estadística. *Encuesta sobre el Suministro y Saneamiento del Agua*.

4. FACTORS BEHIND THE HIGH LEVELS OF WATER LOSSES IN ANDALUSIAN CITIES. SOME HYPOTHESES

In order to explain the high levels of water losses recorded in many Andalusian towns, we may distinguish between two types of factors. On the one hand there are factors with an overall impact, which would affect equally all the Spanish territory, and, on the other hand, there would be specific factors that would explain the differences observed in water losses between cities.

Undoubtedly, the existing legal gap in relation to the management of water service infrastructure is a critical factor to explain the high volumes of water lost by the Spanish

⁸ However, target setting it is still somewhat arbitrary (Beecher, 2002).

networks. There is no regulation that sets leakage objectives for the supplier of water services. Additionally, there is no supervisory body that could monitor and punish excessive levels of water losses. This difficult to understand double absence, the legal and institutional framework, helps explain why in the Spanish cities are water losses so large. Given the Spanish case, it seems clear that leaving full responsibility for the control of water losses to local governments and management firms is not a good option to ensure sustainable management of water resources in cities.

In any case, the aforementioned causes apply equally to all Spanish territory. Now we wonder why there are such marked differences in water loss data across cities. It is clear that there are other causes that explain why in some cities water losses are substantially higher than in others. The purpose of our analysis is to identify those factors relevant in the in the context of each city.⁹

As Garcia and Thomas (2001) pointed out, water suppliers improve efficiency levels in water distribution but are constrained by high repair costs. They try to satisfy daily increasing demands by a) keeping production constant while increasing network efficiency by more frequent maintenance and repair operations and/or b) increasing production while keeping the water network rate of return constant. Since the labor and material cost involved in repairs is much higher than the energy cost associated with increased production and because the unit cost of the water input is close to null, they prefer option b). Thus, the joint production of a desirable output with an undesirable one is more profitable than just increasing efficiency in the production of the desirable output. In this paper, we do not have data about costs, but we have information about a set of variables related to those costs.

We review next different scenarios and variables introduced in the model for its test. Table 1 shows a description of the variables included in the study and the source of the corresponding data.¹⁰

⁹ See Skipworth et al. (1999) for a survey related to several explanatory factors of leakage levels.

¹⁰ It would have been desirable to introduce additional explanatory variables in the model but it was impossible due to the lack of data availability. Future studies should consider introducing a proxy for the type of soil. It would have been also desirable to have information from companies about values of the pressure of the system.

Table 1. Variable description

<i>Variable</i>	<i>Description</i>	<i>Source</i>
<i>WATER_LOSSES</i>	Water loss as a percent of system input volume. 2005.	Town councils and public and private firms.
<i>AGE</i>	Number of years since the installation or complete renovation of the distribution network	Town councils, public and private firms and Ministry of Territorial Policy (Local infrastructures and Equipment Survey).
<i>AGE²</i>	<i>AGE SQUARED</i>	Town councils, public and private firms and Ministry of Territorial Policy (Local infrastructures and Equipment Survey).
<i>FINANCIAL_BURDEN</i>	Debt costs divided by current income. Average 1990-2005.	Local Corporation Budget. Ministry of Economic Affairs.
<i>FLAT_FEE</i>	Total fixed charge for water services. 2005.	<i>Boletín Oficial de la Junta de Andalucía</i> and <i>Boletines Oficiales</i> (official gazettes) of the eight Andalusian provinces.
<i>CONTRACT_OUT</i>	0: if management is "in house" in 2005 1: otherwise	Town councils and public and private firms.
<i>YEARS_OUT</i>	Number of years from taking the contracting-out decision.	Town councils and public and private firms.
<i>PRIVATE</i>	0: if management was not private in 2005; 1: otherwise	Town councils and public and private firms.
<i>URBAN_AGGLOM</i>	0: if municipality does not belong to an urban agglomeration; 1: otherwise	Andalusian Regional Government
<i>CONSORTIUM</i>	0: if municipality does not belong to a consortium; 1: otherwise	Ministry of Territorial Policy.
<i>DENSITY</i>	Population per km ² . 2005.	Municipal Census. National Institute of Statistics
<i>LENGTH</i>	Length of network in meters. 2005.	Town councils, public and private firms and Ministry of Territorial Policy (Local infrastructures and Equipment Survey).
<i>DISP_POP</i>	Percentage of population not living in the main village/city. 2005.	Municipal Census. National Institute of Statistics
<i>GROWTH_POP</i>	Population growth rate between 1996 and 2005.	Municipal Census. National Institute of Statistics
<i>CAP_MIN</i>	Minimum water percentage of reservoir storage in the river basin. Average 1995-2005	Ministry of the Environment
<i>IDEOLOGY</i>	Political sign of local government during the last three elections 0: majority of left-wing parties; 1: otherwise	Ministry of Interior (Electoral results) and Ministry of Territorial Policy (Registry of Mayors).

Our first hypothesis suggests that the age of the networks is related to the rate of water losses. Sudden changes in pressure and corrosion of pipes due to the aggressiveness of the water flow and the soil or the effect of traffic vibrations are factors that over time compromise the tightness of the distribution networks. The estimating regression incorporates two variables to capture this relationship; *AGE*, which reports the number of years since it was made or renewed to complete the distribution network, and its square *AGE2*, which reflects the pace of developments in the relationship over time and allows for a nonlinear effect behind the relationship.

One additional reason often reported by the literature to explain high levels of water losses is the lack of resources to invest in the monitoring, maintenance and conservation of networks (Bakker, 2002; Soler, 2003; Fitch, 2007). The reduction of real losses involves an opportunity cost in using available resources (Picazo-Tadeo et al., 2008). For example, the time elapsed since the leakage until it is detected matters a lot. Shortening the leak detection time implies an added cost due to the implementation of modern control systems. Furthermore, once the leak is detected, an investment is required for the repair. The cost of maintenance and repair of networks is relatively high and sometimes management agencies face serious budgetary difficulties (Pacione, 2006, Thapa et al. 2008). The variable *FINANCIAL_BURDEN*, which is debt costs divided by current income, was included in order to capture the relationship between the financial situation of the municipality and the level of water losses. Also included is the variable *FLAT_FLEE* that reports the companies' ability to generate revenue to meet the fixed costs of supplying the service. Differences among flat fee levels could explain, at least partially, the differences in levels of expenditure devoted to maintain and conserve water service infrastructures (Martínez-Espiñeira et al., 2009).

The type of management ownership can be an added factor to explain differences in water losses. The first question is whether it matters that the management is done in-house versus by a firm. Outsourcing involves greater specialization of the staff and greater professionalism in the service, because the company staff is dedicated exclusively to this activity.¹¹ The dichotomous variable *CONTRACT-OUT* indicates whether the management is done in house or by a company. In addition, the variable

¹¹ When the management is carried out by the local council, it is common for the personnel in charge of the water service to also be responsible for other areas at the same time. For instance, when gathering the data we discovered that in a small village, the person in charge of the municipal service was also responsible for the plumbing when there were leaks in the water distribution network. It is less surprising, but more frequent, for the bureaucrat in charge of management and administration of the water service to share this activity with others at the Town Hall. Contracting out could lead to specialization in water management.

YEARS-OUT, which indicates the number of years since the service is outsourced, was also included as an independent variable in the model.

Moreover, when undertaking measures to control water losses is up to private firms, the objective of profit maximization can leave the problem of water losses in the background. The company may prefer that the water be lost through the network, simply because the costs to be incurred for network maintenance and repair do not outweigh cost savings in terms of additional pumping and extraction of resources and of the production of water (Gilbert, 2007; Picazo-Tadeo et al., 2009). As in the case of Andalusia, a null or very low cost of raw water can make it more profitable not to reduce the level of losses. The model includes the variable *PRIVATE* to capture the relationship between the presence of a private manager and the level of water losses.

We also wanted to test whether being part of supra-municipal associations affects water losses. The joint provision of the service to various municipalities allows towns to take advantage of significant economies of scale in the industry (González-Gómez and García-Rubio, 2008). In these cases, the average costs of the service can be lowered, releasing more resources for the preservation and maintenance of networks. The model incorporates variables indicating the two legal forms that in Andalusia promote municipal associations and, therefore, the joint provision of services by a set of individual municipalities: *URB_AGGLOM* and *CONSORTIUM*.

There are also factors not controllable by local governments or by the manager that can influence the levels of water losses. These include, for example, factors related to the service area and the distribution of the population. We introduced the variables *DENSITY*, *LENGTH*, *DISP_POP* and *GROWTH_POP*. When it comes to the density of users, expected results are ambiguous. On the one hand, one could argue that lower losses could be expected in areas of greater density, since the costs per subscriber associated with network maintenance would be lower. Conversely, it should be borne in mind that in cities with higher population density, the water pressure on the networks will be greater to reach the higher floors, and these higher pressures may be responsible for the deterioration of fittings and valves. Also repairs to the network have an higher associated social cost in heavily populated areas due to the necessary cuts of both sidewalks and traffic.

The length of the network and the percentage of the population dispersed in secondary towns reflect the existence of a wider area to be served by the supplier, which should be linked with higher levels of water losses, due to the more costly maintenance and preservation of the network (Weimer, 1992).

The relationship between water losses and population growth is also ambiguous. On the one hand, population growth implies the existence of new urbanized areas and,

therefore, new pipes for water distribution and less leakage. Conversely, with the population growth the complexity in managing the service increases, which can result in higher leakage. If the main network design does not take into consideration future urban growth, the subsequent extension of the network may require increases in pressure in the main arteries for which these were not originally designed.

Another factor that of course falls beyond the control of the manager or the local government is the volume of rainfall, which conditions the levels of water reserves. Andalusia is a region with high water stress and where it is not uncommon that many municipalities have to cut the water several hours a day during the summer. Sudden variations in pressure, such as those produced by supply cuts, cause much of the pipe breakages and leakages (Lackington, 1991). In order to capture these relationships we used the variable *CAP_MIN*, which indicates the minimum water level reached by the reservoirs in the river basin to which the municipality belongs.

Heated political debates at the local level tend to surround water services issues such as privatization, outsourcing, subsidies, efficiency, or water losses (Gilbert, 2007). The ideology of the party ruling the municipal government may explain different behaviors of local governments towards the issue of water losses. There are at least two possible relations between the ideology of the local government and water losses. First, attempting to reduce apparent losses due to unauthorized consumption may have a high political cost. A high percentage of illegal connections occur in the slums of cities. Undertaking actions to charge for a basic service to the poorest segments of the population could lead to strong social reactions. Normally, left-wing parties, more closely linked to social programs will be more reluctant to control apparent losses due to unauthorized consumption.

Conversely, one can expect that leftwing parties are more sensitive to actual losses and act more decisively to reduce water leakage. The leftwing parties more often include in their electoral programs references to the fact that they are concerned environmental issues. In order to capture the possible relationship between the ideology of local government and water losses, we introduced *IDEOLOGY* a dichotomous variable that takes value 0 with left-wing government and 1 with right-wing government.

5. EMPIRICAL EXERCISE

In this section we describe the steps taken to test the hypotheses stated in the previous paragraph. We intend to find out what factors influence the levels of water

losses in Andalusian cities. We include some brief methodological notes. Additionally, we describe the data and discuss the main results.

Given the nature of the variables involved in our model, we used a simple weighted least regression model relating the variable *WATER_LOSSES* to a set of explanatory variables. The weighting procedure is based on the use of weights to correct for the heteroskedasticity (related to the length and the age of the municipal network) detected in preliminary ordinary regression models.

The analysis was conducted using cross-sectional data from 133 cities of Andalusia. This sample represents 17% of the municipalities in the region and just below 50% of the population. Table 2 shows a descriptive summary of variables. As mentioned in the previous section, Table 1 contains a description of the variables, including the source of the data.

Table 2. Summary descriptive of variables

VARIABLE	MEAN	STD. DEV.	MIN	MAX
<i>WATER_LOSSES</i>	35.78	11.12	19.00	86.39
<i>AGE</i>	37.41	17.39	4.00	105.00
<i>AGE²</i>	1,699.91	1,711.13	16.00	11,025.00
<i>FINANCIAL_BURDEN</i>	5.98	3.12	0.24	16.42
<i>FLAT_FEE</i>	3.75	1.67	0.60	10.84
<i>CONTRACT_OUT</i>	0.89	0.31	0.00	1.00
<i>YEARS_OUT</i>	11.66	7.86	0.00	37.00
<i>PRIVATE</i>	0.50	0.50	0.00	1.00
<i>URBAN_AGGLOM</i>	0.43	0.50	0.00	1.00
<i>CONSORTIUM</i>	0.36	0.48	0.00	1.00
<i>DENSITY</i>	488.12	1089.81	3.49	7542.15
<i>LENGTH</i>	100,252.00	214,821.00	2,418.00	2,049,521.00
<i>DISP_POP</i>	2.82	4.96	0.00	32.18
<i>GROWTH_POP</i>	1.37	3.39	-3.21	27.57
<i>CAP_MIN</i>	51.85	4.05	40.90	55.50
<i>IDEOLOGY</i>	0.14	0.35	0.00	1.00

Table 3 shows the results of the weighted least squares estimation. These results reveal that a good proportion of the explanatory variables introduced in the model appear to have a significant effect on leakage rates (*WATER_LOSSES*).

Table 3. Regression results. Dependent variable: *WATER_LOSSES*.

VARIABLE	Coefficient	t-ratio
<i>AGE</i>	0.542**	(1.970)
<i>AGE</i> ²	-0.009*	(-1.940)
<i>FINANCIAL_BURDEN</i>	-0.748***	(-3.430)
<i>FLAT_FEE</i>	-0.512	(-0.800)
<i>CONTRACT_OUT</i>	18.857***	(4.940)
<i>YEARS_OUT</i>	-1.287***	(-6.210)
<i>PRIVATE</i>	-1.075	(-0.260)
<i>URBAN_AGGLOM</i>	-2.952	(-0.950)
<i>CONSORTIUM</i>	-4.333	(-1.350)
<i>DENSITY</i>	-0.003	(-1.010)
<i>LENGTH</i>	0.000	(0.580)
<i>DISP_POP</i>	0.809***	(2.950)
<i>GROWTH_POP</i>	2.259***	(3.330)
<i>CAP_MIN</i>	1.127***	(4.190)
<i>IDEOLOGY</i>	-2.852	(-1.360)
<i>CONSTANT</i>	-25.704	(-1.610)
Number of obs.	133	
F (15, 117)	15.460***	
R-squared	0.665	
Adjusted R- squared	0.622	

* Significant at 10%, ** Significant at 5%, *** Significant at 1%.

Predictably, the first relationship found is that water losses are greater the older the networks. The state of the network deteriorates over the years and, as a result, the networks suffer greater water losses. For this relationship to hold, the expense made

for servicing and maintaining the networks must be insufficient to offset the progressive deterioration of the networks. It should be noted, however, that beyond a certain age, the rate of growth of losses in networks appears to decrease, even becoming negative. In particular, estimates indicate that the turning point in the sample size occurs around an age of 29 years. This second result may be explained by the fact that, over the years, water utilities have already been obliged to renew much of the network length, so very old networks have already benefited from updated infrastructure.¹²

There also seems to be a significant negative relationship between *FINANCIAL_BURDEN* and *WATER_LOSSES*. It is plausible that, when facing their financial constraints, municipal local governments can react in two ways. They can either limit their spending policies and, therefore, taking less action, in this case, to prevent leakage or they can instead borrow to meet planned expenditure policies during their mandate. The latter mode of action would explain the relationship found. Despite financial constraints, many local governments do not give up their spending policies, including undertaking measures to reduce water leakage, which would. In this case local governments would of course have to resort to borrowing.

Those municipal governments that choose to have healthier public account balances probably devote fewer resources to the reduction of water losses. When this type of decision rests with public managers, they may prefer to allocate the available funds to other activities that render them greater political mileage. This result would be an indication that water loss control is not really among their management priorities. In fact, the reduction of water losses has not traditionally been a foremost priority (Thornton et al., 2008). In this regard, a key issue is that water that is lost through the networks is not seen, nor usually affects the normal functioning of the city. The average citizen is rarely aware that under the ground large amounts of water are wasted and does not directly suffer any short-term effects. Only in extreme cases will leaks cause obvious damage to surrounding infrastructure, such as building foundations, roads, and other networks. In addition, leak repairs can have a negative impact on the welfare of citizens in the short term. Lifting the sidewalks and opening ditches to renovate and maintain distribution networks inconveniences citizens.

Our regression results suggest a positive relationship between *CONTRACT_OUT* and *WATER_LOSSES*. This result, which runs contrary to expectations, could be explained if many of the municipalities that choose to outsource the management lack sufficient

¹² It is noteworthy to point out that 34 years is the longest amortization period contemplated by the Spanish Corporate Tax Law. It makes sense that a good proportion of physical assets affecting the quality of the distribution network are renewed and replaced within a thirty year period, so, although such networks are classified as older, they are starting in practice to become newer.

financial resources and personnel to provide a quality service. It is likely that when the decision was made to outsource, the distribution networks were already in a very bad condition. If municipalities outsource the management of the supply as a way to avoid responsibility, a poor state of the networks can be trigger this decision, outsourcing the management in order to avoid the collapse of the system.

However, the result of *YEARS_OUT* reveals that the strategy of outsourcing paid out at least from the standpoint of long-term sustainable management. The longer since the service was outsourced, the lower is the current level of water losses. It is likely that the estimated relationship between the variables *WATER_LOSSES* and *CONTRACT_OUT* does not fit our expectation because in many cases not enough time has gone by to reveal the positive effects of outsourcing. In fact, about three quarters of all municipalities that have delegated the service have done it only within the last fourteen years.¹³

We found, on the other hand, no relationship between *PRIVATIZATION* and *WATER_LOSSES*. It is true that the private entrepreneur might have little incentive to control water leakage, but it is also true that neither does the public manager. In order to explain the disconnect between private management and water losses, we should clarify that local governments are responsible for controlling the management of the private firms entrusted with the supply service. However, there are problems of control by the municipality including the traditional absence of these controls, the lack of resources and adequately trained technicians, and the asymmetry of information between the private operator, usually large corporations, and City Hall. Moreover, the contractual requirements specified for competitive awards of the concessions lack a common denominator, so they do not necessarily include leakage reduction targets.¹⁴

Among the coefficients of the variables representing the environment in which the service is provided, *DISP_POP* and *GROWTH_POP* are significant and have a positive sign. It is striking that *LENGTH* is not significant, but *DISP_POP*. The result highlights that, rather than the length of network as such, it is the existence of several towns that leads to increased water leakage. It is likely that the service manager and local politicians are more concerned about the state of the network in the core centers and neglect more the infrastructure of some of the surrounding towns. The political gain is

¹³ This suggests that exploring the relationship between the length of time that a network has been privately operated and the rate of leakage would be a worthwhile avenue for future research, although beyond the scope of the present contribution.

¹⁴ Conditions imposed in outsourcing contracts can be considered as an instrument to reduce water losses. Zaki and Amin (2009) show that, as a consequence of the conditions set in the water supply privatisation contract in Pathumthani, a water losses reduction from a staggering proportion of 58.46 % in 1998 (immediately after privatisation) to a proportion of 20.75 % in 2004 was obtained.

largest from increases in expenditure in the most populated areas, where most of the voters reside, and the service manager will face less opposition from local residents in less populated areas. Moreover, population growth makes service management more complex and the resources available insufficient to address any potential issues with the service.

The variable that captures the magnitude of financial resources collected by the manager through the fixed component of the water tariff, *FLAT_FEE*, does not explain differences in the levels of losses. This could be because the income from the fixed charges is not representative enough to justify differences in expenditures for the upkeep and maintenance of networks. For one thing, there is not necessarily an allocation of fixed fee revenues for the upkeep and maintenance and, besides, the fixed rate is capped in Andalusia. Furthermore, it is not uncommon for a portion of the proceeds to be devoted to the other investments which, especially in smaller municipalities may be different from the actual water supply service.

The variable *IDEOLOGY* is not significant either. Perhaps left-wing parties make an effort to overstate environmental issues during the election campaign, but at least with respect to control water loss, it appears that, once in power, there are no significant differences in the actions of the different parties.¹⁵

When it comes to the variable *CAP_MIN*, we find that its estimated coefficient suggests a positive relationship between the level of losses and the minimum water level reaching the reservoirs of the river basin is located in the municipality. A low reservoir level suggests increased frequency of outages as a measure of rationing to ensure some level of supply throughout the dry season and these cuts tend to increase loss of water supply network subject to sudden changes of pressure.

Finally, there was no relation between legal institutions that facilitate the formation of associations of municipalities in the service management and the rates of water leakage.

¹⁵ The Spanish Socialist Party (PSOE) and the Partido Popular (PP) rule in most Andalusian towns. The PSOE is a center-leftwing party, while the PP is a center-rightwing party. In their struggle to dominate the political center, it is normal for them to converge in many of their decisions. Perhaps a variable picking up other ideological trends oriented more to the left of political spectrum and a greater sensitivity to environmental problems would have made it possible to obtain the desired result. However, this type of analysis was not possible because the lack of enough observations, simply because only in very few cases a party to the left of PSOE was in power.

6. SUMMARY AND CONCLUDING REMARKS

The sustainable management of water resources is an increasingly pressing concern, especially in regions that suffer greater degrees of water stress. Paradoxically, although there is clear awareness of this need, in many cities around the world water losses are still high. This concerns not only cities in developing countries but is also a challenge in developed countries.

In this paper we analyze the case of Andalusia, the region with the greatest level of water stress in the European Union and which faces relatively high rates of water losses. We aim, using regression analysis on a cross-section of data from 133 municipalities, at finding out why water losses are so high in some cities of Andalusia. This is the first study, at least in Spain, that analyzes the factors that explain the rates urban water losses.

Among the results obtained, we find that leakage rates can be partly explained by the age of the networks and by the lack of investment at the rate necessary for their upkeep and maintenance. Additionally, we observe that the greater the dispersion of the population among different population centres, the larger the population growth and the lower the availability of water in reservoirs in the river basin the higher the rate of water losses.

Contrary to expectations, we find a negative relationship between indicators of fiscal stress in the municipality and water losses. The explanation is very likely that those local governments which do not give up carrying out their spending policies, including those related to the maintenance of the water supply infrastructure, choose to fall into greater debt. Moreover, even if this is a relationship worthy of further analysis, it appears that outsourcing the service can be a good policy to reduce leakage. The regression results suggest that the longer since the service was outsourced the lower are the recorded water losses. It seems advisable that concession contracts cover a period of time sufficiently long for the effects of outsourcing to become noticeable. Short periods of outsourcing do not seem to result in any significant effect in this regard.

This research could not determine the existence of a relationship between the ideology of local government and water losses. It may be that leftwing parties tend to exaggerate their environmental agenda during the electoral campaign, but at least in reference to water loss, there seems to be no differences between the actions of ruling parties according to their ideological orientation.

We were also unable to confirm any significant relation between private participation in water management and leakage rates. Private firms would appear to have in

principle no incentive to devote resources to the reduction of water leakage and the local governments' ability to control them is often very lax. However, it appears that their desire to be able to renew the concession contract encourages private companies to not completely neglect the maintenance and conservation of the networks. At least, no different behaviour was observed in this sample between private firms and public managers.

In Spain, as long as there is no legal framework that sets leakage targets, the responsibility for sustainable management of urban water resources will remain in the hands of local governments and management companies. In this sense, the reduction of water losses relies on the political will to take decisive action at the city level.

In Andalusia, something that could lead in the future to act more decisively would be increased degrees of water stress leading to relatively frequent water cuts or to a decline in water quality. The inconvenience caused to the user due to the lack of availability or to the poor quality of the water could cause citizens to demand a better service, which could lead to a reduction in water leakage rates.

Obviously it would be better to act before reaching an extreme situation. The problem is that, usually, local governments and service management companies have little incentive to undertake the necessary actions to reduce water losses. This is due to the difficulties they typically face when trying to raise revenues to cover the maintenance costs needed to reduce water losses. The possibility of shifting the costs to water users with no major citizen opposition or to allocate more financial resources at different levels of government would facilitate the implementation of the actions needed to reduce leakages. However, perverse dynamics should be avoided whereby those entities that manage with a worse record in the management of the service receive increased funding.

Without doubt, in the scenario described it would be appropriate for public agencies to follow a double line of action. On the one hand, it would be appropriate for the legislature to establish maximum levels of water losses. In anticipation that these were exceeded, sanctions should be envisaged aimed at both the municipalities and the companies managing the service. Moreover, it would be desirable that an independent body had the authority to analyse and report on the status of the urban supply networks and, depending on the conditions of service in each municipality, fixed different targets for water losses in each city.

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