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Sección ARTÍCULOS

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Environmental taxation and industrial water use in Spain

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ABSTRACT: The Spanish Water Act, 2001 shifted responsibility for wastewater treatment from municipal to regional government, and as a consequence the Autonomous Communities have begun to levy a Sanitation Charge, apparently with environmental objectives. Industrial demand for water in Aragon is estimated in this paper using a double logarithmic model with panel data to establish whether regional Sanitation Charges rationalise water consumption. The key explanatory variable is the Sanitation Charge, in addition to the water supply charges payable in the towns and cities of Aragon and other variables which capture the characteristics of the firms in the sample. The reduction in water demand achieved appears to be due to the environmental charge rather than to any actual increase in firms' water costs.

JEL Classification: H23; H32; H71.

Keywords: Industrial water consumption; Sanitation Charge; tax centralisation; regional government.

Fiscalidad ambiental y uso industrial del agua en España

RESUMEN: Con la Ley de Aguas del 2001, la competencia sobre depuración de aguas residuales, que venían desempeñando los municipios a través del cobro de tasas, se ha encomendado a las Comunidades Autónomas, quienes deben implantar para su gestión un Canon de Saneamiento. Para determinar si este Canon racionaliza el consumo de agua, en este trabajo se estima la demanda industrial de agua en Aragón, utilizando para ello un modelo logarítmico con datos de panel en el que la variable explicativa clave ha sido el Canon del Saneamiento, además de la tasa por el suministro de agua pagada por las industrias en los diferentes municipios aragoneses, y otras variables que captan las características particulares de las empresas de la muestra y que están relacionadas con el consumo de agua. Los resultados obtenidos muestran que la reducción del consumo industrial de agua

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parece debida a la tributación ambiental, más que a un incremento en el coste del agua para las empresas.

Clasificación JEL: H23; H32; H71.

Palabras clave: Consumo industrial de agua; Canon de Saneamiento; centralización fiscal; nivel regional de gobierno.

1. Introduction

Widespread public concern about the use of water resources has encouraged governments to create mechanisms to improve water management, although they have been clearly insufficient. Drought and water shortages are real problems, and pollution from wastewater discharge persists. Meanwhile, non-compliance by several member States with the obligations established by the EU Water Framework Directive (60/2000/CE) pushed the European Environment Agency to perform a pilot study [1] of the effectiveness of water use and treatment policies in France, Denmark, Estonia, Netherlands, Poland and Spain, in order to identify and understand policy successes and failures.

That study (henceforth EEA Report) suggested that economic instruments and, specifically, environmental taxes on industrial discharges, were the best option for environmental protection and clearly superior to the command and control instruments that have conventionally been used in this area, though without much success. From the standpoint of environmental management, meanwhile, Coch (2001), Stavins (2001), Kraemer *et al.* (2003), Mattheiß *et al.* (2009), ONEMA (2009) and OECD (2011) consider that economic instruments are better than command and control instruments, because they internalise externalities by including a fee or additional cost in the price of outputs and generating extra public funding. They also materialise the Polluter Pays Principle, changing users' behaviour and encouraging eco-efficient, rational use of resources. However, other scholars have argued that for an effective environmental management all these strategies should be utilized in a harmonized manner depending on the strengths and weaknesses of the surrounding economic, social and institutional circumstances of the societies such as availability of financial funds, status of internal market and citizen awareness over environmental issues (OECD, 2001; Sorrell and Sijm, 2003; OECD, 2007 and Demir, 2011).

The EEA Report found that taxes on wastewater discharges were relatively low in Spain and did not produce the necessary stimuli to achieve the desired environmental ends, even though regional and municipal authorities are empowered to levy environmental taxes, which can in fact be extremely useful at the lower tiers of government, where the power to tax is constrained by the theoretical recommendations of fiscal federalism (Dalmazzone, 2006; Garcia-Valiñas, 2007; and Alm and Banzhaf, 2011).

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[1] European Environment Agency (2005), Effectiveness of urban wastewater treatment policies in selected countries: an EEA pilot study, EEA Report No. 2/2005, Luxembourg.

The EEA Report also concluded that Spain and France were far from complying with the conditions established in the EU Directive, in contrast to Denmark and the Netherlands. Meanwhile, Poland and Estonia (which joined the EU somewhat later) had made adequate progress. The success of water use and treatment arrangements in the Netherlands and Denmark was found to be partly attributable to the exercise of the relevant competences exclusively by a single authority (municipalities or institutions entrusted with managing the various hydrographical basins). The effects of sharing powers over the use, treatment and pricing of water are apparent in the Spanish case, where policy depends on negotiation between the Autonomous Communities or regions and central government [2]. The design and levy of wastewater treatment charges (i.e. the Sanitation Charge) was devolved to the regions of Spain in the late 1980s, and it is the Autonomous Communities that are responsible for compliance with the objective of the Urban Waste Water Directive (Council Directive 91/271/EEC).

The Charge levied by the Spanish regions has both an environmental and a financial purpose. Some regions include the pollution load of industrial wastewater alongside water consumption in the calculation of the Sanitation Charge, which suggests that it can help cut pollution and meet environmental objectives. The EEA Report, of course, pays close attention to the of fiscal incentives applied to reduce environmental pollution, and the main purpose of this paper is therefore to test whether the Sanitation Charge actually does reduce water pollution in order to establish whether the regional governments of Spain are working in the right direction in the fight against pollution, or whether the Sanitation Charge is merely another funding instrument of funding with no impact on taxpayers' behaviour.

For the first time in the literature, therefore, we decouple the price of industrial water supplies from the price of pollution discharged in order to look at their separate impacts on demand for industrial water. This failure to address what in our view is a key empirical issue is a mistake, because the purpose and nature of both prices (water supply *versus* water pollution) are radically different (financial *versus* environmental purpose, and cost *versus* tax nature).

The paper is structured as follows. The second section contains an in-depth analysis of the legislation governing water use and taxation in Spain, which is inherently complex and emanates from all three tiers of government (central, regional and local) more as a regulatory patchwork than a framework. This very legislative profusion is probably responsible for some of the errors contained in the EEA Report; for example where it asserts that the responsibility for wastewater treatment lies with the municipalities in Spain. The third section of the paper describes the measurements carried out using a microdata sample to test whether the design of the water-related taxes has helped mitigate environmental harm from industrial wastewater discharges at the regional level. To this end, we focus on the Sanitation Charge established in the Autonomous Community of Aragon, one of the regions that take the pollution load

[2] The industrial structure of water and sanitation utilities may influence policy outcomes. While some countries (e.g. England and Wales) have moved towards the aggregation of provision, others (e.g. Spain and Italy) have allowed a much more fragmented model to develop.

in discharges into account along with the volume of water consumed to establish the amount of the Sanitation Charge payable by industrial water users. The study ends with a final section setting out our main conclusions.

2. A brief overview of European water taxation: The case of Spain

Water taxation in the member States is affected by a raft of EU regulations and in particular by Directive 60/2000/CE, which creates a European framework for active water policies and establishes the cost-recovery principle for water-related service costs. Though it does not impose any specific tax measures, the Directive mentions that environmental charges could contribute to the attainment of cost-recovery goals by ensuring that prices are right. Accordingly, water charges should include all pollution costs, which are added to the market price of the services by way of surcharges to encourage clean production processes through appropriate market reactions. Meanwhile, the system should avoid distorting competition, because the Urban Waste Water Directive (271/1991/EEC) obliges all EU member States.

The water charges created by the EU member States (summarised in Table 1) can be divided into three categories comprising charges on water abstraction, charges on water consumption and sewage treatment services, and charges on water-related pollution.

Let us now consider the Spanish context in greater detail, since Spain is the focus of our empirical analysis. The achievement of the cost-recovery principle for water-related service costs established in the Spanish Water Act (Real Legislative Decree 1/2001)[3] currently requires a range of charges at both the national and sub-national levels, which are set at different points in the complete water cycle. The majority of such charges are based on the consumption of a scarce resource, or on the pollution produced, or potentially produced, by water consumption and subsequent discharges. Charges are thus intended to finance hydraulic infrastructure, whether for water abstraction and distribution or for treatment to make used water fit for reuse and consumption. At the level of central government, the amended Water Act establishes a **Public Goods Charge for Water** (paid for the occupation, use and exploitation of water-related public goods), a **Pollution Charge** (to finance the study, control, protection and improvement of the environment in each river basin), a **Water Regulation Charge** (to cover the benefits obtained from State infrastructure to regulate surface and ground water sources), and a **Water Use Charge** (to finance water infrastructure works undertaken by the State to facilitate water availability and use).

These levies are defined from an environmental standpoint, although its green influence is weak. The Pollution Charge establishes a pollution-price relationship that

[3] The Spanish Water Act has recently been amended, including changes to art. 111 *bis* concerning cost recovery with the result that cost recovery will henceforth depend on discretionary decisions by the competent authority (Ministry of Agriculture, Food, and the Environment). A new law, the *Ley de medidas urgentes en materia de medio ambiente,* or «Urgent Environmental Measures Act» was also enacted on December 19th, 2012, in accordance with the provisions of Royal Decree Law 17/2012, of May 4th.

Table 1. Water charges in the EU-27

	Abstraction	*Use and discharge*	*Pollution*
Austria		X	
Belgium	X	X	X
Bulgaria		X	X
Cyprus			
Czech Republic	X	X	X
Denmark		X	X
Estonia		X	
Finland		X	
France	X	X	X
Germany	X		X
Greece		X	
Hungary	X	X	X
Ireland			
Italy		X	
Latvia	X	X	X
Lithuania	X	X	X
Luxembourg			
Malta		X	
Netherlands	X	X	X
Poland			
Portugal			
Romania	X	X	X
Slovakia			X
Slovenia			
Spain		X	X
Sweden		X	X
United Kingdom	X		

Source:
— OECD/EEA database for environmental policy instruments and natural resources management *http://www2.oecd.org/ecoinst/queries/index.htm*).
— OECD (2003): *Task force for the implementation of the Environmental Action Programme for Central and Eastern Europe (EAP)*, Centre for Cooperation with Non-Members Environment Directorate CCNM/ENV/EAP(2003)22.
— *http://www.economicinstruments.com/.*
— Klarer, Francis and McNicholas (1999): *Improving Environment and Economy*, Sofia Initiative on Economic Instruments, Regional Environmental Centre.

approximates to the basic Polluter Pays Principle, and the Water Regulation and Water Use Charges have environmental objectives insofar as they aim at the rationalisation of water use. As Gago and Labandeira (1997) argue, however, the main thrusts of the two last Charges are financial, and this limits their environmental effects strictly speaking.

According to Ministerio de Medio Ambiente (1998), meanwhile, the receipts actually obtained from such charges is very low, accounting for only around 50% of tax bills, and collection is often long delayed[4]. This hinders recovery of the financial resources necessary for adequate control, administration and maintenance of hydraulic infrastructure and for the protection of public water assets. Moreover, it reveals how little consumers have internalised process costs. This is important not only in terms of revenue generation, but especially for its economic effects on demand. In fact, none of the charges encourages users to use scarce hydraulic resources rationally.

It is necessary to distinguish between economic and financial instruments in this context. Economic instruments provide incentive to change behaviour patterns, in contrast to financial instruments, which are essentially oriented towards cost recovery and therefore cannot significantly influence the actions of water consumers (Horbulyk, 2005 and Cantin *et al.,* 2005). In this regard, Horbulyk (2005) stresses the importance of differentiating between the goals behind pricing strategies. Cost recovery and efficient pricing are different objectives and may require different instruments. In fact, it is far from usual for just one policy instrument to meet the twin goals of efficient resource allocation and attainment of public revenue requirements, and the choice of instrument therefore needs to be made so as to ensure effectiveness for one purpose or the other. Young and McColl (2005) go one step further, arguing that one instrument should target no more than one goal, which should be that for which it is most effective. It seems reasonable in any event to think of financial and economic instruments as complementary and not as substitutes.

At the lowest tier of government in Spain, the Local Finance Regulation Act permits Local Corporations to establish charges and public prices for «sewage services, and likewise for the treatment and purification of wastewater, including special oversight of private sewers» and for the «distribution of water, gas, electricity ..., including line connection charges and the installation and use of meters and similar devices, when such services or utilities are provided by Local Corporations». These are the sole tax figures which municipalities may establish (they cannot fix taxes, since they have no legislative capacity); this significantly limits their leeway in pursuing environmental objectives, as the overall amount of the charge must be linked to the cost of providing the service (Art. 24.1). Alternatively, it must be directly or indirectly associated with the cost of mitigating pollution or preserving the resource affected. Crucially, however, such levies cannot be used to modify behaviour patterns by establishing additional costs via taxation.

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[4] This is one of the problems inherent in management of water charges by agencies other than the national Revenue Service, because they have less enforcement capacity. Furthermore, all of the charges are *parafiscal* items, and therefore they are not integrated with tax and environmental policies but are managed and collected by the *Confederaciones Hidrográficas* (Hydrographical Confederations), the water boards responsible for the management of river basins, and other public agencies, which have the authority to grant discharge licences. Parataxation is not an area that is naturally suited to environmental objectives, because it can encourage «corporate impulses» which are difficult to control and may result in deviations from general policy objectives (Rosembuj, 1995). Moreover, revenue collection is problematic, because effective enforcement would require the Hydrographical Confederations to forego the very significant support they receive from central government control and management structures. This has been a constant in Spain.

The provisions of applicable legislation appear to favour raising the applicable rates of levies subject to direct or objective assessment as a means of introducing financial incentives to limit water consumption or reduce the pollution contained in wastewater discharges, taking into consideration the financial capacity of the taxpayer wherever possible. The situation of municipal water charges remains highly fragmented in Spain, although it has become increasingly common to levy charges that increase in line with the quantity of water actually consumed. Nevertheless, many Spanish municipalities still levy a fixed charge per user. Such charges are not only regressive but are also marginally decreasing, so that the more the water consumed or discharged, the less is paid for each fiscal unit utilised. Contrary to popular belief, moreover, the fact that everybody pays the same is not equitable, as those who consume less water in fact subsidise those who consume more (Field, 1995). In short, the current design of water-related charges lacks any environmental objective at the municipal level, but is intended rather to finance municipal services, and we may add that the impact upon taxpayers is sometimes regressive.

In addition to local charges for the supply of water, sewage services and wastewater treatment, most of the Spanish regions have by now established a Sanitation Charge as a means to meet the objectives of the Urban Waste Water Directive. Meanwhile, responsibility for wastewater treatment, traditionally a matter for local corporations financed by user charges, was assigned to the regions since the approval of the Water Act (although many municipalities still in fact provide the service and will continue to do so until the situation of their sometimes considerable legacy investments can be regularised, the regions assume their new powers in this area, or there a regionally financed wastewater purification service of the required quality becomes available). The receipt of subsidies from central government for the construction of sewage treatment plants was linked to the settlement by the regions of the Sanitation Charge. In fact, this charge has in fact become commonest environmental levy found at regional level.

In 2011, 15 out of 17 regions are applying a Sanitation Charge with two main objectives, namely to reduce wastewater discharges and to finance the capital and operating costs of water infrastructure. The Sanitation Charge is usually managed by the regional agency responsible for the implementation of wastewater treatment policy and other activities related to water planning. The public or private water supply utilities are required to apply the Sanitation Charge and transfer the receipts obtained to the regional agencies, acting as substitutes for the taxpayer and thereby facilitating administration and management.

In all regions the Sanitation Charge is levied on wastewater discharges into the environment. However, it is both difficult and costly to measure the environmental harm caused by discharges, and the charge is therefore not applied directly but instead indirectly via the taxation of water consumption. However, some regions have established surcharges on the pollution load contained in effluents discharged by industrial users.

As shown in Table 2, nearly all of the regions establish the Sanitation Charge payable on industrial water use based on a fixed component (connection charge) and

Table 2. Characteristics of regional sanitation charges (Spain) in 2011. Industrial uses

	First approved [Last major reform]	*Fixed Charge*	*Variable Charge*	*Pollution load*
Andalusia	2010 [2011]	€1/month per taxpayer	€0.25/m^3 per month	
Aragon	1997[1] [2002]	€16.229 per taxpayer per month	Depends on type of pollution	X
Asturias	1993 [1994]	€5-€1,280 per taxpayer per month depending on annual consumption	€0.599/ m^3	X
Balearic Islands	1991 [1992]	€2.4-€420.7 depending on meter calibre. Special tariffs exist for hotels, restaurants and bars	€0.1472/ m^3	
Cantabria	2002 [2006]	€14.88 per taxpayer per year	€0.3638/m^3 or with a tariff depending on the pollution load	X
Catalonia	1981[2] [2003]		€0.0927/m^3 + €0.3633/m^3 until September (€0.1454/ m^3 + €0.5702/m^3 from October)	X
Canary Islands [3]	1990 [1994]		Depends on pollution load and volume of waste water	X
Castile-La Mancha	2002[4]	0.42€/m^3 x factor depending on pollution load	€0.42/m^3 x factor depending on pollution load	
Galicia	1993 [2011]	€2.5 per taxpayer per month	€0.421/m^3 or another tariff depending on pollution	X
La Rioja	1994 [2000]		€0.32/m^3 x factor depending on pollution load	X
Madrid	1984 [2003]	€0.0209 twice-monthly x factor depending on meter calibre	€0.2927-€0.5104 twice-monthly depending on both consumption and the pollution load	X
Murcia	2000 [2002]	€30 per source of supply per year	€0.30/m^3 x factor depending on pollution load	X

Table 2. *(continue)*

	First approved [Last major reform]	*Fixed Charge*	*Variable Charge*	*Pollution load*
Valencia	1992 [1993]	€84.54-€2,957.1 per year depending on meter calibre. This tariff can be modified depending on a series of factors like the pollution load	€0.414/m^3. The tariff can be modified depending on a series of factors like pollution load	X
Navarre	1988		€0.619/€/m^3 x a factor depending on the pollution load	X
Basque Country	2008		€0.06/m^3	

Source: Own work.

[1] Subsequently abolished, but approved again in 2001.
[2] The Sanitation Charge was actually approved in 1999 as an amalgamation of other levies.
[3] Receipts have been transferred to the Island Councils since 1994.
[4] The Sanitation Charge did not actually come into force until 2006.

a variable component (consumption charge). The variable charge is calculated simply by multiplying the tax base by the established price. However, the tax base for industrial use is itself commonly determined or changed by the pollution load contained in industrial discharges into the river system. This is the case of the Sanitation Charges applied in Aragon, Asturias, Cantabria, Catalonia, Galicia, La Rioja, Madrid and Valencia, among others.

What can be said about the environmental utility of the Sanitation Charge from an analysis of its constituent parts? On the one hand, it will perform a regulatory function as soon as any party responsible for discharges is obliged to pay and, therefore, it may help reduce pollution. On the other, though discharges are indirectly levied through consumption, the calculation of the quota includes the pollution load in the majority of cases, allowing adjustment of the tax base to the harm caused or, where appropriate, to the costs of treatment and purification of discharges. Consequently, effective incentives to reduce emissions of pollutants do exist. Nevertheless, water consumption elasticity is generally low, which means that charges must be set high if they are significantly to reduce water consumption and discharges. Moreover, the Sanitation Charge is used to finance the whole of the water cycle in general, and its objectives therefore go far beyond implementing the «polluter pays principle», including all water management activities, such as the construction of collectors and the application of a range of wastewater recycling techniques, revealing the markedly financial nature of the tax.

To conclude, we would emphasise that Spanish legislation governing water taxation allows for the simultaneous existence of a considerable range of different charges. However, the Sanitation Charge is the only one which could be called an environmental tax. Ministerio de Medio Ambiente (1998) underlines the general shortage suffered by the Spanish water supply system and draws attention to the serious problem of established revenue-generation capacity, is insufficient to meet both operating costs and the capital expenditure required. This is especially important, because the water cycle requires the creation of new or improved services in Spain, and above all in certain arid regions, in order to expand both the supply of drinking water and wastewater treatment facilities.

This could be achieved through network modernisation or the implementation of instruments that allow for the individualised measurement of consumption. Such actions require the allocation of significant resources, which in the current context of fiscal crisis can only be raised via a rationalisation of existing resources or the creation of new environmental charges. The resulting prices must incorporate all external environmental costs (from the source, through production, distribution and use, to final elimination) and encourage environmentally respectful behaviour.

This is the question examined in the next section. Can rational water use be encouraged through consumers' reactions to tax charges and price in the current decentralised context of Spain by establishing environmental charges on industrial discharges (i.e. the Sanitation Charge) and local water supply prices (i.e. Price on water supply) at the lower tiers of government.

3. An econometric model for environmental taxation of industrial water uses

This section proposes an explanatory model of industrial water demand, based on the environmental taxation of wastewater discharges. It starts by justifying the empirical approach to the topic and summarising existing empirical literature on industrial water consumption. Next, it presents the data sources used in the study, the hypotheses tested and the variables employed. The section concludes with a description of the specification and the principal results obtained from calculation of the model.

To justify our approach to the subject of environmental taxation of water, let us note that until now only Arbués *et al.* (2010) have estimated industrial water consumption in Spain, although research into domestic and agricultural demand is more abundant. Studies of industrial water consumption are also relatively scarce in the international literature, and they tend to concentrate on estimating the price elasticity of demand, yet they hardly take water charges into account. We have in fact found only two empirical contributions which examine the potential consequences of environmental taxation in the industrial sector (Reynaud, 2003; and Feres and Reynaud, 2005). On the other hand, the existing ecological charges, at least in Spain, are of a markedly financial nature, and it is therefore essential to test empirically whether such charges discourage environmentally harmful behaviour. We consider this to be a crucial issue for the design of corrective charges, and the EEA Report underlines it as one of the greatest weaknesses in Spanish water pricing policy.

3.1. A review of the literature on industrial water consumption

Very few analyses of water demand pay attention to the industrial and service sectors, even though residential and agricultural demand have been closely studied (see the excellent surveys of residential water use published by Arbués *et al*., 2003 and Worthington and Hoffman, 2008; and the surveys for agricultural water use by Varela-Ortega *et al*., 1998, and Johansson *et al*., 1998). Even so industrial water consumption continues to increase and is responsible for the lion's share of pollution.

The empirical studies described in the literature were carried out in diverse geographical locations in North America, Europe, Asia, and Africa. Practically all of them share the common objective of determining water price elasticities and output elasticity, and many break their findings down by subsectors. The services sector has thus normally been studied as a subsector of industry, and only a very few studies analyse it in isolation (see Schneider and Whitlatch, 1991, or Williams and Suh, 1986). These studies normally concentrate on manufacturing companies (i.e. on the chemicals, textiles, forestry, steel and metals, minerals and food sectors) and ignore other industries which also require water for their processes (power stations, mining, etc.). Most of these papers also contain two parallel studies, one of them focusing on the sample as a whole and the other segmented by branches of activity. However, the methods employed differ both functionally and with regard to the explanatory variables selected and their measurement, and to the econometric techniques employed.

Table 3 summarises key aspects of the principal empirical studies focusing on environmental taxation of industrial water use. Some estimate the *quantitative demand for water* based on its *price*[5]; the *prices of other water-related inputs* used, such as physical capital, energy, raw material or the labour factor; *variables* which do not depend on either inputs or outputs, such as *technological change*, *plant age, business sector, state of the technology*; the *time dimension* of the sample analysed, in the case of panel data; and the *output level* obtained. These studies usually consider two types of output factor. In the first place, output *sensu stricto* is expected to have a positive impact on water demand, because if water is used to manufacture a product, the level of production a firm achieves will probably affect the quantity of water it consumes. Secondly, the generation of sub-products (such as the pollution generated) will, *a priori*, have an ambiguous effect on water demand. This is in fact the only way

[5] The question of whether it is preferable to use average or marginal prices has aroused intense controversy. On this point, see Renzetti (1992, 2005a), Espey *et al.* (1997), Dalhuisen *et al.* (2003), Arbués *et al.* (2003, 2010), De Gispert (2004), *Taylor et al.* (2004), Gaudin (2006),Olmstead, Hanemann and Stavins (2007). Both options have their drawbacks, and various scholars (e.g. Shin, 1985, Nieswiadomy 1992) have sought a solution to this dilemma (which also occurs in studies of domestic consumption of water, electricity and gas, the prices of which are also structured in blocks). However, it appears that the appropriateness of one or other variable depends upon the sample type, the tax structure, information costs, etc.

Table 3. Comparative experience in the estimation of industrial demand for water

	Function and econometric technique	*Water input utilised and measurement*	*Specification*	*Other explanatory variables*	*Geographical area (year) and sample*
Rees (1969)	Demand	Price of purchased water	Average values	Plant age.	Southeast England
De Rooy (1974)	Demand OLS	Price of purchased water	Average values	Labour factor (price according to index) and type of technology (index or code).	New Jersey, with information for 30 companies
Grebemstein and Field (1979)	Costs (translog model) GLS	Price of water	Average values	Capital factor and labour factor.	USA (1973), with aggregate data
Babin, Willis and Allen (1982)	Costs (translog model) GLS	Price of water	Average values	Physical capital (price according to interest rates of loans for investment); labour factor (salaries); and output (quantity in monetary units).	USA (1973), for 245 firms with aggregate data
Ziegler and Bell (1984)	Demand (double logarithmic model) OLS	Price of purchased water	Average and marginal values	Plant age; business sector (dummy); and type of technology (dummy).	USA (1984) for 23 businesses, with aggregate data
Williams and Suh (1986)	Demand (linear logarithmic model) OLS	Price of purchased water	Average and marginal values	Value added in the industry and number of users of water in the industry.	USA (1976) for 82-120 municipalities, with aggregate data
Renzetti (1988)	Costs (translog model) GLS	Price of self-supplied, purchased, pre-treated, recirculated and purified water	Marginal values calculated using instrumental variables	Other inputs (prices) and output (average quantity according to labour factor).	Canada (1981) for 372 companies, with aggregate data
Renzetti (1992)	Costs (translog model) GLS	Price of purchased, pre-treated, recirculated and purified water	Marginal values calculated using instrumental variables	Output (quantity in monetary units).	Canada (1985) for 2,000 firms, with aggregate data
Renzetti and Dupont (1998)	Costs (translog model) Multistage Least Squares	Price of purchased, pre-treated, recirculated and purified water	Marginal values calculated using instrumental variables	Type of industrial sector (dummy) and type of technology (dummy).	Canada (1991) for 88 companies

Wang and Lall (1999)	Production (translog model) OLS	Quantity of purchased water		Physical capital (quantity in monetary units.); energy (quantity en monetary units); labour factor (number of workers); raw materials; and characteristics of companies (size, sector, location, etc.).	China (1993) for 2,000 establishments
Onjala (2001)	Costs (translog model) Multistage	Price of purchased, pre-treated, recirculated and purified water	Marginal values calculated using instrumental variables	Other inputs (prices).	Kenya (1990-2000) for 51 plants
Renzetti and Dupont (2001)	Costs ((translog model) GLS	Quantity of purchased water. Price of purchased and recirculated water	Marginal values calculated using instrumental variables	Technological change (numerical index of trend); physical capital (interest rate); energy (price according to other indicators); labour factor (price according to other indicators); material (average price of raw materials; and output (quantity measured by income/price index).	Canada (1981, 1986 and 1991) for 58 activities, with aggregate data
Renzetti and Dupont (2002)	Costs (translog model) GLS	Quantity of self-supplied and purchased water. Price of pre-treated and recirculated water	Marginal values	Physical capital (interest rate); energy (weighted index of price of gas, electricity, fuel, etc.); labour factor (average weekly salary); materials (price according to purchase prices index of non-durable assets); and output (quantity measured by income-revenue/output prices index) ; and industrial sector (dummy).	Canada (1981, 1986 and 1991) for 58 companies
Feres and Reynaud (2005)	Costs (translog model)	Price of water	Average values	Physical capital (price according to real interest rate plus depreciation); pollution (evaluation of effluent according to environmental demand parameters); energy (price according to the sector in question); labour factor (average labour cost); materials (price according to sector); output (monetary value); and technology type (index or code).	Sao Paulo, Brazil (1999) for 404 enterprises, with aggregate data
Reynaud (2003)	Costs (translog model) GLS	Price of self-supplied, purchased and pre-treated water	Average values	Contamination (valuation of effluent according to charges paid per discharge/price index); labour factor (number of workers); and output (quantity according to annual monetary value).	France (1994-96) for 51 plants. with aggregate data
Kumar (2006)	Distance (translog model)	Price of purchased water	Average values	Physical capital (quantity in monetary units); time dimension (dummy); labour factor (salaries); materials (quantity in monetary units); output (quantity in monetary units); and industrial sector type (dummy).	India (1996-97) for 92 companies
Arbués et al (2010)	Demand (Koyck flow adjustment demand model)	Price of purchased water	Perceived price	Level of output, size of firm, number of workers, type of use (dummy = 1 if industrial; =0 if services), lagged water consumption.	Zaragoza, Spain (1996-2000) for 298 service and industrial users connected to the urban water network

Source: Authors' compilation.

in which the literature (Reynaud, 2003; and Feres and Reynaud, 2005) has included environmental pollution in water demand estimations [6].

Some studies calculate *firm's production levels* (in physical or monetary units) on the basis of *input quantities,* while others estimate firms' *minimum production costs* by analysing *input quantities*, the *output* level and the *type of activity* and *technology*. Finally, a considerable number of papers estimate the *production costs* incurred by firms to obtain their output on the basis of the *input prices* used and even the *quantity of water* consumed.

With the exception of the demand function, which can be analytically specified in a linear, logarithmic or double-logarithmic functional form, the remaining functional forms are specified via a translog model. The results obtained in the literature for the water price show that industrial water demand is price inelastic. The reasons for these common findings are that water has very few or no substitutes, it is cheap and it represents only a small share of total costs. However, industrial water price elasticity is greater than in the domestic or agricultural sectors (Renzetti, 2005a; Reynaud, 2003; or Williams and Suh, 1986). This is reasonable given that industry can seek alternative sources (pre-treated, recirculated or purified water) or it can recycle water in production processes to adapt to any hike in the price. This suggests that any price policy implemented to allocate water to competing uses will be more efficient if it is applied to the industrial use of water [7].

3.2. Hypotheses tested

The hypotheses estimated in this study were set based on the above review of the literature. Given that the aim of this study is to test whether the Sanitation Charge reduces water pollution through water consumption in industry, a number of other explanatory variables were considered in addition to the Sanitation Charge. These comprised the price of water, the output level, the fixed capital of the firm, the average salary, other raw materials, technological level and company age. Finally, this paper seeks for the first time in the literature to separate the effects of the price paid for water supplies and of the price paid for pollution in water discharges on the demand for water for industrial use. It is this distinction that will allow us to draw conclusions about the effectiveness of the Sanitation Charge in the fight against pollution.

The starting-point for this empirical analysis was the data contained in Aragon Sanitation Charge Census supplied by the *Instituto Aragonés del Agua* for 2002 and 2003. The Census provides annual information on the volume of water consumed by each firm, the fixed tax rate and the tax rate applicable for the calculation of the

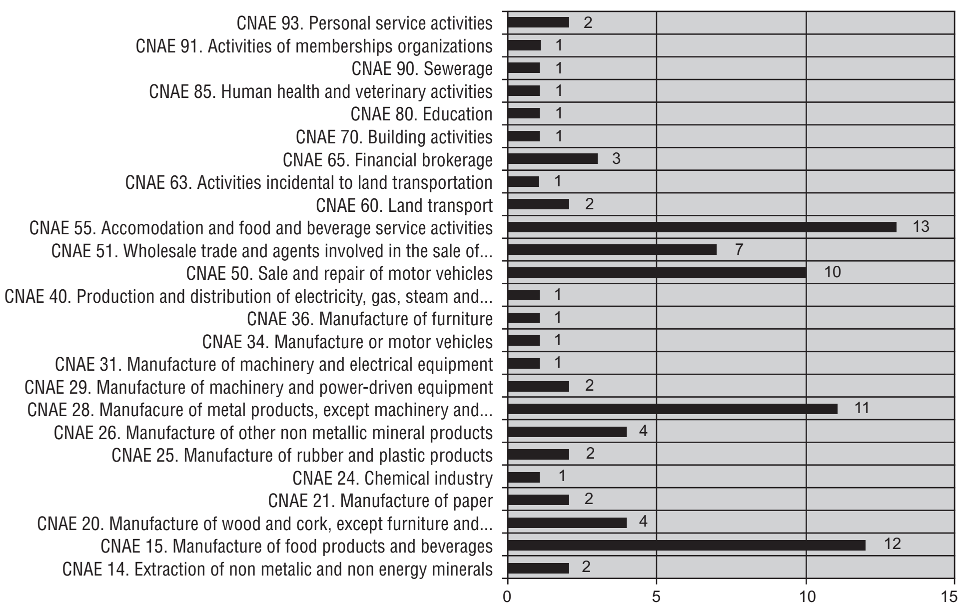
[6] These sub-products have been measured using environmental indices or variables associated with the ecological charges paid.

[7] According to Vermeend and Van der Vaart (1998, industrial use of underground water in the Netherlands declined after the introduction of a water abstraction tax.

Sanitation Charge[8], and the resulting tax liability. The Aragon Sanitation Charge Census contains data for 284 firms in 2002 and 299 in 2003, comprising all those that actually paid the charge. We may note here, however, that not all of the region's municipalities were subject to the Sanitation Charge in the years examined (including, for example, the city of Zaragoza) and others were allowed 50% rebates[9]. Disappointingly, the Census does not include other economic and financial data for the firms concerned. This information was supplemented by data from SABI (Iberian Balance Sheets Analysis System), a database containing economic and financial details of some 500,000 Spanish and Portuguese firms, in order to obtain annual data and for each company on the other variables included in the model (employees, salaries, profits, output, etc.).

Companies were excluded if the information obtained from either of the two databases was incomplete, resulting in a sample of 87 firms for both 2002 and 2003. As information on the source (supplied or self-abstracted) of the water used by each firm is available, we were able to calculate the fee or price payable by those companies using supplied water (i.e. the water supply price). This meant reviewing the tax regulations which established the price for water consumption in each municipality where the sample firms were established in the years studied. To be precise, we determined the fixed tax rate, marginal tax rate and fixed and variable charges payable in respect of water supplies by each firm in 2002 and 2003. Figure 1 classifies the

Figure 1. Distribution of activities by CNAE-93 branches. Number of firms. 2002-2003



[8] The tax rate takes into account the wastewater pollution load.

[9] See BOA (Official Gazette of the Autonomous Community of Aragon) of June 29, 2005.

87 sample firms by activity according to the 1993 Spanish National Classification of Economic Activities (CNAE in the Spanish acronym), which defines branches 1 to 45 as industrial activities, accounting for 44 of the sample firms, and branches 50-95 as service sector activities, accounting for 43 firms.

The sample firms are distributed across all branches of activity. The industrial branches containing largest number of firms are food and beverages (CNAE-15), with 12 companies, and metal products manufacturing except machinery and equipment (CNAE-28), with 11 companies. The other firms are distributed among the 11 remaining branches. In the service sector, the hotels and restaurants branch (CNAE-55), with 13 companies, and sale and repair of motor vehicles (CNAE-50), with 10 companies, are the most numerous. The remaining companies are distributed among the other branches.

Panel data were used to solve the problems inherent in time series-based econometric studies, because this technique allows the use of fewer periods (2002-2003) and makes it easier to assess the differences in the behaviour of the 87 sample firms. Meanwhile, data are expressed in real terms, deflated by the consumer price index to get around the difficulty posed by comparison of the same variables over time. The variables utilised, their symbols, sources and expected signs are summarised in Table 4 [10].

In this context, we shall try to establish the extent to which municipal water prices and sanitation charges on wastewater discharges have discouraged water consumption by Aragonese firms [11]. In addition, we shall consider the possible influence on water consumption of certain characteristics of the sample firms (fixed capital, technology, company size, production volume and consumption of other commodities), which have also been examined in the literature.

Water consumption in the Aragonese industrial sector, is proxied by the number of cubic metres demanded by each company (**$WUSE_{it}$**); subindex «i» is allocated to each of the 87 companies and the subindex «t» to each financial year (2002-03).

a) **Price of water ($WPRICE_{it}$):** The aim is to determine the extent to which the water prices paid affect industrial demand for water in Aragon, since it is easily predictable *a priori* that water will display negative price elasticity. This hypothesis is tested using the average price per cubic metre in constant euros or, alternatively, the marginal price of water paid by each firm.

b) **Environmental taxation of water ($GREENCHARGE_{it}$):** The aim is to establish whether the environmental charge paid by firms actually creates the necessary disincentives for the use of water as a scarce good, consumption of which produces negative environmental effects. This variable is constructed in alternative forms in order to accommodate both the average tax rate and the marginal tax rate (of the Sanitation Charge) paid by each firm. It is expected to be negative.

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[10] The tables contained in the Appendix provide information regarding the most important descriptive statistics and the correlation matrix of the principal variables (tables 1.A and 2.A).

[11] For the sake of simplicity, we refer to industrial use of water to mean the use of water by industry and services taken as a whole.

Table 4. Definition, expected sign and source of the variables

Symbol	*Hypothesis*	*Expected sign*	*Source*
WUSEit	Number of cubic metres of water demanded by each company.		Aragon Sanitation Charge Census. *Aragonese Water Institute*.
$WPRICE_{it}$	Price elasticity of water demand.	–	Own calculation from the regulations governing the water supply prices in each municipality.
$GREENCHARGE_{it}$	Fiscal disincentives created by the ecological tax on water consumption (Sanitation Charge).	–	Aragon Sanitation Charge Census. *Aragonese Water Institute*.
$FIXCAPITAL_{it}$	Relationship between fixed capital and water demand.	Indefinite	Iberian Balance Sheet Analysis System (SABI).
$AVEWAGE_{it}$	Cross-elasticity of water demand and salaries.	Indefinite	Iberian Balance Sheet Analysis System (SABI).
$RAWMAT_{it}$	Relationship between consumption of commodities and water demand.	+	Iberian Balance Sheet Analysis System (SABI).
$OUTPUT_{it}$	Water demand elasticity with regard to output.	+	Iberian Balance Sheet Analysis System (SABI).
$INTANASS_{it}$	Technological level.	–	Iberian Balance Sheet Analysis System (SABI).
$COMPAGE_{it}$	Company age.	+	Iberian Balance Sheet Analysis System (SABI).

In the case of industrial water use, firms can differentiate clearly between the price paid for water consumed and the Sanitation Charge, allowing perfect visualisation of the environmental tax. Hence, there is no chance of firms confusing the price of water with the environmental charge, because the management and inspection procedures applied by the *Instituto Aragonés del Agua* in relation to the Sanitation Charge are independent of billings in respect of the management of the water actually consumed. This is because the firms are required to contract officially authorised firms to measure both the volume of wastewater and the pollution load as necessary factors for the calculation of the Sanitation Charge payable by each firm [12]. Hence, there can be no doubt that the Sanitation Charge is perfectly visible for firms.

[12] Firms are required to file form model 883 (Statement of water uses, pollution load and employment conditions) with the *Instituto Aragonés del Agua*, so they are perfectly aware that the volume of water consumed and the pollution load are the factors determining the amount of the Sanitation Charge payable. If the firms must also pay a price for water supply, the *Instituto Aragonés del Agua* bills the price for water supply and the Sanitation Charge as separate items in the same invoice.

c) **Use of fixed capital ($FIXCAPITAL_{it}$):** Firms' water consumption and their fixed capital may display a complementary relationship when increased water demand is accompanied by more intensive use of plant and equipment. However, investment in fixed capital can also reduce water consumption, resulting in substitutability of the two production factors. Individual firms' fixed capital is measured by the value of their tangible fixed assets, expressed in thousands of euros and in constant terms. The expected sign of this variable is ambiguous, although most empirical studies have in fact found a substitutability relation between water consumption and fixed capital.

d) **Employment ($AVEWAGE_{it}$):** This variable relates average wages to water consumption, since almost all empirical research reviewed, with the exception of Kumar (2006), has found a substitutability relation between water consumption and employment, although complementarity may exist in some cases for reasons of scale or company size. The variable is constructed as the coefficient of staff costs divided by the firm's headcount. A positive sign is expected.

e) **Other raw materials ($RAWMAT_{it}$):** Given the low substitutability of water by other factors of production, this variable tests there is any complementarity between water consumption and the use of other inputs, drawing on existing empirical studies. The consumption value of other productive factors is thus estimated in terms of expenditure on raw materials in constant euros. The relationship between water demand and operating expenditure should be positive.

f) **Output level ($OUTPUT_{it}$):** Given the production function underlying all industrial activity, a positive relationship must exist between the level of output and the productive factors employed (including water consumption) as all the research reviewed has indeed found. Moreover, this variable is closely related to company size and the number of employees, as the correlation coefficient between these variables confirms. The output variable has been constructed as the value of operating revenue in constant euros. Water demand elasticity in relation to output should be positive.

g) **Technological level ($INTANASS_{it}$):** This variable was included in the model given that the use of the most advanced technology available reduces water consumption. The value of intangible assets expressed in constant euros is used as a proxy for a firm's technological level. A negative coefficient is expected for this variable.

h) **Company age ($COMPAGE_{it}$):** Obsolescence of a firm's plant may entail reduced efficiency in the use of water. Hence, the influence of a company's longevity upon water demand is likely to be positive, as older facilities consume more water. The variable was constructed using the difference between the years of the study and the year in which each of the sample firms was established.

3.3. Specification of the model and principle results

Having analysed the different hypotheses to be tested, let us now turn to the specification of the model. The aim is to determine the relationship between water consumption and the Sanitation Charge (among other variables). As explained above, water consumption by Aragonese firms should be explained by the Sanitation Charge, the price paid for water, and a set of variables which capture firms' individual characteristics in relation to water consumption. Considering the set of possible functional forms (demand, production, costs and distance), a double logarithmic demand function is used [13], given that the main aim of the study is to estimate the impact of the Sanitation Charge . To this end, the logarithmic model estimated for industrial water consumption, using panel data, is as follows:

$$WUSE_{it} = D(WPRICE_{it}, GREENCHARGE_{it}, FIXCAPITAL_{it}, AVEWAGE_{it}, RAWMAT_{it}, OUTPUT_{it}, INTANASS_{it}, COMPAGE_{it}) \quad [1]$$

The logarithmic estimation of the model of industrial water consumption in Aragon using Ordinary Least Squares shows problems of autocorrelation, heteroscedasticity and endogeneity [14]. For this reason, feasible generalised least squares were used. The results are shown in the first two columns of Table 5.

As may easily be observed, water price (WPRICE) can contribute to the efficient management of the resource, because the higher the average price paid by companies, the less water they demand. The same process occurs if the marginal price is employed as a proxy for the water price. Nevertheless, demand price elasticity is clearly lower than 1 (inelastic demand), and the percentage variation in demand is therefore lower than the percentage variation in the price. The magnitude of price elasticity is similar to the estimations obtained by the majority of international studies of water demand (–[1.1/0.1]) (see Dalhuisen *et al.* (2003), Arbués *et al.* (2003), Arbués, *el at* (2004 and 2010) or Worthington and Hoffman (2006)).

This inelastic behaviour is associated with the scarcity or absence of convenient substitutes in many fields of water use. It may also be due to low water prices (spending on water consumption is very small as a proportion of total business costs), or it may be that a significant number of the firms in the sample are self-supplied, either from wells or direct abstraction from nearby sources, paying only an initial sum of around €85 the administrative concession but nothing at all for the volume of water

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[13] The double-log functional form yields direct estimates of elasticities (Williams, 1985) and (Dandy *et al*., 1997). It also leads to a constant-elasticity form of demand. This implies that the proportional sensitivity of use to price changes is the same for low and for high prices. Nevertheless, the use of this functional form has been criticised because of its lack of consistency with utility theory (Al-Quanibet and Johnston, 1985). See Arbués *et al*. (2003)

[14] The Hausman test was used to analyse the exogeneity of the explanatory variables, and empirical signs were obtained of the possible endogeneity of the WPRICE and GREENCHARGE variables, which is a logical result as Williams and Suh (1986) and Renzetti (1988, 1992) argue.

consumed. This is perhaps why we did not find that industrial demand for water is more price-sensitive than available estimates of agricultural and residential demand, contrary to the results published by Williams and Suh (1986) and Renzetti (2003).

Table 5. Logarithmic estimation of the model, using Feasible Generalised Least Squares for industrial water consumption in Aragón

	Marginal values	*Average values*	*Marginal values with industrial activities and time dummies*	*Average values with industrial activities and time dummies*
	Coefficient (t-Statistic)	*Coefficient (t-Statistic)*	*Coefficient (t-Statistic)*	*Coefficient (t-Statistic)*
WPRICE	–0.009* (–1.80)	–0.012** (–2.44)	0.008 (1.61)	0.006 (1.37)
GREENCHARGE	–0.555** (–7.42)	–0.667** (–7.08)	–0.602** (–5.15)	–0.355** (–3.79)
FIXCAPITAL	0.443** (10.41)	0.456** (10.62)	0.003 (0.06)	0.019 (0.39)
AVEWAGE	–0.383** (–3.27)	–0.370** (–3.09)	0.165 (0.66)	0.573** (2.29)
RAWMAT	0.007 (0.28)	0.004 (0.17)	–0.133** (–5.56)	–0.127** (–5.38)
OUTPUT	0.299** (4.86)	0.301** (4.84)	0.856** (9.81)	0.809** (9.58)
INTANASS	–0.036** (–5.88)	–0.035** (–5.68)	–0.014** (–2.14)	–0.013** (–2.03)
COMPAGE	0.503** (3.99)	0.470** (3.73)	0.956 (0.69)	0.104 (0.72)
D-ACTIVITIES1			0.426 (0.68)	0.231 (0.37)
D-ACTIVITIES2			–1.359** (–2.41)	–1.914** (–3.23)
D-ACTIVITIES3			–1.811** (–3.41)	–2.117** (–3.69)
D-ACTIVITIES4			3.364** (4.71)	2.953** (4.01)
D-ACTIVITIES5			–7.072** (–6.79)	–7.691** (–7.14)
D-ACTIVITIES6			–0.184 (–0.29)	–0.881 (–1.35)
D-ACTIVITIES7			1.749** (3.60)	1.344** (2.65)
D-ACTIVITIES8			–3.332** (–5.88)	–3.891** (–6.57)

Table 5. *(continue)*

	Marginal values	*Average values*	*Marginal values with industrial activities and time dummies*	*Average values with industrial activities and time dummies*
	Coefficient (t-Statistic)	*Coefficient (t-Statistic)*	*Coefficient (t-Statistic)*	*Coefficient (t-Statistic)*
D-ACTIVITIES9			–0.878 (–1.53)	–1.438** (–2.36)
D-ACTIVITIES10			0.824 (1.29)	–0.589 (–0.87)
D-T2003			–0.258** (–2.98)	–0.254** (–2.96)
Observations	174	174	174	174
R^2	0.838	0.838	0.874	0.874
Adjusted R^2	0.831	0.830	0.859	0.858
F-statistic	107.63**	107.44**	56.48**	56.29**

* Significantly different from 0 at a confidence level of 90-95% in the bilateral test.
** Significantly different from 0 at a confidence level of 95-99% in the bilateral test.

Meanwhile, the Sanitation Charge (GREENCHARGE) displays a negative and significant sign for both average and marginal tax rates, and it therefore does contribute to the rationalisation of water use. In addition, the results obtained are in the higher range of estimations available for the price elasticity of agricultural and residential consumption (Williams and Suh, 1986 and Renzetti, 2003). As Renzetti (2005b) argues, then, the reduction in water consumption is due to the environmental charge and not to the increase in firms' water costs. This may be because the calculation of the Sanitation Charge takes the wastewater pollution load into account. However, it is also possible that this result is influenced by cost-free access to water in those cases in where firms supply themselves by self-abstraction, and by the price subsidies enjoyed by the rest.

The results obtained for the relationship between water consumption and the use of other productive factors were in line with expectations. Thus, a complementary relationship can be established between water use and firms' physical capital (FIXCAPITAL) and employment (indirectly through AVEWAGE), while the complementarity between water use and operating costs (RAWMAT) was not found to be significant. The complementarity between fixed capital and water consumption indicates that greater investment in capital goods is accompanied increased demand for water in the firms concerned. In the case of employment, it is size or scale which motivates complementarity.

The relationship found between industrial water use and the level of output (OUTPUT) means that water can be defined as a normal good, that is to say as a reflection of the underlying production function, which relates the quantity of a specific product manufactured to the quantities of the productive factors required. Once again, the elasticity presents similar values to those obtained in the various international studies available (0.34/1.94).

Likewise, there is apparent empirical evidence to suggest that those firms which invest most in research and development (INTANASS) also use the best water-saving technologies, thereby helping to reduce water consumption. Furthermore, the positive coefficient obtained for the variable which captures company age (COMPAGE) indicates that the deterioration or obsolescence of physical capital decreases technical performance and impairs efficient water use.

The model was also calculated including dummies for similar business activities and time dummies in order to capture the possible influence of characteristics from each one of the sectors and the economic cycle [15]. Some results change when these additional factors are included in the model (shown in the last two columns of Table 5), allowing us to check the robustness of the variables used in the model. To begin with, the price of water (WPRICE) is no longer significant. While this result could be taken to reinforce our previous reflection about the inelasticity of water consumption, it may also reflect weakness in the design of the water supply tariff [16], which has traditionally been viewed as a «political» (i.e. subsidised) price. Hence, the water price should be reconsidered given the obligations imposed by EU Urban Waste Water Directive, in order to eliminate the «political» pricing of water services, address environmental issues and finance a more complete and expensive service. Meanwhile, the relationship between water consumption and the operating costs (RAWMAT) is negative and significant, which suggests, contrary to what was expected in theory, that there is some substitutability between water and other inputs. Physical capital (FIXCAPITAL) and company age (COMPAGE) cease to be significant in this expanded model, and the employment (AVEWAGE) variable also loses some significance and switches from positive to negative. The influence of these variables on water consumption in industry is therefore sensitive to the specification of the model, while the results remain robust for GREENCHARGE, OUTPUT and INTANASS. Finally, the time dummy is negative, revealing a downward trend in industrial water consumption, although a longer time series would be needed to establish the medium-term time effect. Dummies capturing the branches of activity are generally significant and show that paper manufacturing and accommodation activities consume the most water, while the production and distribution of energy, wholesale trade and transport consume the least.

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[15] Table 3.A. of the Appendix shows the activities included in each sector dummy. Although our time series comprises only two years, we have also included a time dummy for 2003, in order to check if there was any change in the economic cycle during the period considered which might have influenced the model.

[16] See Barberán *et al* (2006 and 2008).

4. Final considerations

The growing concern in advanced societies over environmental problems, and specifically over the use of scarce resources like water justifies intervention by the regulator to improve management. Various intervention mechanisms exist to protect the environment (regulations, property rights, environmental taxes, etc.), but taxation offers many advantages compared to other tools. This paper has analysed the effectiveness of the Sanitation Charge levied on industries in the Aragon region of Spain in correcting the environmental problems caused by discharges of wastewater (leaving aside financial aims). This issue demands attention in view of the gravity of the potential environmental impacts from industrial water use in respect of other urban and agricultural uses. It was also one of the main motivations for the research behind this paper, together with the absence of empirical studies on the subject, owing to the difficulty of obtaining the necessary information, and the need to identify the design issues that must be addressed to set an effective corrective tax.

One of the basic design problems affecting the Sanitation Charge is the connection between tax base and environmental damage. The conventional way to address such a link is by indirectly taxing the production of wastewater discharges into the environment (i.e. through the consumption of water from any source), assuming that water consumption is associated with the generation of wastewater. From the corrective effectiveness, we consider that the pollution load of industrial wastewater has a crucial role to play as a modulating factor in the calculation of the tax payable, together with the intensity or magnitude of the charge itself. In some Spanish regions, including Aragon, the pollution load of wastewater for industrial uses is taxed together with the volume of water consumed, so that the composition or quality of the water discharged is taken into account in the calculation of the Sanitation Charge payable by each firm. We believe this is a key aspect of environmental tax design, so that the case of Aragon is representative of an effective corrective tax.

In order to achieve the aim proposed for this study, the price paid for water pollution was for the first time separated from the price paid for water supplies in the estimation of water demand. This split differentiates our paper from published studies of water demand, and we believe it is essential given the differing purpose and nature of the two prices.

The results obtained for the Autonomous Community of Aragon show that the reduction achieved in industrial water consumption is due rather to the Sanitation Charge than to any increase in water supply prices. This suggests that the Aragonese Sanitation Charge is well designed, because it changes polluters' behaviour. This outcome is associated both with the intensity of the Sanitation Charge and a tax design which modulates the tax charge based on the environmental damage caused by the taxpayer. Whether the stimulus achieved through the Sanitation Charge is sufficient from an environmental standpoint is another question.

Nevertheless, the result is constant regardless of the model specification (i.e. whether marginal or average prices are used), and whether or not dummies are included to capture the possible influence of sector characteristics and the business cycle on industrial water demand. Meanwhile, the coefficient for the price of the water supply (WPRICE) ceases to be significant when dummies are included, reinforcing the hypothesis that water consumption is price inelastic, although it may also reflect weaknesses in the design of the water supply tariff.

Our empirical study also sought to capture the possibility that increasing demand for water in industry may be due to output growth (scale effect) and to changes in the productivity of water consumption (technological effect). To this end, we have included variables reflecting both the volume of production (OUTPUT) and the level of technology used in the activity (INTANASS) alongside our key variable (the Sanitation Charge) and price variable (price for water supply). All of these additional variables explain water demand and are robust to the inclusion of sector dummies (D-ACTIVITIESX) intended to capture the influence of changes in the industrial fabric of the region on water demand (composition effect). In any event, the effect of the output variable will clearly depend on the internal use of water in a given firm (reused and recycled water etc.) However, it seems logical to suppose that a longer time series would be required for industries to take up new water-saving technologies, and for water consumption and pollution to be reduced by their use.

This study could be extended by comparing the environmental effects of the Sanitation Charges applied in other regions of Spain, and this paper may therefore be considered a base for future research. Considering the differences observed in the Sanitation Charges applied by the Autonomous Communities, it might be appropriate for central government to establish mandatory tax design criteria in order to ensure a minimum level of environmental quality throughout Spain.

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APPENDIX

Table 1.A. Descriptive statistics for the principal variables

	Mean	*Std. deviation*	*Minimum*	*Maximum*	*Sum*	*Variance*	*Skewness*	*Kurtosis*
WUSE	61,725.58	331,588.31	0.00	2,678,319.00	1.09872D+07	1.09951D+11	6.57247	43.19291
WPRICE (average)	0.34	0.65	0.00	4.76	60.50455	0.42890	3.80164	19.74961
WPRICE (marginal)	0.22	0.35	0.00	1.60	38.45079	0.12292	2.06026	4.60823
GREENCHARGE (average)	0.37	0.35	0.00	1.88	65.99939	0.12584	2.14245	4.87834
GREENCHARGE (marginal)	0.20	0.16	0.00	1.26	36.43248	0.026833	4.41980	25.62184
FIXCAPITAL	2,366.66	6,678.17	2.44	51,540.74	421,266.07393	4.45980D+07	5.74984	35.13859
AVEWAGE	23.81	9.45	7.59	79.05	4,238.34589	89.24278	1.90179	7.18877
RAWMAT	3,828.89	11,630.23	0.00	84,008.73	681,543.19801	1.35262D+08	5.68661	34.04182
OUTPUT	8,672.07	31,784.59	14.95	237,808.25	1,543,629.22929	1.01026D+09	6.28221	39.70969
INTANASS	0.04	0.12	4,66583D-16	0.93	7.44826	0.014218	5.28112	32.59091
COMPAGE	18.81	13.92	3.00	72.00	3,349.00000	193.82419	1.86899	3.83836

Table 2.A. Correlation matrix of the principal variables, in logarithms

	WUSE	*WPRICE (average)*	*GREEN-CHARGE (average)*	*WPRICE (marginal)*	*GREEN-CHARGE (marginal)*	*FIXCAPI-TAL*	*AVEWAGE*	*RAWMAT*	*OUTPUT*	*INTANASS*	*COMPAGE*
WUSE	1.00000										
WPRICE (average)	–0.06503	1.00000									
GREEN-CHARGE (average)	0.32405	0.12882	1.00000								
WPRICE (marginal)	–0.05416	0.99919	0.12217	1.00000							
GREEN-CHARGE (marginal)	–0.27195	0.14319	0.40774	0.13811	1.00000						
FIXCAPITAL	0.41639	–0.08468	–0.26435	–0.07767	–0.27727	1.00000					
AVEWAGE	0.16402	0.14054	–0.07344	0.13846	–0.18835	0.26815	1.00000				
RAWMAT	0.16052	–0.07519	–0.15604	–0.07275	–0.14645	0.13891	0.09576	1.00000			
OUTPUT	0.39180	–0.05559	–0.25891	–0.05160	–0.25929	0.66653	0.54232	0.50672	1.00000		
INTANASS	0.03835	–0.05501	–0.08677	–0.05632	–0.04843	0.32920	0.09742	0.15997	0.33949	1.00000	
COMPAGE	0.28612	–0.14595	–0.21301	–0.14413	–0.22971	0.37442	0.45746	0.36425	0.58450	0.21560	1.00000

Table 3.A. Activities included in sector dummies

D-ACTIVITIES 1.	Manufacture of food products.
D-ACTIVITIES 2.	Manufacture of vehicles, machinery and metal products.
D-ACTIVITIES 3.	Chemical industry and manufacture of plastic, wood and rubber products.
D-ACTIVITIES 4.	Manufacture of paper.
D-ACTIVITIES 5.	Production and distribution of energy.
D-ACTIVITIES 6.	Sale and repair of motor vehicle.
D-ACTIVITIES 7.	Accommodation.
D-ACTIVITIES 8.	Wholesale trade, intermediaries and transportation.
D-ACTIVITIES 9.	Real estate activities and financial mediation.
D-ACTIVITIES 10.	Services provided to the community and other social activities.