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Key Points:

- Water consumption is largely out of control in the hotels and restaurants sector
- The shadow price of water is higher than the observed price
- Water price elasticity enables the use of pricing in water demand management

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Economic analysis of the water demand in the hotels and restaurants sector: Shadow prices and elasticities

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Abstract Despite the growing economic importance of tourism, and its impact on relative water shortage, little is known about the role that water plays in the productive process of hotels and restaurants and, therefore, the possible implications of water demand management policy for this sector. This study aims to fill this gap. It is based on the microdata of 676 firms in the sector, operating in the city of Zaragoza (Spain) for a 12 year period. Based on the Translog cost function, we estimate the shadow price of water in the short run and, from a long-run perspective, its direct price elasticity, its cross elasticities relative to labor, capital, and supplies, and its elasticity with respect to the level of output. The results obtained show that water provides sector firms returns that are on average higher than its price, although in the case of hotels the margin is really narrow. This situation provides policy makers with a margin for applying price increases without affecting the sector's viability, with some caution in the case of hotels. Water demand elasticity equals −0.38 in the case of hotels, but it is not significant in the case of restaurants and bar-cafes; hence, only in hotels is there potential for influencing water use patterns, encouraging the resource's conservation through pricing policy. Moreover, capital is a substitutive factor of water, and the elasticity of water with respect to output is 0.40, all of which should also be considered by policy makers in water resource management.

1. Introduction

Awareness of the environmental and economic problems derived from the overuse of water resources has generated growing social interest in the efficient and sustainable use of water, particularly drinking water [*United Nations*, 2000; *WWAP* (*World Water Assessment Programme*), 2012]. Numerous economic studies have focused on water demand in households (see reviews by *Brookshire et al*. [2002], *Arbués et al*. [2003], *Worthington and Hoffman* [2008], and *Nauges and Whittington* [2010]), but there are fewer referring to industrial sectors (see reviews by *Renzetti* [2002a, 2002b], de *Gispert* [2004], and *Worthington* [2010]) and very few related to the services sector. We have found only two studies that focus on water demand in services [*Lynne et al*., 1978; *Moeltner and Stoddard*, 2004] and another five that provide details of service sector activities together with the industrial sector [*Williams and Suh*, 1986; *Schneider and Whitlatch*, 1991; *Reynaud*, 2003; *Dachraoui and Harchaoui*, 2004; *Bell and Griffin*, 2008].

However, the service sector, especially personal services such as education, healthcare, and hotels and restaurants, has similar characteristics to the household sector in terms of water quality requirements, uses of the resource, and its importance for quality of life. Although personal services do not represent a large proportion of total water demand, they do require drinking water and contribute to the relative water shortage in urban areas. Within this sector, hotels and restaurants play a special role in relation to use of water, especially in tourist countries.

In Spain, the importance of the use of water in the hotels and restaurants activities is heightened by the economic importance of tourism, which represents 10.8% of the country's Gross Domestic Product (GDP) [*INE* (*Instituto Nacional de Estadística*), 2012]. Moreover, it is especially stressed by the fact that the regions where water shortage is high are largely areas that receive more tourists and the highest demand occurs during peak seasonal water shortages. The latest data indicate that, in 2006, tourist activities used 11.8% of the entire water supply for human consumption in Spain; this figure is as high as 42.9% in the Balearic Islands. Specifically, the use of water in hotel establishments is particularly high relative to household use,

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Table 1. Price Elasticity of Water Demand in Different Economic Activities[a]

Lower and Upper Elasticity	Range (Lower-Upper)	Economic Activities	Area	Authors
−0.11/−1.07	0.96	Hotels and motels/Department stores	USA	*Lynne et al.* [1978]
0.54/−0.66	1.20	Electric and electronic/Paper	USA	*Babin et al.* [1982]
−0.14/−0.44	0.30	Commercial/Industrial	USA	*Williams and Suh* [1986]
−0.36/−0.73	0.37			
−0.12/−0.54	0.42	Petrochemical/Light industry	Canada	*Renzetti* [1988]
−0.15/−0.59	0.44	Rubber/Paper	Canada	*Renzetti* [1992]
−0.66/−2.17	1.51	Petroleum/Food industry	Canada	*Renzetti* [1993]
−0.07/−0.37	0.30	Nonfood industry and commercial/Food industry	Hawaii	*Malla and Gopalakrishnan* [1999]
−0.57/−1.20	0.63	Power generation/Leather	China	*Wang and Lall* [2002]
−0.10/−0.79	0.69	Alcohol/Others	France	*Reynaud* [2003]
−0.23/−0.63	0.40	Eat-drink/Recreation	USA	*Moeltner and Stoddard* [2004]
−0.22/−3.10	2.88	Sugar/Beverage	Mexico	*Guerrero* [2005]
−0.30/−0.94	0.64	Pharmaceutical/Leather	India	*Kumar* [2006]
0.31/−1.09	1.40	Industrial/Commercial	USA	*Bell and Griffin* [2008]

[a]Authors' own summarizing.

since the amount of water consumption per guest per day in hotels is 3 times greater than the daily water consumption per person in households [*Ministerio de Medio Ambiente*, 2007].

Therefore, greater efficiency in water use in these establishments could have a significant positive effect on mitigating water shortage problems and the sustainability of tourism. Hence, there is abundant literature concerning different aspects of water use in this sector. Among them are studies focused on the influence of establishment characteristics on the amount of water use [*Deng and Burnett*, 2002; *Gopalakrishnan and Cox*, 2003; *Bohdanowicz and Martinac*, 2007; *Charara et al*., 2011] and others that evaluate water savings obtained by establishments with the adoption of different measures such as replacement of appliances and fixtures [*Meade and González-Morel*, 1999; *Environment Agency*, 2004; *Hamele and Eckardt*, 2006; *Barberán et al*., 2013]. Nevertheless, we do not find any study undertaken on the economic analysis of water demand in the hotel sector.

An analysis of water demand provides information that is required to design water management policies, particularly water tariffs, which are the main instrument of intervention on the demand side of management [*OECD*, 1987; *Brookshire et al*., 2002]. The short-run viability of a water pricing policy aimed at encouraging the resource's conservation depends on users' ability to absorb price increases and it can be established by calculating the shadow price of water. The long-run efficacy of that policy will depend on users' response reflected in water demand elasticity. This information is useful in the design of a water pricing policy aimed at fully recovering water supply costs, either through generalized price increases or price discrimination between different types of users. It is also useful for water service supply planning to have information about the impact of variations in the price of other production factors and production level on water demand, which can be established by calculating cross elasticities and output elasticity.

There is thus a need for studies that analyze water demand in specific activities, such as hotels and restaurants, or multiactivity studies with a breakdown of the results by activity. The reason is that results vary considerably between economic activities and between countries, both for direct price elasticity and the shadow price of water, as shown in Tables 1 and 2. Likewise, the results vary for the elasticity of water demand with respect to output and cross elasticities between production factors.

The objective of this study is to obtain empirical evidence about the characteristics of water demand in hotels and restaurants, in order to ultimately establish the possibilities of water demand management policies. The study that follows calculates shadow price, direct price elasticity, cross elasticities between factors and elasticity with respect to output in the hotels and restaurants sector and its three main subsectors (hotels, restaurants, and bars-cafes). Two scenarios are considered, a short-run context in which water is a quasi-fixed factor and a long-run context in which all factors are variable. The estimations are based on a sample of firms operating in the city of Zaragoza (Spain), all of which are connected to the city's public water supply network.

Table 2. Shadow Prices of Water in Different Economic Activities[a]

Lower and Upper Shadow Price	Ratio (Upper/Lower)	Economic Activities	Price Paid	Area	Authors
16/64 US$/acre-foot	4	Minerals industry/Paper	n.a.	USA	*Young and Gray* [1972]
0.05/26.83 Yuan/m^3	536.6	Power generation/Transportation equipment	0.70–1.20 Yuan/m^3	China	*Wang and Lall* [2002]
0.005/0.288 CAD$/m^3	57.5	Textile/Refined petrol and coal	n.a	Canada	*Renzetti and Dupont* [2003]
−0.34/1.29 CAD$/m^3		Primary textile/Rubber products	n.a.	Canada	*Dachraoui and Harchaoui* [2004]
1.16/30.54 Rupees/m^3	26.3	Leather/Paper	1.94 Rupees/m^3	India	*Kumar* [2006]
0.39/12.51 US$/m^3	32.1	Precision instruments/Transportation equipment	n.a.	Korea	*Ku and Yoo* [2012]

[a]"n.a.," not available. Authors' own summarizing.

The paper is organized as follows. Section 2 presents the case study. Section 3 focuses on the specification of the model, particularly cost functions. Section 4 contains some econometric issues related to the estimation of the cost functions. Sections 5 and 6 present the results obtained, distinguishing between those related to the short run (section 5) and the long run (section 6). Finally, section 7 presents our conclusions.

2. Case Study

This study focuses on hotels and restaurants sector establishments in the city of Zaragoza, the capital of the Autonomous Region of Aragón, Spain. The city is in the center of the north-east quadrant of the Iberian Peninsula, approximately 300 km from the most important cities in northern Spain (Madrid, Barcelona, Valencia, and Bilbao). It has approximately 675,000 inhabitants and their gross disposable per capita income in 2008 was 17,838 €, 115.6% of the Spanish average [*INE* (*Instituto Aragonés de Estadística*), 2010]. The services sector represented 68.9% of its Gross Value Added (GVA) in 2007, followed by industry (19.6%), construction (11.1%), and agriculture (0.4%).

The city has 57 hotels with a total of 10,480 beds [*Zaragoza Convention Bureau*, 2009, 2011]. It also has hostels and boarding houses, making a total of 111 establishments and 10,982 beds [*IAEST*, 2010]. In 2010, the city had 799,938 visitors, representing 1,340,193 nights of accommodation, 76.5% of which were by Spaniards.

We do not have direct information about the number of restaurants and bars-cafes in the city, but they can by estimated from data provided by *Fundación Hostelería de España* [2011], assuming that restaurants and bars-cafes tend to be proportionally distributed according to gross disposable income and population, respectively. Thus, by applying these simple criteria, we obtain a reasonable estimation of 890 restaurants and 3740 bars-cafes.

The supply pattern predominantly comprises small firms, as shown by the ratio between establishments and firms for the entire region: 1.24 in hotels, 1.12 in restaurants, and 1.06 in bars-cafes [*Fundación Hostelería de España*, 2011].

The data used in this study are drawn from two statistical sources:

1. Firms' accounting information was taken from the *Sistema de Análisis de Balances Ibéricos* database (hereinafter, SABI). This is a database created by INFORMA D&B, in collaboration with Bureau Van Dijk, which provides general information and the annual accounts of more than 1.2 million Spanish firms, using multiple public and private information sources (for more information, see http://www.informa.es/en).

   The analysis considers only registered firms operating in Zaragoza belonging to the following subsectors of the Spanish National Classification of Economic Activities 2009 (hereinafter, CNAE-2009):

   a. Subsector 5510 "Hotels and similar accommodation," generically referred to here as HOTELS.

   b. Subsector 5610 "Restaurants and similar eating establishments," generically referred to as RESTAURANTS.

   c. Subsector 5630 (bars, taverns, cantinas, breweries, and cafes) "Drinking establishments," generically referred to as BARS-CAFES.

2. Information about the quantity of water consumed, and its cost, for each firm provided by the Zaragoza City Council.

After debugging the sample to ensure the necessary data consistency and regularity, we established a sample of 676 firms comprising 83 HOTELS, 241 RESTAURANTS, and 352 BARS-CAFES. We will refer generically to all of them as the hotels and restaurants sector. This aggregate approximately corresponds to H—hotels and restaurants sector of the International Standard Industrial Classification of All Economic Activities, Rev.3.1 (ISIC Rev.3.1), United Nations. This sample does not include firms with establishments operating within the city of Zaragoza but registered elsewhere, since water consumption data for these establishments could not be matched to the firms' accounts data drawn from SABI (which refer to the total accounts of all establishments, operating within the city or elsewhere). This means that the sample provides a partial view of the sector's activities in Zaragoza city, slightly biased toward local firms.

The data used in this study cover the period from 1995 to 2006. Monetary magnitudes measured by euros are expressed in real terms using the price index for hotels, restaurants and bars-cafes activities published by *Instituto Nacional de Estadística*, with a 2006 base, equal to 100.

For each firm, production value is measured by operating income, in SABI terms, defined as the sum of sales and other operating income. Production cost is obtained by adding together the cost of all production factors: capital, labor, water, and supplies. Specifically, the cost of capital is measured as the sum of equity and debt costs; the cost of labor, by employees costs; supplies costs (energy, beverages, food, cleaning and personal hygiene products, and miscellaneous materials and services; not including water), by costs of purchased goods and services. The water bill issued by the Council to each establishment enables a direct estimation of the cost of the water used.

The price of capital, P_k, defined as the Weighted Average Cost of Capital (*WACC*), is calculated as the weighted average between the cost of debt and the cost of equity for each firm [*Modigliani and Miller*, 1963; *Miles and Ezzell*, 1980; *Brealey et al.*, 2013]:

$$P_k = WACC = Cd(1-t)\left(\frac{D}{E+D}\right) + Ce\left(\frac{E}{E+D}\right) \tag{1}$$

where D is the firm's debt (bonds and loans); E is the firm's equity (capital and reserves); Cd is the cost of debt, measured as the average interest rate paid by each firm (that is, total financial expenses divided by total debt); t is the corporate tax rate; and Ce is the cost of equity, measured as the average interest rate paid by each firm.

Tariffs for water consumption in the city of Zaragoza in the period under review include a fixed part, which enables connection to the supply, and a volume charge applied according to a continuous progressive tariff of 205 prices [see *Barberán and Domínguez*, 2006, pp. 208–212]. This means that all consumed water is paid at the same price, which increases progressively as consumption rises. In our case, the price of water for each firm is obtained by dividing the water bill, excluding the fixed part, by the quantity of water consumed. Consequently, this price is a very good approximation of the price in the official tariff.

The price of supplies is treated as unobservable, since it includes an extremely heterogeneous set of production factors.

Table 3 summarizes the main magnitudes related to the production process of this sample from the hotels and restaurants sector in the analyzed period.

The data on this table highlight the differences between the three subsectors. The size of the firms in HOTELS, measured by number of employees, is nearly 50% greater than the average size of all firms in the sample, but in terms of invested capital they are 4 times greater than the average. Similar differences are found for cost of capital, supplies, water consumption, and production value. Furthermore, HOTELS incur the highest average cost paid per unit of capital and per unit of water, which is reflected in the weights structure of the cost of production for this subsector.

RESTAURANTS rank second place in terms of size, production, and factors consumed; the firms in this subsector support the highest labor cost per employee. BARS-CAFES are the smallest firms and present the lowest factor unit costs.

Table 3. Basic Magnitudes of the Sample From the Hotels and Restaurants Sector in Zaragoza (Yearly Averages for 1995–2006)[a]

	Aggregate	Hotels	Restaurants	Bars-Cafes
Number of firms	676	83	241	352
Quantities per Firm				
Water (m^3)	657.1 (3325.8)	1808.7 (8873.8)	647.4 (1370.8)	392.3 (1038.1)
Invested capital (€)	408918.4 (1159989.0)	1703922.8 (3135970.0)	257843.0 (347364.1)	206997.5 (428570.1)
Cost of capital (€)	25732.8 (108309.6)	136669.2 (294719.5)	14415.1 (65563.36)	7323.3 (11477.18)
Labor (Number of employees)	9.3 (11.1)	14.3 (22.1)	10.4 (10.0)	7.3 (5.9)
Supplies (€)	278960.6 (333476.3)	409560.7 (632658.6)	345483.0 (319582.3)	202620.6 (171562.9)
Share of Different Factors in Total Expenditure (w_i)				
Water	0.30 (0.68)	0.63 (0.76)	0.26 (0.60)	0.25 (0.71)
Capital	3.68 (8.63)	8.79 (12.32)	2.61 (8.47)	3.21 (7.54)
Labor	31.08 (11.36)	34.54 (13.52)	32.23 (9.35)	29.48 (12.21)
Supplies	64.93 (12.40)	56.04 (17.03)	64.90 (10.13)	67.06 (12.47
Factor Prices per Firm				
Water (€/m^3)	1.01 (0.58)	1.18 (0.58)	1.12 (0.52)	0.91 (0.61)
Capital (%)	4.06 (7.81)	5.38 (10.43)	4.58 (7.93)	3.39 (7.81)
Labor (€/employee)	18868.6 (11784.8)	19184.1 (8709.6)	20202.4 (13866.7)	17881.0 (10309.6)
Production Value per Firm				
Production value (€)	521887.2 (791266.4)	998176.5 (1868997.0)	606774.2 (533250.4)	351461.7 (296818.4)

[a]Authors' own calculation based on SABI database and Zaragoza City Council. Figures in brackets are standard deviations.

There are also differences in the relative share of different factors in total production cost. Capital, labor, and water are more important in HOTELS, with supplies being of less significance. Water cost in HOTELS represents 0.63% of the aggregate cost, while in RESTAURANTS and BARS-CAFES, it represents 0.26% and 0.25%, respectively. In the sample, it represents 0.31% of the aggregate cost.

A common feature of the three subsectors, according to our sample drawn from the SABI database, is the progressive reduction in size of the companies during the study period. Average production value for the firms fell, in real terms, by 51% from 1995 to 2006, going from 899,797 € at the beginning to just over 438,654 €. The greatest reduction was in BARS-CAFES, more than 75%, while the HOTELS figure fell by 43%. This adjustment is also significant in employment, which went from an aggregate average of the three subsectors of 16.9 to 7.5 jobs/firm. The reduction in employment was the lowest in RESTAURANTS, where it went from an average of 14.7 to 9.3 jobs. HOTELS reduced employment by an average of nearly 13 jobs, going from 24 to 11.3. A similar change is found in invested capital.

Figure 1 shows several aspects of interest regarding the use of water. It is clear that the use of the resource increased in all cases. The average figure for 1995 is a consumption of 205.7 m^3/firm. Eleven years later, in 2006, this figure tripled to 750.0 m^3/yr. The evolution of the three subsectors presents similar characteristics, with logical differences in water consumption volume.

The variable cost of water, deflated according to the sector's price index, showed rather systematic behavior over this period even for the average of the three subsectors. After an initial increase in the firsts 2 years (68.6% in the aggregate), the real cost of water decreased regularly until 2003 (−33.7% on average compared to 1997); the series tend to stabilize in the final part of the period. The real average variable cost ranged from 0.55 to 1.47 €/m^3 in the three subsectors but the differences between them tend to be smaller after 2003.

In 1995, water represented 0.17% of the total operating costs for a representative firm in this sector, although this figure increased to 0.33% by 2006. The most significant movement is found in RESTAURANTS, where the percentage grew from 0.11% to 0.37%. The change has been smoother for BARS-CAFES (from 0.12% to 0.27%), and the weight of water even decreased slightly in the cost structure of HOTELS (0.63% in 1995 and 0.51% in 2006). As shown in Figure 1c, from 2004 the series of the three subsectors, plus that of the aggregate, exhibit a downward profile.

Consumption per unit of production shows a progressive and considerable reduction in water use efficiency in the sector, despite the change of trend in the last 2 years. In 1995, 0.34 m^3 of water was consumed per euro of production value, while this figure increased to 1.71 by 2006, peaking at 3.30 in 2004. The highest consumption ratio, for the whole period, is found in BARS-CAFES, with 4.43 m^3/€ in 2004; the lowest value occurs in the same subsector in 1995 with 0.14 m^3/€.

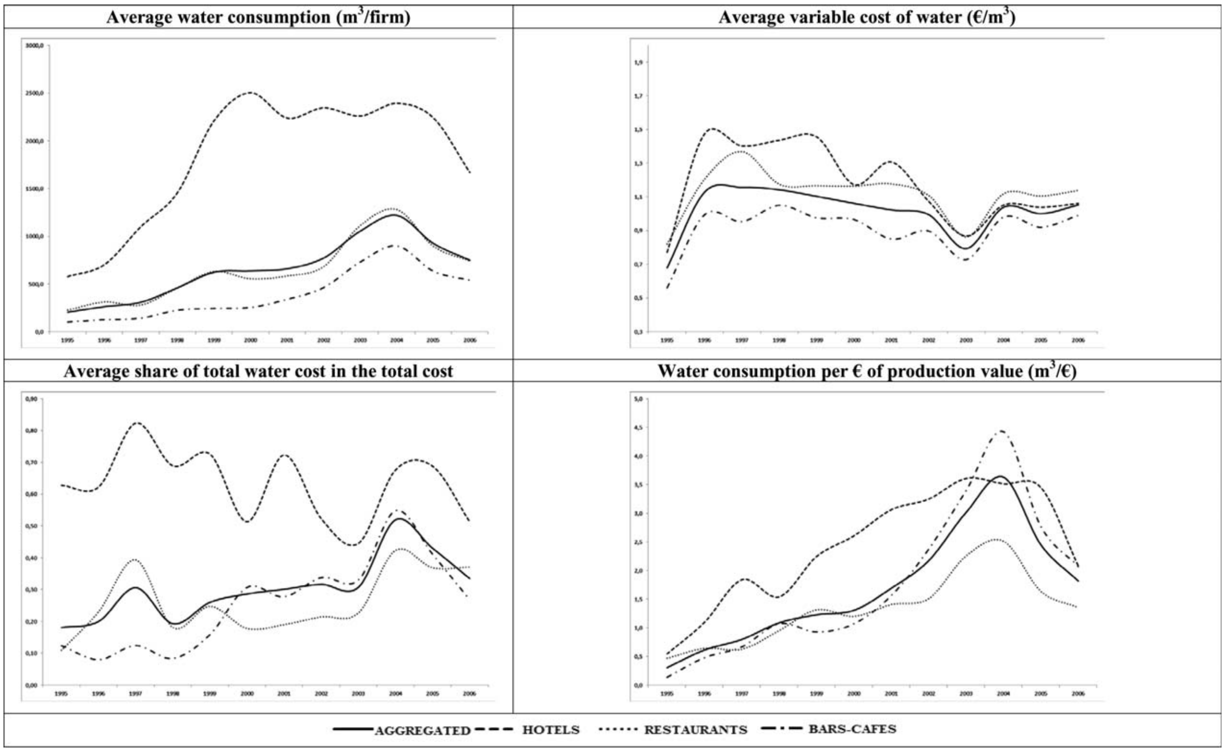

Figure 1. Evolution of some measures related to the water factor 1995–2006 (yearly average).

3. Specification of the Analytical Model

We assume that there is a common aggregate production function for the hotels and restaurants sector, which includes HOTELS, RESTAURANTS, and BARS-CAFES. If the prices of the four production factors (capital, labor, water, and supplies) and production levels are exogenously determined, the theory of duality between cost and production implies that the production function can be represented by a cost function.

Among the alternative specifications for the cost function, we prefer the Translog because of its flexibility. The Translog cost function was introduced by *Christensen et al*. [1971, 1973], and has been widely used in numerous analyses of different economic sectors' cost structures and of the characteristics of the demand of different production factors, including shadow price calculation. For water, it has been used, among others, by *Grebenstein and Field* [1979], *Babin et al*. [1982], *Renzetti* [1992], *Dupont and Renzetti* [1998, 2001], *Reynaud* [2003], *Dachraoui and Harchaoui* [2004], *Guerrero* [2005], *Féres and Reynaud* [2005], and *Ku and Yoo* [2012].

The specification of the long-run cost function is given by the following expression:

$$\ln G=\alpha+\alpha_Y \ln Y+\sum_{i=1}^{4}\alpha_i \ln p_i+\frac{1}{2}\alpha_{YY}(\ln Y)^2+\frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4}\alpha_{ij}\ln p_i \ln p_j+\sum_{i=1}^{4}\alpha_{Yi}\ln Y \ln p_i \qquad (2)$$

$$(\mathrm{i,j=K,\ L,\ W,\ and\ S})$$

where K is the capital, L is the labor, W is the water, S is the supplies, G is the total production cost, Y is the value of production, and p is the price of the different production factors.

All production factors are variable in the long-run cost function defined in (2). Therefore, as argued in *Al-Mutairi and Burney* [2002], it is implicitly assumed that the firms are in a static equilibrium. This ensures an optimal combination of factors, in the sense that it minimizes production cost. Moreover, in equilibrium, the relative prices of factors are equal to their marginal productivity.

In the short run, however, the variable nature of the production factors is more problematic. In this respect, *Al-Mutairi and Burney* [2002] question the variable nature of capital in some sectors, as it is determined according to the long-run demand forecast; they suggest that it should be considered a quasi-fixed factor. *Dupont and Renzetti* [2001] test whether water, in the case of the Canadian manufacturing industry, is fixed or quasi fixed in the production function, obtaining evidence of the latter.

We now focus on the case of water for the hotels and restaurants sector.

The most immediate interpretation is that water is a variable factor in the production function. However, in the short run, its consumption is largely out of the firm's control. Indeed, it basically depends on the characteristics of the facilities, which could be modified in the long run, and users' behavior, which is difficult to control. We therefore believe that, in the short run, water can be classified as a quasi-fixed factor in the hotels and restaurants sector's productive technology. This same reasoning leads us to question the variable nature of the capital factor, which is difficult to adjust in the short run.

If we only treat capital as a quasi-fixed factor, and water remains variable, the short-run cost function is the following:

$$\begin{aligned}\ln GV=&\alpha+\alpha_Y\ln Y+\alpha_K\ln Q_K+\sum_{i=1}^{3}\alpha_i\ln p_i+\frac{1}{2}\alpha_{YY}(\ln Y)^2+\frac{1}{2}\alpha_{KK}(\ln Q_K)^2\\&+\frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\alpha_{ij}\ln p_i\ln p_j+\alpha_{YK}\ln Y\ln Q_K+\sum_{i=1}^{3}\alpha_{Yi}\ln Y\ln p_i+\sum_{i=1}^{3}\alpha_{Ki}\ln Q_K\ln p_i\\&(\mathrm{i},\ \mathrm{j}=\mathrm{W},\ \mathrm{L},\ \mathrm{and}\ \mathrm{S})\end{aligned} \tag{3}$$

where *GV* is the sum of all variable costs that include labor (L), water (W), and supplies (S); Q_K represents the quantity of the capital factor.

If we only treat water as a quasi-fixed factor, and capital remains variable, the short-run cost function is

$$\begin{aligned}\ln GV'=&\alpha+\alpha_Y\ln Y+\alpha_W\ln Q_W+\sum_{i=1}^{3}\alpha_i\ln p_i+\frac{1}{2}\alpha_{YY}(\ln Y)^2+\frac{1}{2}\alpha_{WW}(\ln Q_W)^2\\&+\frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\alpha_{ij}\ln p_i\ln p_j+\alpha_{YW}\ln Y\ln Q_W+\sum_{i=1}^{3}\alpha_{Yi}\ln Y\ln p_i+\sum_{i=1}^{3}\alpha_{Wi}\ln Q_W\ln p_i\\&(\mathrm{i},\ \mathrm{j}=\mathrm{K},\ \mathrm{L},\ \mathrm{and}\ \mathrm{S})\end{aligned} \tag{4}$$

where GV' is the sum of the costs incurred by labor (L), capital (K), and supplies (S); Q_W represents the quantity of water consumed.

Finally, if both water and capital are classified as quasi-fixed factors, the short-run cost function is

$$\begin{aligned}\ln GV''=&\alpha+\alpha_Y\ln Y+\alpha_K\ln Q_K+\alpha_W\ln Q_W+\sum_{i=1}^{2}\alpha_i\ln p_i+\frac{1}{2}\alpha_{YY}(\ln Y)^2\\&+\frac{1}{2}\alpha_{KK}(\ln Q_K)^2+\frac{1}{2}\alpha_{WW}(\ln Q_W)^2+\frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}\alpha_{ij}\ln p_i\ln p_j+\alpha_{YK}\ln Y\ln Q_K\\&+\alpha_{YW}\ln Y\ln Q_W+\sum_{i=1}^{2}\alpha_{Yi}\ln Y\ln p_i+\alpha_{KW}\ln Q_K\ln Q_W+\sum_{i=1}^{2}\alpha_{Ki}\ln Q_K\ln p_i+\sum_{i=1}^{2}\alpha_{Wi}\ln Q_W\ln p_i\\&(\mathrm{i},\ \mathrm{j}=\mathrm{L}\ \mathrm{and}\ \mathrm{S})\end{aligned} \tag{5}$$

where GV'' is the sum of the variable costs incurred by labor (L) and supplies (S).

Cost equations (2)–(5) can be estimated directly. However, efficiency can be gained by also estimating the demand equations of cost-minimizing factors. Logarithmically deriving the above cost functions relative to prices, and using Shepard's lemma, for functions (2), (3), (4), and (5) we obtain the following cost-minimizing factor share equations:

$$\frac{\partial \ln G}{\partial \ln p_i} = w_i = \alpha_i + \alpha_{Yi} \ln Y + \sum_{j=1}^{4} \alpha_{ij} \ln p_j \quad (\text{i, j=K, L, W, and S}) \tag{6}$$

$$\frac{\partial \ln GV}{\partial \ln p_i} = w_i = \alpha_i + \alpha_{Yi} \ln Y + \alpha_{Ki} \ln Q_K + \sum_{j=1}^{3} \alpha_{ij} \ln p_j \quad (\text{i, j=W, L, and S}) \tag{7}$$

$$\frac{\partial \ln GV'}{\partial \ln p_i} = w_i = \alpha_i + \alpha_{Yi} \ln Y + \alpha_{Wi} \ln Q_W + \sum_{j=1}^{3} \alpha_{ij} \ln p_j \quad (\text{i, j=K, L, and S}) \tag{8}$$

$$\frac{\partial \ln GV''}{\partial \ln p_i} = w_i = \alpha_i + \alpha_{Yi} \ln Y + \alpha_{Ki} \ln Q_K + \alpha_{Wi} \ln Q_W + \sum_{j=1}^{2} \alpha_{ij} \ln p_j \quad (\text{i, j=L and S}) \tag{9}$$

where w_i is the share of factor i in the total variable production cost.

Cost functions (2)–(5) are well specified if they ensure price symmetry. Besides, they must be homogeneous of degree one in prices and production in the case of function (2); in prices, production and capital in the case of function (3); in prices, production, and water in the case of function (4); and in prices, production, water, and capital in the case of function (5). This discussion leads to the following constraints affecting the estimated parameters:

1. For long-run equations (2) and (6):

$$\begin{gathered} \alpha_{ij} = \alpha_{ji} \quad i \neq j \\ \sum_{i=1}^{4} \alpha_i = 1; \sum_{i=1}^{4} \alpha_{Yi} = 0; \sum_{j=1}^{4} \alpha_{ij} = 0; \sum_{i=1}^{4} \alpha_{ij} = 0 \quad (\text{i, j=K, L, W, and S}) \end{gathered} \tag{10}$$

2. For short-run equations (3) and (7):

$$\begin{gathered} \alpha_{ij} = \alpha_{ji} \quad i \neq j \\ \sum_{i=1}^{3} \alpha_i = 1; \sum_{i=1}^{3} \alpha_{Yi} = 0; \sum_{i=1}^{3} \alpha_{Ki} = 0; \sum_{j=1}^{3} \alpha_{ij} = 0; \sum_{i=1}^{3} \alpha_{ij} = 0 \quad (\text{i, j=W, L, and S}) \end{gathered} \tag{11}$$

3. For short-run equations (4) and (8):

$$\begin{gathered} \alpha_{ij} = \alpha_{ji} \quad i \neq j \\ \sum_{i=1}^{3} \alpha_i = 1; \sum_{i=1}^{3} \alpha_{Yi} = 0; \sum_{i=1}^{3} \alpha_{Wi} = 0; \sum_{j=1}^{3} \alpha_{ij} = 0; \sum_{i=1}^{3} \alpha_{ij} = 0 \quad (\text{i, j = K, L, and S}) \end{gathered} \tag{12}$$

4. For short-run equations (5) and (9):

$$\begin{gathered} \alpha_{ij} = \alpha_{ji} \quad i \neq j \\ \sum_{i=1}^{2} \alpha_i = 1; \sum_{i=1}^{2} \alpha_{Yi} = 0; \sum_{i=1}^{2} \alpha_{Ki} = 0; \sum_{i=1}^{2} \alpha_{Wi} = 0; \sum_{j=1}^{2} \alpha_{ij} = 0; \sum_{i=1}^{2} \alpha_{ij} = 0 \quad (\text{i, j = L and S}) \end{gathered} \tag{13}$$

There is no consensus on whether to individually estimate the cost function or the cost-share equations. Another option, apparently more interesting and which we follow, is to estimate the two functions together [*Guilkey and Lovell*, 1980].

It is clear that the parameters provide valuable information about the cost structure of the sector in question. In particular, we can calculate the shadow prices of fixed or quasi-fixed production factors, together with the corresponding substitution elasticities with respect to the variable factors.

For example, function (5) can be used to evaluate the shadow price of capital, $\frac{\partial GV''}{\partial Q_K} = z_K$, and the shadow price of water, $\frac{\partial GV''}{\partial Q_W} = z_W$. We can also obtain the substitution elasticities (denoted by σ) between water consumption (Q_w) and the other variable inputs (v = L, S), and between capital consumption (Q_k) and the variable inputs, using the following expressions:

$$\sigma_{W,v}=\frac{\partial \ln GV''}{\partial \ln Q_W}+\frac{\frac{\partial^2 \ln GV''}{\partial \ln Q_W \partial \ln p_s}}{\frac{\partial \ln GV''}{\partial \ln p_s}}; \qquad \sigma_{K,v}=\frac{\partial \ln GV''}{\partial \ln Q_K}+\frac{\frac{\partial^2 \ln GV''}{\partial \ln Q_K \partial \ln p_s}}{\frac{\partial \ln GV''}{\partial \ln p_s}} \tag{14}$$

With regards to the variable inputs, we can calculate the corresponding direct and cross substitution elasticities as well as direct and cross price elasticities (denoted by η). The relationship between them is simple, and given by the following expressions:

$$\begin{aligned} &\text{Cross Elasticities :} && \text{Direct Elasticities :} \\ &\sigma_{ij}=(\alpha_{ij}+w_i w_j)/w_i w_j \text{ where } \sigma_{ij}=\sigma_{ji} && \sigma_{ii}=(\alpha_{ii}+w_i^2-w_i)/w_i^2\,; \\ &\eta_{ij}=\sigma_{ij}w_j && \eta_{ii}=\sigma_{ii}w_i \end{aligned} \tag{15}$$

Cross elasticities, price or substitution, provide the same type of information: a positive (negative) sign implies that inputs i and j are substitutive (complementary). Indeed, as shown in (15), cross substitution elasticities are normalized cross price elasticities, which are symmetrical. In this study, in order to homogeneously treat the relationships between the different inputs (variable or fixed), we refer to cross relationships with substitution elasticities (σ_{ij}). Additionally, we refer to direct price elasticity (η_{ii}) for the variable inputs.

Finally, the demand elasticity of a variable factor i with respect to output Y can be obtained from the following expression:

$$\mu_{iY}=\frac{\partial Q_i}{\partial Y}\frac{Y}{Q_i}=\frac{\alpha_{Yi}}{w_i}+\eta_Y \tag{16}$$

where η_Y represents the elasticity of the respective variable cost with respect to the output Y.

4. Econometric Estimation of Cost Functions

As a preliminary step, it is important to remember that any model must be specified taking into account the nature of the data. In this respect, unit root tests for panel data sets are carried out for the main variables included in our regressions. In all cases, we obtain evidence in favor of being I(0) with a time trend. Consequently, all estimated models will include a time trend variable, which can also be used as a proxy for technological change.

Furthermore, these are panel-type models. If i represents a cross-sectional unit (i = 1, 2, . . ., N) and t represents a time period (t = 1995, 1996,. . ., 2006), we can express cost functions (2)–(5) as follows:

$$y_t=\mu+x_t\beta+\varepsilon_t \tag{17}$$

where y_t is a (N × 1) vector; x_t is an (N × k) matrix of observations in period t, which also includes a time trend and a dummy variable called D2004, with a value of 1 for the year 2004 and 0 otherwise, to capture a turning point in the economic cycle; k is the number of parameters. The $\mu=[\mu_1, \mu_2, \ldots, \mu_N]'$ vector captures individual heterogeneity or, in other terms, it controls for the effects of omitted variables. It can be considered a fixed vector of parameters to be estimated or a random vector with a normal distribution, $\mu \sim N\left[0, \sigma_\mu^2 I_N\right]$. In the first case, we obtain the so-called fixed effects model while the second is the random effects model. Finally, ε_t is a (N × 1) vector of random terms.

Discussion about random or fixed effects models appears routinely in all panel estimations [*Hsiao*, 2003]. The key issue in this selection is whether or not the omitted variables (represented with μ) are correlated with the explanatory variables included in the model (x_t). As is well known, if this is the case, fixed effects models are consistent and efficient, as they provide a means for controlling for omitted variable bias, while random effect estimators are inconsistent. Because of this, in our case, we propose the Fixed Effect (FE) model as the most compelling specification, as we assume that the omitted variables in our model are probably correlated with the ones included.

We also pay attention to the fact that the water price variable included in equations (2) and (3) could be endogenous. If this is the case, the Two-Stage Least Square-Fixed Effect (2SLS-FE) estimation method should be used. The selection between FE and 2SLS-FE methods is carried out by testing the null hypothesis of

Table 4. Selection of Fixed or Quasi-Fixed Nature of Capital and Water Inputs for the Hotels and Restaurants Sector[a]

J Test	Extended Equation (1)	Extended Equations (2), (3), or (4)	Conclusion
	t-ratio	t-ratio	
Capital: quasi-fixed versus variable input	0.20 (0.85)	−0.18 (0.86)	Inconclusive
Water: quasi-fixed versus variable input	1.53 (0.13)	0.02 (0.98)	Inconclusive
Capital and water: quasi-fixed versus variable inputs	2.11 (0.04)	−0.89 (0.37)	Capital and water as quasi-fixed

[a]Figures in brackets are *p* values.

exogeneity through the *Hausman* [1978] test. The estimation by 2SLS-FE was carried out by instrumenting the water price with one period lag of the variable (and the other exogenous variables). Hausman tests result in 120.77 (p value = 0.000) and 48.60 (p value = 0.000), respectively, for equations (2) and (3). Hence, we obtain evidence in favor of the 2SLS-FE estimation in both cases.

Next, we concentrate on cost functions (2)–(5) themselves. As mentioned before, we assume that all production factors are variable in the long run; hence, cost function (2) is useful to model long-run behavior. However, for the short run, it is necessary to determine the variable or quasi-fixed nature of capital and/or water inputs, which is equivalent to a model selection exercise among cost functions (3)–(5). Following *Dupont and Renzetti* [2001], we use the *J* test. The discussion contemplates pairs of nonnested models. In our case, the selection between competing models is done through the t-ratio. Results appear in Table 4. In the case of capital factor, we have to choose between cost functions (2) and (3), using artificially extended equations. First, production function (2) is extended by the estimated value $\ln \hat{G}V$ as an additional "artificial" regressor; then, production function (3) is extended by the estimated value $\ln \hat{G}$. In this case, the test is inconclusive since the "artificial" regressors are not significant in any of the equations. An analogous result is obtained in the case of water factor. However, if we consider the two production factors together, the *J* test shows that both capital and water are quasi-fixed factors.

Table 5. Estimated Parameters for the Analysis of the Short-Run Behavior of the Hotels and Restaurants Sector[a]

	Cost Function (4): Quasi-Fixed Water and Capital	Labor Share Equation, According to (8)
Endogenous variable	$\ln GV''$	w_L
Explanatory variables		
α		−0.415 (0.000)
D_{HOTEL}	0.065 (0.01)	
$D_{RESTAURANT}$	0.069 (0.00)	
$D_{BARS\text{-}CAFES}$	0.091 (0.00)	
D2004	−0.045 (0.04)	0.004 (0.50)
Trend	−0.002 (0.49)	−0.001 (0.23)
$\ln Y$	−0.844 (0.00)	−0.005 (0.05)
$(\ln Y)^2$	0.157 (0.00)	
$\ln Q_K$	0.125 (0.16)	−0.000 (0.00)
$(\ln Q_K)^2$	0.012 (0.19)	
$\ln Q_W$	0.077 (0.04)	−0.000 (0.78)
$(\ln Q_W)^2$	−0.004 (0.41)	
$\ln p_L$	−0.415 (0.00)	0.085 (0.00)
$\ln p_L \ln p_L$	0.085 (0.00)	
$\ln Y \ln p_L$	−0.004 (0.05)	
$\ln Q_W \ln p_L$	−0.000 (0.78)	
$\ln Q_K \ln p_L$	−0.000 (0.00)	
$\ln Y \ln Q_W$	− 0.006 (0.01)	
$\ln Y \ln Q_K$	−0.020 (0.00)	
$\ln Q_W \ln Q_K$	0.003 (0.25)	

[a]D2004 is a dummy variable with a value of 1 if year = 2004 and 0 otherwise. D_{HOTEL} is a dummy variable with a value of 1 in the case of i = HOTEL; $D_{RESTAURANT}$ is a dummy variable with a value of 1 in the case of i = RESTAURANT; $D_{BARS\text{-}CAFES}$ is a dummy variable with a value of 1 in the case of i = BAR-CAFES. Figures in brackets are *p* values.

5. Results I: Shadow Prices and Short-Run Elasticities

According to previous results, we now analyze the short-run behavior of the three subsectors based on the joint estimation of expressions (5) and (9), using an FE panel model. Expression (5) includes three different scales in order to capture any differences in deviations from the individual mean (over time) in the three categories, HOTELS, RESTAURANTS, and CAFES. The main results are shown in Table 5. All the parameters have the expected sign. Furthermore, parameters are mostly statistically significant; one of the exceptions refers to the trend parameters, which means that, in the short run, the impact of technological change has not made any significant change in the allocation of factors.

Using the estimates corresponding to the short-run case, which appears in Table 5, we can calculate the shadow prices of the quasi-fixed factors, water

Table 6. Shadow Prices of Quasi-Fixed Factors Substitution and Demand Elasticities of the Variable Factors in the Short-Run (S/R)

	Aggregate	Hotels	Restaurants	Bars-Cafes
Shadow Prices of Quasi-Fixed Factors. Comparison With the Observed Prices				
Price of Water (€/m^3)				
Estimated shadow price (€/m^3)	4.42	1.23	3.69	6.77
Observed price (€/m^3)	1.03	1.18	1.12	0.91
H_0: Observed price = Estimated shadow price	−338.2 (0.00)	−4.01 (0.00)	−180 (0.00)	−380 (0.00)
Price of Capital (%)				
Estimated shadow price (%)	5.68	2.71	7.97	6.94
Observed price (%)	4.28	5.38	4.58	3.39
H_0: Observed price = Estimated shadow price	−16.95 (0.00)	3.05 (0.00)	−19.70 (0.00)	−22.61 (0.00)
Short-Run (S/R) Elasticities for the Variable Factors				
S/R substitution elasticity: labor and supplies (σ_{LS})	0.609 (0.00)	0.632 (0.00)	0.613 (0.00)	0.598 (0.00)
S/R labor demand elasticity (η_{LL})	−0.413 (0.00)	−0.401 (0.00)	−0.412 (0.00)	−0.415 (0.00)
S/R supply demand elasticity (η_{SS})	−0.196 (0.00)	−0.232 (0.00)	−0.201 (0.00)	−0.183 (0.00)

and capital, which will be compared with the observed prices. As regards the variable factors, labor and supplies, we will calculate the substitution elasticity between them as well as their direct short-run price elasticities. Table 6 shows the results for the aggregate data and for the three subsectors.

The results for the shadow price of water in the hotels and restaurants sector show that firms are willing to pay for an extra unit of the factor more than 4 times the price they in fact are paying (4.42 €/m^3 versus 1.03 €/m^3). This is in line with the results obtained in the literature about shadow prices of water in industry and/or services activities as a whole [*Wang and Lall*, 2002; *Kumar*, 2006; *He et al.*, 2007; *Liu et al.*, 2009; *Ku and Yoo*, 2012]. Table 6 shows strong heterogeneities among the three subsectors. BARS-CAFES has the highest difference between shadow price and real prices (6.77 €/m^3 versus 0.91 €/m^3), followed by RESTAURANTS (3.69 €/m^3 versus 1.12 €/m^3). By contrast, HOTELS are willing to pay a similar price as the one they are actually paying (1.23 €/m^3 versus 1.18 €/m^3).

These results are also in line with the results obtained in the literature about relevant differences between shadow prices in different activities. This heterogeneity can be attributed to different intensity in water use in each case: more intensity, as found in HOTELS, appears to imply a lower shadow price. In all cases, differences between observed and shadow prices are significant at the 5% level.

Similarly, the shadow prices of capital are significantly higher than observed in the cases of RESTAURANTS and BARS-CAFES, but significantly lower in the case of HOTELS. These results are related to the different levels of invested capital in each of the three subsectors.

Short-run elasticities show significant substitutability between labor and supplies in the three subsectors. Demand for those variable factors is normal and inelastic in the short run, although labor's response to changes in prices is greater than that of supplies.

6. Results II: Long-Run Elasticities

From previous results and for the case of the water factor (shadow prices higher than the observed ones), it is deduced that firms in our sample have no incentive to reduce water consumption in response to an increase in water price in the long run, especially in the cases of RESTAURANTS and BARS-CAFES. In order to check whether firm behavior is consistent with theoretical expectations, we proceed to analyze long-run behavior.

Long-run behavior is derived from the joint estimation of expressions (2) and (6), using a 2SLS-FE specification. The main results are shown in Table 7. Once again, the parameters have the expected sign and are mostly statistically significant. Note that the coefficient for the trend variable in the water share equation is, now, significant and negative. This means that technological change significantly reduces the use of the water factor in this sector in the considered period.

The estimates of the long-run model enable us to calculate the long-run demand elasticities of factors, the cross elasticities between the factors and the elasticities of factors with respect to the level of output. The results are shown in Table 8.

Table 7. Estimated Parameters for the Analysis of the Long-Run Behavior of the Hotels and Restaurants Sector[a]

	Cost Function (1): All Variable Inputs	Capital Share Equation, According to (5)	Labor Share Equation, According to (5)	Water Share Equation, According to (5)
Endogenous variable	ln G	w_K	w_L	w_W
Explanatory Variables				
α		0.1385 (0.00)	−0.4362 (0.00)	0.0376 (0.00)
D_{HOTEL}	0.0089 (0.706)			
$D_{RESTAURANT}$	0.0218 (0.133)			
$D_{BARS\text{-}CAFES}$	0.071 (0.000)			
D2004	−0.025 (0.25)	−0.0001 (0.96)	−0.002 (0.808)	0.002 (0.01)
Trend	0.0055 (0.09)	−0.0001 (0.78)	0.0015 (0.17)	−0.0003 (0.00)
ln Y	−1.0686 (0.00)	−0.003 (0.01)	0.0087 (0.00)	−0.0013 (0.00)
$(\ln Y)^2$	0.1338 (0.00)			
ln p_K	0.1385 (0.00)	0.0094 (0.00)	−0.0030 (0.01)	0.0001 (0.23)
ln p_L	−0.4362 (0.00)	−0.0029 (0.007)	0.0654 (0.00)	−0.0013 (0.00)
ln p_W	0.0378 (0.00)	0.0001 (0.23)	−0.0013 (0.03)	0.0038 (0.00)
ln p_K ln p_K	0.0094 (0.00)			
ln p_K ln p_L	−0.0029 (0.007)			
ln p_K ln p_W	0.0001 (0.23)			
ln p_L ln p_L	0.0654 (0.00)			
ln p_L ln p_W	−0.0013 (0.03)			
ln p_W ln p_W	0.0038 (0.00)			
ln Y ln p_K	−0.0035 (0.00)			
ln Y ln p_L	0.0088 (0.00)			
ln Y ln p_W	−0.0013 (0.00)			

[a]D2004 is a dummy variable with a value of 1 if year = 2004 and 0 otherwise. D_{HOTEL} is a dummy variable with a value of 1 in the case of i = HOTEL; $D_{RESTAURANT}$ is a dummy variable with a value of 1 in the case of i = RESTAURANT; $D_{BARS\text{-}CAFES}$ is a dummy variable with a value of 1 in the case of i = BAR-CAFES. Figures in brackets are *p* values.

Water demand elasticity for the aggregate equals 0.082, which is positive but not significant. In other words, in general, the response of water consumption to a change in its own price is null. This general conclusion is mainly due to results for water elasticities in the cases of RESTAURANTS (0.324) and BARS-CAFES (0.091), both nonsignificant. However, the result for HOTELS is very different as, in this case, water demand is normal, inelastic (−0.375) and significant. All these results confirm our expectations and we can conclude that only HOTELS, where the shadow price of water was very close to the observed price, have certain incentives to reduce their water consumption. The obtained values are in the lower part of the range of elasticities obtained by studies in industrial and/or services sectors that provide results detailed by branches of activity (see Table 1), and studies that only provide aggregate results, both high [*Grebenstein and Field*, 1979; *Schneider and Whitlatch*, 1991; *Dupont and Renzetti*, 2001; *Féres and Reynaud*, 2005; *Linz and Tsegai*, 2009] and low elasticities [*De Rooy*, 1974; *Stone and Whittington*, 1984; *Dupont and Renzetti*, 1998; *Arbués et al.*, 2010; *Féres et al.*, 2012].

Table 8. Demand Elasticities, Substitution Elasticities and Factor Demand Elasticities With Respect to the Level of Output in the Long-Run (L/R)

	Aggregate	Hotels	Restaurants	Bars-Cafes
Long-Run Demand Elasticities				
L/R water demand elasticity (η_{WW})	0.082 (0.55)	−0.375 (0.00)	0.324 (0.06)	0.091 (0.514)
L/R capital demand elasticity (η_{KK})	−0.639 (0.00)	−0.785 (0.00)	−0.581 (0.00)	−0.595 (0.00)
L/R labor demand elasticity (η_{LL})	−0.477 (0.00)	−0.466 (0.00)	−0.474 (0.00)	−0.482 (0.00)
L/R supplies demand elasticity (η_{SS})	−0.239 (0.00)	−0.292 (0.00)	−0.240 (0.00)	−0.224 (0.00)
Long-Run Substitution Elasticities				
L/R substitution elasticity between water and capital (σ_{WK})	2.511 (0.04)	1.399 (0.00)	3.200 (0.08)	2.74 (0.06)
L/R substitution elasticity between water and labor (σ_{WL})	−0.169 (0.75)	0.386 (0.17)	−0.395 (0.54)	−0.234 (0.68)
L/R substitution elasticity between water and supplies (σ_{WS})	−0.15 (0.65)	0.266 (0.21)	−0.42 (0.39)	−0.13 (0.69)
L/R substitution elasticity between capital and labor (σ_{KL})	0.668 (0.00)	0.860 (0.00)	0.616 (0.00)	0.603 (0.00)
L/R substitution elasticity between capital and supplies (σ_{KS})	0.643 (0.00)	0.817 (0.00)	0.573 (0.00)	0.602 (0.00)
L/R substitution elasticity between labor and supplies (σ_{LS})	0.703 (0.00)	0.698 (0.00)	0.709 (0.00)	0.697 (0.00)
Long-Run Factor Elasticities With Respect to the Output Level				
L/R elasticity of water with respect to the output level (μ_{WY})	0.398 (0.00)	0.645 (0.00)	0.341 (0.00)	0.316 (0.00)
L/R elasticity of capital with respect to the output level (μ_{KY})	0.650 (0.00)	0.804 (0.00)	0.655 (0.00)	0.553 (0.00)
L/R elasticity of labor with respect to the output level (μ_{LY})	0.803 (0.00)	0.887 (0.00)	0.831 (0.00)	0.726 (0.00)
L/R elasticity of supplies with respect to the output level (μ_{SY})	0.770 (0.00)	0.855 (0.00)	0.798 (0.00)	0.691 (0.00)

Regarding the other factors, the results show that all of them present a normal and inelastic demand in the three subsectors. Capital is the factor that responds the most to changes in its own price (in the aggregate, its elasticity is −0.639), followed by labor (−0.477) and supplies (−0.239). Capital elasticity for HOTELS is as expected, as the shadow price was lower than the observed one. However, capital elasticities for RESTAURANTS and BARS-CAFES (where the shadow price was higher than the observed one) are not as expected. These unexpected results can be explained by the characteristics of these subsectors in terms of volatility in returns together with the reduced professional level of many managers.

The substitution elasticities show that, in the case of HOTELS, all production factors are substitutive in the long run (although the relationship of water to labor and supplies is not significant). For RESTAURANTS and BARS-CAFES, the relationship among factors, when significant, always shows substitutability relationships. In all cases, the highest substitutability levels are found between water and capital (2.511, for the aggregate).

The substitutability between water and capital is in line with the results obtained by studies in industrial and/or services sectors [*Dupont and Renzetti*, 2001; *Renzetti and Dupont*, 2003; *Dachraoui and Harchaoui*, 2004; *Féres and Reynaud*, 2005; *Kumar*, 2006; *Linz and Tsegai*, 2009] and confirm the results of studies that directly measure the impact of replacement of water-consuming equipment in the hotels and restaurants sector [*Meade and González-Morel*, 1999; *Environmental Agency*, 2004; *Hamele and Eckardt*, 2006; *Barberán et al*., 2013].

The relationship between water and labor, in the case of HOTELS, is also in line with the results obtained by previous studies [*Grebenstein and Field*, 1979; *Babin et al*., 1982; *Dupont and Renzetti*, 2001; *Renzetti and Dupont*, 2003; *Dachraoui and Harchaoui*, 2004; *Féres and Reynaud*, 2005; *Guerrero*, 2005; *Linz and Tsegai*, 2009]. With regards to the relationship between water and supplies, the results obtained in other studies are controversial; some of them find that energy is a substitute of water [*Dupont and Renzetti*, 2001; *Féres and Reynaud*, 2005], although others find that they are complementary [*Renzetti and Dupont*, 2003; *Linz and Tsegai*, 2009; *Feres et al*, 2012]. Something similar occurs with supplies, where some studies find that it is a complementary to water [*Dupont and Renzetti*, 2001; *Kumar*, 2006; *Féres and Reynaud*, 2005] and others find it substitutive [*Renzetti and Dupont*, 2003; *Guerrero*, 2005].

Finally, Table 8 shows the factor demand elasticities with respect to the level of output in the long run. As can be seen, output growth in hotels and restaurants sector is expected to increase the demand for all factors. More precisely, and for the aggregate, an increase of 1% in the output level results in the following increases in the use of production factors: 0.803% for labor, 0.77% for supplies, 0.65% for capital, and 0.398% for water. As regards subsectors, HOTELS show the highest responses while BARS-CAFES the lowest. These results indicate that there are economies of scale in the hotels and restaurants sector; they are in line with those obtained for studies that estimate the output elasticity of water intake [*De Rooy*, 1974; *Williams and Suh*, 1986; *Renzetti*, 1988; *Dupont and Renzetti*, 1998, 2001; *Wang and Lall*, 2002; *Reynaud*, 2003; *Dachraoui and Harchaoui*, 2004; *Ku and Yoo*, 2012].

7. Final Considerations

The analysis of how to treat the water factor in the short-run cost function of the hotels and restaurants sector shows that there is evidence for modeling capital and water as quasi-fixed factors. These findings are consistent with our intuition that water consumption is largely out of control in the short run. This enabled us to establish two scenarios, one short run and one long run, and to obtain information about the characteristics of the sector's water demand that is very useful for water price policy makers, as initially intended.

The values obtained for the shadow price of water in the short run show that the marginal product in hotel and restaurants firms is higher than the average paid price. However, substantial differences were found in the shadow prices of HOTELS, RESTAURANTS, and BARS-CAFES, so that only the last two subsectors could assume substantial increases in current water prices without compromising their economic viability. Policy makers thus have some limitations for applying price policies.

In the long run, water demand is normal and inelastic in the case of HOTELS (−0.375), but not for RESTAURANTS and BARS-CAFES. These results are consistent with the relationship obtained between shadow and observed prices; moreover, the results show that policy makers can use price policy as a demand management tool, encouraging preservation of resources, only in the case of HOTELS. For this subsector only, a price increase would invert the trend found in our study of increasing use of water in the sector, favoring sustainability; furthermore, as the elasticity value is less than one, the resource's conservation would not be incompatible with the increase in operating income in order to fully recover the cost of providing the municipal water supply. Resource conservation in RESTAURANTS and BARS-CAFES will depend largely on the regulation of technical characteristics and the promotion of innovation in appliances and fixtures that use water such as taps, toilets, and dishwashers; moreover, in some cases, it may also depend on the potential advantages of making water saving a marketing tool in the context of increasing citizens' awareness of environmental issues.

The long run substitution elasticities obtained enable us to characterize capital as a water substitutive factor. This implies that an increase in the prices of capital contributes to an increase in water consumption in the hotel and restaurants sector. This relationship should not be ignored by policy makers, as they affect water demand. Furthermore, the values obtained for the elasticity of water with respect to the output (0.398, for the aggregate and 0.654 for HOTELS) indicate that the demand for water increases less than output, but proportionality is not irrelevant, so it should also be considered by policy makers.

We believe that this study makes a significant contribution to knowledge of water demand in the hotels and restaurants sector. The results show the possibility of greater intervention by policy makers aimed at the sector's sustainable development, water conservation, and the financial sufficiency of the urban water supply service.

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