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An investigation of productivity, profitability, and regulation in the Chilean water industry using stochastic frontier analysis

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ABSTRACT

The firms' performance assessment for regulation requires estimating profit change and its drivers. This study estimates and decomposes profit changes into components such as output and input price changes, output growth, and markups. Using the stochastic frontier analysis, we compute the drivers of productivity change, such as technical change, returns to scale, and efficiency change. We apply the profit decomposition to several full private water companies (FPWCs), concessionary water companies (CWCs), and a public water company (PWC) in Chile over two years. Results showed that profit and total factor productivity levels increased over time at 1.967% and 1.062% per annum, respectively. Technical change, gains in efficiency, and a reduction in input prices were the main drivers contributing to positive profit growth. We also found that the PWC was more productive and profitable than private companies, with FPWCs outperforming CWCs. The results of our study can aid policymakers in understanding how resources are used, why some companies in the water industry perform better than others, and how these changes impact productivity over time.

1. Introduction

One of the main arguments for privatizing the water and sanitation industry is that private water companies could efficiently manage the large amount of capital expenditure needed to modernize and sustain the aging infrastructure [1]. The firms have the opportunity to borrow freely from the capital markets in order to finance their activities without having to comply with the borrowing constraints faced in the public sector. Moreover, the privatized water utilities have the incentive to improve efficiency by reducing their costs, improve quality of service, and thus, provide water and sewerage services to the consumers at an affordable price. This is the case in the Chilean water industry which was privatised during the years 1998–2004 forming two types of companies namely full private water companies (FPWCs) and concessionary water companies (CWCs) [2]. Moreover, 3.3% of urban customers receive water and sewerage services from a public water company (PWC) [3,4]. As in other countries, the Chilean national economic regulator, Superintendencia de ServiciosSanitarios (SISS), was set up to regulate water companies' performance and protect customers from monopoly power. The main duty of the regulator is to set water tariffs that guarantee the financial sustainability of the companies and stimulate efficiency which should be passed to customers in terms of lower tariffs [5]. In order to achieve this, the efficiency of the water companies is evaluated by comparing the observed costs of a firm with that of a hypothetical efficient water company, i.e., a "model company", which is designed in a way it is a technically and economically efficient provider [6].

From a policy perspective, there is always a need for a better understanding of how well resources are used and what the sources of productivity and profitability changes are [7,8]. There have been several attempts in the literature to analyze the relationship between profit and productivity change. For example, Miller and Rao [9] decomposed profit change into three sources:price effect, productivity effect, and activity effect. Waters and Tretheway [10] measured profit, productivity and price change in railway industry, whereas Grifell-Tatje and Lovell [11] developed an analytical framework in which profit change over time was first decomposed into price and quantity effects. The quantity effect was further decomposed into productivity and activity effects, which were further broken up to include the impact of efficiency change, technical change and scale effect. De Witte and Saal [12] followed Grifell-Tatje& Lovell's [11] approach to decompose profit change in the Dutch water sector. Subsequently, Salerian [13], Fox et al. [14], Lawrence et al. [15] presented a model that analyzed the contributions of productivity change, price change, and growth in firm size to profitability change. The above studies estimated productivity change mainly using non-parametric methods such as index numbers and linear programming (Data Envelopment Analysis (DEA))

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techniques [16,17]. Non-parametric approaches were also used in Saal and Parker [18], Maziotis et al. [19,20] and Molinos-Senante et al. [21] to compare profit, price and productivity changes in the English and Welsh water sector. Nevertheless, Kumbhakar and Lien [22], Sipilainen et al. [23], Alem [24] and Molinos-Senante and Maziotis [25] are other studies that analyzed the sources of profitability and productivity change in the agriculture and water sector by using index numbers and parametric techniques (econometric) such as stochastic frontier analysis (SFA) techniques.

Focusing on the Chilean water and sewerage industry, there were several studies that estimated the efficiency and productivity of the water companies by using both non-parametric [5,26,27] and parametric techniques [2,6,28]. Because previous studies used divergent methods, their conclusions are divergent. One the one hand, studies by Molinos-Senante and Garrido [5] and Molinos-Senante et al. [2] found that FPWCs performed better than CWCs. The opposite was found by Sala-Garrido et al. [27] and Molinos-Senante and Maziotis [28]. In spite the relevant contribution to the literature of the previous studies, all of them measured productivity performance of Chilean water companies. To the best of our knowledge, there are not any studies in the Chilean water industry to assess the financial performance of the private and public companies using parametric techniques. This information is very relevant to support, the from an analytic perspective, the regulation of the water companies.

Against this background, the primary objective of this paper is to analyze the financial and productivity performance of several private and public water utilities in Chile over the period 2010–18. In order to do this, we applied, for the first time, the methodology developed by Kumbhakar and Lien [22] and Sipilainen et al. [23] which allowed us to analyze the relationship between profit and productivity using parametric techniques. We measured performance in terms of profit and decompose its change into output growth, output price and input price changes, technical change (TC), returns to scale (RTS), efficiency change and markups. We also related profitability with total factor productivity (TFP) growth which is widely used in the literature.

From a policy perspective, the methodology and conclusions of our study can be of great interest to water regulators for several reasons. First, in countries or regions where price cap schemes are employed in conjunction with a system of yardstick competitions, information about the profit change of water companies would be very useful in assisting water tariff reviews. Second, the decomposition of profit change into several drivers can provide more knowledge and better understanding of why some water companies are better than others and may be useful in setting targets as well as helping those that are underperformers.

2. Methodology

According to the literature [29,30], TFP is defined as the ratio of output, Y, to input, X in case of a single output and input case. TFP change is then measured as the difference between the rate of change in output and input, $\dot{Y} - \dot{X}$, where a dot above the variable denotes its rate of change. The measurement of TFP change can be extended in a multi-output and multi-input framework by taking aggregate measures of outputs and inputs and their rates of change. Based on the approach developed by Kumbhakar and Lien [22]and Sipilainen et al. [23], TFP change can be decomposed as follows:

$$T\dot{F}P = \dot{Y} - \dot{X} \equiv \sum_m R_m \dot{y_m} - S_j \dot{x_j} = TC + EC + \left(1 - RTS^{-1}\right) \dot{y_C} + \left(\dot{y_P} - \dot{y_C}\right) \equiv TC + EC + Scale + Markup \tag{1}$$

where $R_m = p_m y_m / R$, $R = \sum_m P_m y_m$ in which R denotes the total revenue and R_m presents the observed (actual) revenue share of output y_m; p presents the vector of output prices $\left(p = p_1 \dots, p_m\right)$; y is the set of outputs; and S_j is the observed (actual) expenditure share of input X_j $\left(S_j = w_j x_j / C\right)$; C denotes the total cost $\left(C = \sum_j w_j x_j\right)$; w is the set of input prices $\left(w = w_1, \dots, w_j\right)$ [24] and RTS is the returns to scale of the firm. The components of the TFP are calculated as follows:

$$TC = -\frac{\vartheta lnC}{\vartheta t} \tag{2}$$

$$EC = \frac{\vartheta CE}{\vartheta t} \tag{3}$$

where CE is the cost efficiency of the firm.

$$RTS^{-1} = \sum_m \frac{\vartheta lnC}{\vartheta ln y_m} \tag{4}$$

$$y_C = RTS \left[\sum\nolimits_m \frac{\vartheta lnC}{\vartheta ln y_m} \dot{y}_m\right] \tag{5}$$

$$y_P = \sum\nolimits_m R_m \dot{y}_m \tag{6}$$

where $\dot{y}_m$ is the rate of change in output y_m.

Following Kumbhakar and Lien [22] and Sipilainen et al. [23], we used the relationship in Eq. (1) to define profitability change. This was done by defining the profit of a firm as the difference between revenue and costs:

$$Profit\,(\pi) = Revenue\,(R) - cost(C) \tag{7}$$

Profit change can be expressed as:

$$\begin{aligned} \frac{d\pi}{dt} &= \left(\sum_m p_m \frac{\vartheta y_m}{\vartheta t} + \sum_m y_m \frac{\vartheta p_m}{\vartheta t}\right) - \left(\sum_j w_j \frac{\vartheta x_j}{\vartheta t} + \sum_j x_j \frac{\vartheta w_j}{\vartheta t}\right) \\ &= \left(\sum_m p_m y_m \frac{\vartheta ln y_m}{\vartheta t} + \sum_m y_m p_m \frac{\vartheta ln P_m}{\vartheta t}\right) \\ &\quad - \left(\sum_j w_j x_j \frac{\vartheta ln x_j}{\vartheta t} + \sum_j x_j w_j \frac{\vartheta ln w_j}{\vartheta t}\right) \\ &= R\left(\sum_m R_m \dot{y}_m + \sum_m R_m \dot{p}_m\right) - C\left(\sum_j S_j \dot{x_j} + S_j \dot{w_j}\right) \end{aligned} \tag{8}$$

Dividing Eq. (8) by total cost, we get:

$$\frac{1}{C}\frac{d\pi}{dt} = \frac{R}{C}\left(\sum_m R_m \dot{y_m} + \sum_m R_m \dot{p_m}\right) - \left(\sum_j S_j \dot{x_j} + S_j \dot{w_j}\right) \tag{9}$$

Eq. (1) can be rewritten as:

$$-\sum_j S_j \dot{x_j} = TC + EC + \left(1 - RTS^{-1}\right) \dot{y_C} + \left(\dot{y}_p - \dot{y_C}\right) - \sum_m R_m \dot{y}_m \tag{10}$$

Substituting (10) into (9) we get the following decomposition:

$$\begin{aligned} \frac{1}{C}\frac{d\pi}{dt} &= \frac{R}{C}\left[\sum_m R_m \dot{y}_m + \sum_m R_m \dot{p}_m\right] - \sum_j S_j \dot{w}_j + TC \\ &\quad + EC + \left(1 - \sum_m \frac{\vartheta lnC}{\vartheta ln y_m}\right) \dot{y}_c + \left(\dot{y_p} - \dot{y}_c\right) - \sum_m R_m \dot{y}_m \end{aligned} \tag{11}$$

$$\begin{aligned} \frac{1}{C}\frac{d\pi}{dt} &= \left(\frac{R}{C} - 1\right) \dot{y_P} + \left(\frac{R}{C}\right) \dot{p} - \dot{w} + TC + EC \\ &\quad + \left(1 - RTS^{-1}\right) \dot{y_C} + \left(\dot{y_p} - \dot{y_C}\right) \end{aligned} \tag{12}$$

$$\frac{1}{C}\frac{d\pi}{dt} = \left(\frac{R}{C} - 1\right) \dot{y_P} + \left(\frac{R}{C}\right) \dot{p} - \dot{w} + TFP \tag{13}$$

where $\dot{p} = \sum_m R_m \dot{p_m} and \dot{w} = \sum_j S_j \dot{w}_j$.

Eq. (12) shows the decomposition of profit change into several components. The interpretation of these components was done based on Kumbhakar and Lien [22]:

- TC denotes technical change . Technical progress (positive technical change) increases profitability;
- $\left(1 - RTS^{-1}\right) \dot{y_C}$ captures the scale part. Profitability will go up if RTS>1 and the aggregate output cost $\left(\dot{y_C}\right)$ is small;
- $\left(\dot{y_P} - \dot{y_C}\right)$ denotes the markup component. A positive markup component implies increases in profitability [25];
- EC presents efficiency change. Efficiency gains over time will increase profitability;

– $\left(\frac{R}{C}-1\right)\dot{y}_p$ is the output growth part. Increases in output growth will drive profitability up;
– $\left(\frac{R}{C}\right)\dot{p}$ is the output price change part. Profitability will increase if output prices rise over time;
– $\dot{w}$ is the input price effect. A negative price change means increases in profitability [23].

TFP and its components were derived using econometric techniques. In particular, we estimated a translog cost function because it is continuous and non-negative, positively linearly homogeneous, non-decreasing, and concave on price; non-decreasing, and quasi-convex on output [24,31]. Assuming $j = 1, 2, \ldots, J$ inputs and $m = 1, 2, \ldots, M$ outputs, the translog cost function is as follows:

$$lnC = a_i + \sum_{j=1}^{J}\beta_j ln\hat{w}_j + \sum_{m=1}^{M} a_m lny_m + \sum_{m=1}^{M} a_{mt} lny_m t + \sum_{j=1}^{J}\beta_{jt} ln\hat{w}_j t + \frac{1}{2}\left[\sum_{m=1}^{M}\sum_{m=1}^{M}\gamma_{mm} lny_m lny_m\right] + \frac{1}{2}\left[\sum_{j=1}^{J}\sum_{j=1}^{J}\delta_{jj} ln\hat{w}_j ln\hat{w}_j\right] + \theta t + \frac{1}{2}\theta_t t^2 + \sum_{m=1}^{M}\sum_{j=1}^{J}\mu_{mj} lny_m ln\hat{w}_j + \sum_{z=1}^{Z}\xi_z Z_z + u_i + v_i \tag{14}$$

where lnC represents log form of total cost, w_j represents the price of inputs j, and y_m is the set of outputs m, whereas $ln\hat{w}_j = lnw_j - lnw_1\ (\forall j)$ implies linear homogeneity in inputs prices [23]. The term $\sum_{z=1}^{Z}\xi_z Z_z$ represents the impact of Z environmental variables on costs. The time trend captures how total costs change over time, and thus captures the impact of technical change. Moreover, the last two terms in Eq. (14) denote the inefficiency and noise, respectively. In particular, u_i is the inefficiency term and is assumed to follow the half normal distribution and v_i is the noise term which is assumed to follow the normal distribution. Greek symbols are the unknown parameters assumed to be equal for all water companies across years. It should be noted that a_i is the intercept parameter which accounts for heterogeneity of the evaluated water companies and assumed to be fixed [2]. Thus, Eq. (14) refers to the true fixed effect model proposed by Greene [32]. Thus, the maximum likelihood techniques were used to allow for water companies specific fixed effects and time-varying inefficiency specification. To estimate the translog cost frontier for the Chilean water industry, all variables were normalized before taking the logarithms by dividing each variable by its mean value so that the first order parameters can be interpreted as elasticities at the sample mean [33]. SFA is a parametric approach that takes into consideration both statistical noise and inefficiency. Thus, any deviation from the efficient frontier is attributed to both these factors. SFA assumes a functional form a priori for the underlying production technology. The inefficiency term could different assumptions for its distribution such as exponential and half-normal. Finally, SFA econometric models take into account operating characteristics in modeling approach. The estimation of production technologies using SFA techniques could allow studying technological characteristics of the sector such as economies of scale.

Cost efficiency of a firm at any time can be calculated from the inefficiency term of Eq. (14) as $CE = \exp(u_i)$, which is then used to calculate efficiency change in Eq. (12). Moreover, we imposed symmetry restrictions on the second-order parameters and linear homogeneity in input prices prior to the estimation of Eq. (14) [24]. Using Eq. (14) we computed the terms of profitability change as defined in Eq. (12).

3. Data and sample selection

Our empirical study focused on the assessment of profitability change during the period 2010–2018 for 21 Chilean water companies with different ownership: FPWCs (n = 12), CWCs (n = 10) and PWC (n = 1). More details about the privatization of the Chilean water industry and the current regulatory framework are described in Donoso [34].

The selection of inputs, outputs and environmental variables to estimate profitability change and its drivers was based on previous studies from the Chilean water industry and elsewhere (see the revisions by [35–37]). The annual number of water and sewerage customers was selected as output. The output price was defined as the ratio of the water and sewerage turnover in nominal terms and the selected output. Economic profits were defined as the difference between turnover (revenue) and total costs. Total costs were defined as the sum of operating expenditure (OPEX) and capital expenditure (CAPEX) andcompanies' investments to maintain and improve the water and sewerage network. They were expressed in Chilean pesos per year. Both OPEX and CAPEX were deflated by the consumer price index taken from national statistics[1] The price of capital was defined as the ratio of capital expenditure and the financial value of physical assets [38,39]. The price of OPEX was approximated by the Chilean producer price index taken from national statistics [40–42]. It was used to normalize costs and input prices.

Based on Carvalho and Marques [43]; Berg and Marques [44]; Marques et al. [45,46]; Molinos-Senante et al. [2,26], the potential environmental variables influencing water companies' costs and inefficiency are as follows: (i) customer density computed as the ratio of the number of customers and the network length; (ii) non-revenue water defined as the percentage of water that is produced but is charged; (iii) drinking water quality which is an index provided by the Superintendencia de ServiciosSanitarios (SISS) that takes value between zero and one with one meaning that the company fulfilled all the quality standards and; (iv) wastewater treatment quality which is an index also reported by SISS with values ranging between zero and one. A value of 1 means that the water company passed all treatment standards.

Table 1 depicts the descriptive statistics for the variables used in our study. The source of data comes from the website of the national economic regulator (SISS).

4. Results and discussion

4.1. Translog cost function estimation

As it was described in the methodology section, the first stage in our analysis was computing the translog cost function whose parameters are shown in Table 2. Convergence issues related to the SFA shape parameter were not observed [31,47]. The estimated coefficient of the output is positive and statistically significant. It means that on average one percent increase in the number of customers will increase water companies' costs by 0.891%, respectively. This implies the existence of small economies of scale in the Chilean water industry. According to this value, on average, a one percentage increase in the number of customers could lead to 0.891 percentage increase in total costs.

The squared term of customers is negative and statistically significant which means that as the cost elasticity of providing water and sewerage services to final users is decreasing at this output. The cost function is non-decreasing in input prices since the capital price coefficient is highly significant and positive for all observations in the sample. The price for OPEX was derived as $1 - 0.441 = 0.559$. The large coefficients for CAPEX and OPEX suggest that the water industry is both capital and OPEX intensive. Capital price is increasing over time as indicated by its interaction term with time which is statistically significant. This implies that on average companies might have required more capital than OPEX to maintain and improve the network over time. The estimated average cost efficiency was found to be 0.731, which indicates that on average need to reduce their costs by 27% to maintain the same level of output. Cost efficiency scores for each water company are shown as supplemental material.

Looking at the environmental variables, it can be concluded that customer density has a negative and statistically significant coefficient. This implies that increased customer density reduces the overall costs

[1] The exchange rate on July, 5th 2022 was USD 1≈ CLP 927 and EUR 1≈967 CLP.

Table 1
Descriptive statistics for Chilean water companies evaluated.

Variables	Units	Mean	Std.Dev.	Minimum	Maximum
Number of customers	nr	213984	379308	3304	1950626
Capital expenditure	CLP/year	17553951	27352348	24274	106445668
Operating expenditure	CLP/year	31478579	43172556	823816	210144159
Total turnover	CLP/year	54792713	82426693	863446	396196019
Price for capital expenditure	CLP/year	0.077	0.077	0.009	0.406
Price for operating expenditure	Index	0.882	0.076	0.771	1.000
Price for customers	CLP/nr	337.533	214.889	133.317	1408.683
Density	nr/km	57.304	15.943	19.407	104.694
% non revenue water	%	29.6	11.9	3.5	64.8
Drinking water quality	Index	0.974	0.052	0.700	1.000
Wastewater treatment quality	Index	0.967	0.052	0.667	1.000

Observations: 207
Note: Costs, turnover and prices are in 2018 prices.

Table 2
Estimates of true fixed effects cost model.

Variables	Coeff.	S.Err.	T-stat	p-value
Customers	0.891	0.073	**12.278**	0.000
Capital price	0.441	0.044	**10.128**	0.000
Time	−0.016	0.008	**−2.099**	0.036
Capital price^2	0.469	0.066	**7.099**	0.000
Customers*capital price	0.029	0.021	1.357	0.175
Customers^2	−0.076	0.017	**−4.576**	0.000
Capital price*time	0.023	0.008	**2.979**	0.003
Customers*time	−0.019	0.004	**−5.346**	0.000
Time^2	−0.013	0.005	**−2.424**	0.015
Density	−0.244	0.025	**−9.718**	0.000
Density^2	0.302	0.037	**8.130**	0.000
% non revenue water	−0.413	0.251	***−1.645***	0.100
Drinking water quality	0.766	0.364	**2.106**	0.035
Wastewater treatment quality	0.622	0.306	**2.033**	0.042
Sigma	0.553	0.037	**14.959**	0.000
Lamdba	2.307	0.300	**7.693**	0.000
Cost efficiency	0.731			
Log-likelihood	−9.497			

Observations: 207
Total cost is the dependent variable.
Bold coefficients are statistically significant from zero at 5% level.
Bold italic coefficients are statistically significant from zero at 10% level.

of servicing water customers and therefore, leads to higher levels of efficiency. This result is consistent with past research for the Chilean water industry [2]. However, the economies of customer density are exhausted for large numbers of customers and thus, companies' costs eventually increase as indicated by the positive and statistically significant squared term of density. The negative sign of non-revenue water indicated that investments to predict non-revenue water eventually decrease companies' costs. Thus, companies can provide good quality of service at a low cost. The positive and statistically significant coefficient of the quality indicators indicate there is a positive correlation between quality improvements and total costs.

4.2. Profitability and total factor productivity change

According to results shown in Fig. 1 and Table 3, on average, the rate of TFP and profitability change in the Chilean water industry was 1.062% and 1.967% per year, respectively. The trend in profitability change and its drivers reveal several interesting conclusions. During the years 2010–13, profitability experienced negative rates of change, 1.622% per year which was mainly attributed to a deterioration in productivity. This is results is consistent with previous studies by Molinos-Senante et al. [2]and Sala-Garrido et al. [27] who also found a deterioration in the productivity during the years 2010–12. Productivity declined due to technical regress and negative scale effect. This implies that the industry did not manage to adopt new technologies to reduce costs. Moreover, serving more customers might have led to higher costs suggesting that the industry might be operating under diseconomies of scale. Therefore, any increases in the prices charged to customers and considerable gains in efficiency were offset due to technical regress and diseconomies of scale leading therefore to losses in profitability. However, this situation changed the following years. During the years 2014–16, profitability increased by approximately 2.98% every year which was attributed to improvements in technology and the reduction in input costs.

We also note that less efficient water companies continued to improve their daily operations as shown by the positive rates of efficiency change. During that period small gains in scale were also found, a rate of 0.048% per year suggesting that the existence of small economies of scale. The last sub-period of our sample, 2017–18, is characterized by high rates of profitability, 5.821% per year. It appears that on average companies became more productive and profitable by adopting best industries' practices and by a reduction in the price of capital and operating costs. Furthermore, adjustments in the scale of operations by serving more customers might have led to lower costs and thus higher profits as shown by the positive rates of scale effect.

As far as the sources of TFP growth are concerned, TC and EC were the major determinants of productivity change, whereas markup and scale effects had an immaterial impact on productivity change. It is shown that during the period of study, on average TC increased at an annual rate of 0.666% and EC improved at a rate of 0.391% per year. This finding implies that less efficient water companies improved their managerial practices and adopted best industry's practices. Scale effect contributed marginally to TFP growth as it increased by 0.005% per year. This finding implies that adjustments in the scale of operations slightly reduced costs. Therefore, scale, TC and EC contributed positively to TFP and profitability growth. Another component that contributed positively to profitability change was the output price effect. This means that the prices charged to customers by the water companies led to a small increase in profitability by 0.194% per year. The input price effect was found to be negative at 0.682% per year, which suggests that reductions in capital and operating costs might have led to reductions in their input prices contributed positively to profitability growth. Finally, the output growth, the increase in the number of customers, marginally contributed to profitability growth by 0.028% per year.

Fig. 2 gathers TFP and profit changes over the period 2010–18 by water company ownership type. The results indicated that, on average, the public water company showed higher rates of profitability and productivity than private companies, whereas FPWCs performed better than CWCs. In particular, it is shown that on average the public water company increased their profitability and productivity by 2.493% and 2.178% per year. Full private's TFP and profitability improved by 1.294% and 2.075%, respectively whereas CWCs reported a lower change in TFP and profit, by 0.671% and 1.784%, respectively. Our finding is consistent with past studies by Molinos-Senante and Garrido (2015) and Molinos-Senante et al. (2018a) where the authors found that FPWCs were more productive than CWCs.

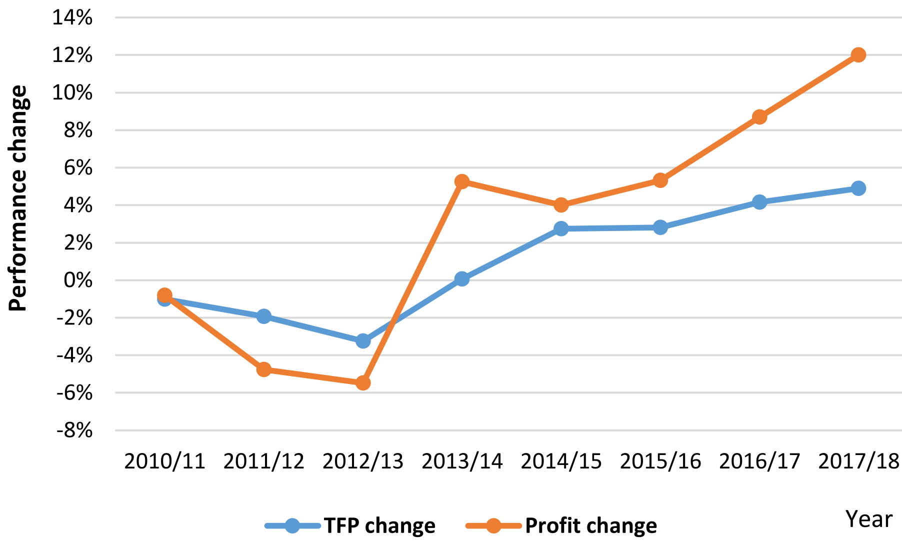

Fig. 1. Average total factor productivity (TFP) and profit change for Chilean water companies.

Table 3
Decomposition of profitability and TFP for Chilean water companies — average estimates.

Period	Output growth	Output price growth	Input price growth	Markup	Scale	Technical change	Efficiency change	Total factor productivity	Profit change
2010/11	−0.146%	0.703%	−0.660%	0.000%	−0.427%	−4.303%	3.720%	−1.010%	0.207%
2011/12	0.115%	−0.608%	0.432%	0.000%	−0.073%	−3.036%	1.185%	−1.924%	−2.848%
2012/13	0.105%	1.290%	0.367%	0.000%	−0.098%	−1.614%	−1.541%	−3.253%	−2.225%
2013/14	−0.110%	2.775%	−2.446%	0.000%	−0.140%	−0.031%	0.239%	0.068%	5.179%
2014/15	−0.101%	−1.147%	0.242%	0.000%	−0.043%	1.356%	1.438%	2.751%	1.261%
2015/16	0.154%	−1.652%	−1.204%	0.000%	0.326%	2.852%	−0.368%	2.810%	2.516%
2016/17	0.036%	−0.038%	−0.364%	0.000%	0.200%	4.263%	−0.296%	4.167%	4.529%
2017/18	0.172%	0.231%	−1.825%	0.000%	0.297%	5.840%	−1.251%	4.886%	7.114%
Average	0.028%	0.194%	−0.682%	0.000%	0.005%	0.666%	0.391%	1.062%	1.967%

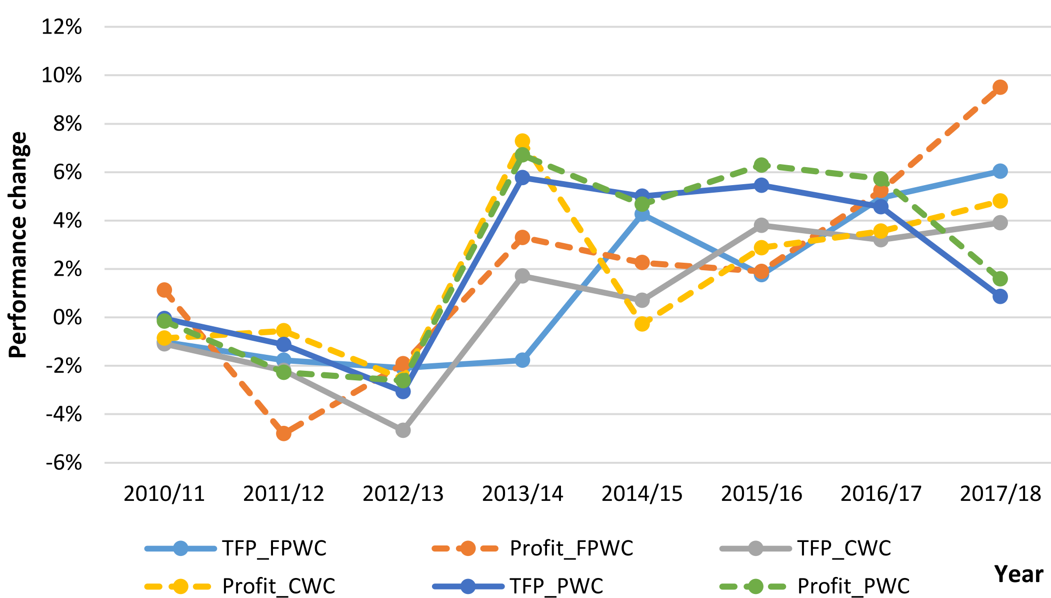

Fig. 2. Average total factor productivity (TFP) and profit change for Chilean water companies according to its ownership: full private water companies (FPWC), concessionary water companies (CWC) and public water company (PWC).

The drivers of TFP and profit change varied across type of water companies (Tables 4–6). It is reported that for the public water company changes in technology and in input prices accounted for the increases in profit over time. The rate of technical progress was 2.828% per year, whereas the rate of reduction in capital and OPEX prices was 0.415% per year. We note the impact of technical progress on TFP and profit steadily increased from 2013/14 onward, which increased at a rate of 4.918% per year (Table 4). Although the public company showed leadership in adopting new technologies, it did not perform well in their daily operations as shown by the negative sign in EC. Losses of 0.744% per year in efficiency were reported on average. These losses were evident during the last two years of our study. These

Table 4
Decomposition of profitability and TFP for the public water company.

	Output growth	Output price growth	Input price growth	Markup	Scale	Technical change	Efficiency change	Total factor productivity	Profit change
2010/11	−0.035%	−0.029%	0.045%	0.000%	0.044%	−1.824%	1.734%	−0.046%	−0.155%
2011/12	0.001%	0.774%	1.915%	0.000%	0.057%	−0.697%	−0.485%	−1.126%	−2.267%
2012/13	0.068%	0.681%	0.302%	0.000%	−0.081%	0.554%	−3.537%	−3.064%	−2.616%
2013/14	−0.016%	−0.486%	−1.435%	0.000%	0.090%	2.029%	3.655%	5.774%	6.707%
2014/15	−0.102%	−0.566%	−0.329%	0.000%	0.106%	3.388%	1.513%	5.007%	4.668%
2015/16	−0.314%	−0.220%	−1.380%	0.000%	0.392%	4.914%	0.143%	5.448%	6.294%
2016/17	−0.048%	−0.301%	−1.507%	0.000%	0.099%	6.414%	−1.947%	4.566%	5.724%
2017/18	−0.036%	−0.167%	−0.928%	0.000%	0.043%	7.846%	−7.027%	0.862%	1.587%
Average	−0.060%	−0.039%	−0.415%	0.000%	0.094%	2.828%	−0.744%	2.178%	2.493%

Table 5
Decomposition of profitability and TFP for full private water companies — average estimates.

	Output growth	Output price growth	Input price growth	Markup	Scale	Technical change	Efficiency change	Total factor productivity	Profit change
2010/11	−0.390%	1.722%	−0.811%	0.000%	−0.744%	−4.269%	3.994%	−1.018%	1.125%
2011/12	0.349%	−1.486%	1.902%	0.000%	−0.038%	−3.052%	1.325%	−1.765%	−4.804%
2012/13	−0.030%	−0.026%	−0.226%	0.000%	−0.179%	−1.551%	−0.360%	−2.091%	−1.922%
2013/14	−0.432%	2.939%	−2.571%	0.000%	−0.309%	0.054%	−1.519%	−1.775%	3.303%
2014/15	−0.375%	−1.698%	−0.063%	0.000%	−0.127%	1.476%	2.920%	4.269%	2.259%
2015/16	−0.100%	−1.355%	−1.593%	0.000%	0.160%	3.037%	−1.435%	1.762%	1.900%
2016/17	−0.129%	−0.173%	−0.606%	0.000%	0.197%	4.451%	0.289%	4.936%	5.240%
2017/18	0.290%	1.350%	−1.821%	0.000%	0.368%	6.058%	−0.389%	6.037%	9.499%
Average	−0.102%	0.159%	−0.724%	0.000%	−0.084%	0.775%	0.603%	1.294%	2.075%

findings suggest that the public water company could improve TFP and profitability by improving their managerial practices.

The results from the FPWCs (Table 5) indicated that TC, EC and prices (input and output) contributed positively in TFP and profitability, whereas output growth and scale effect had an adverse on profitability. It is found that technical progress and gains in efficiency accounted for a 0.775% and 0.603%, respectively increase in TFP and profit. Increases in the prices charged to the customers and a reduction in the cost of capital and operating inputs had a positive impact on full private companies' profitability. In contrast, the scale effect decreased at a rate of 0.084% per year leading therefore to a deterioration in TFP and profit. The findings suggest that the FPWCs made substantial efforts to adopt new technologies and improve day-to-day operations over time. Further increases in TFP and profitability could be achieved by increasing their scale of operations.

The results from the CWCs (Table 6) demonstrated that all components made a positive contribution in profit change. Reductions in capital and operating costs might have led to lower input prices and thus higher profitability over time. It is shown that input prices dropped at a rate of −0.659% per year. Although CWCs experienced technical regress during the first years of our sample, it eventually became positive from 2013/14 onwards. On average the rate of technical progress was 0.318% per year contributing positively to TFP and profit. Gains in efficiency and adjustments in the scale of operations accounted for an increase in profit by 0.249% and 0.104%. However, substantial efficiency losses were reported during the last years of our study, 1.271% per year. An average output growth of 0.193% per year jointly to increases in output prices by 0.260% led to higher increases in profitability. Thus, CWCs could further improve their profitability by improving their managerial practices and by increasing their scale of operations.

Finally, in Fig. 3 and Table 7 we present the results from the decomposition of TFP and profitability change at a water company level by taking the average of the estimates during the years 2010–18. The results highlighted that the majority of FPWCs showed positive rates of profitability change which ranged from 2.072% to 10.458% over time on average, with TC being the major determinant. Gains in efficiency and scale effect were also had a considerable impact on TFP and profit. Nevertheless, there were several FPWCs who showed a reduction in profitability. Any reductions in input prices were offset by technical regress, efficiency losses and the existence of diseconomies of scale. Thus, this group of companies could regain economic profitability by becoming more productive.

In contrast to FPWCs, nine out of ten CWCs reported positive rates of profitability which were mainly attributed to the price effect, output and input prices technical progress, and gains in efficiency. This group of companies could further increase their profitability by increasing the size of their operations. Moreover, negative economic profitability could be eliminated by improving managerial practices and learning from the best companies in the industry. Finally, the PWC showed a positive rate of profitability over time mainly due to technical change and a reduction in input prices. It could further increase profitability by improving its day-to-day operations.

5. Conclusions

The evaluation of a firm's performance requires the estimation of profit change and its determinants. Physical measures of productivity and price change are part of profit change. However, there might be other determinants that may have an effect on profit change such as scale effect and output growth. The assessment of profitability change can be of great interest to regulated industries such as Chilean water and sewerage industry as it can provide information about the effectiveness of price cap regulation in the performance of companies.

This paper estimated and decomposed changes in profitability and productivity of several water companies in Chile over the years 2010–18 using parametric techniques. Profit changes were decomposed into output growth, output price change, input price change, TC, scale, and markup components. The output growth, output price change, and input price change components are determined outside the production process (technology) using observed data. TC, scale, and markup components are determined from the technology, i.e., econometric estimation of a cost function. These three components constitute the physical measure of productivity (TFP) change. The decomposition results provide useful information about effects of regulatory regime, adoption of best practice technologies, adjustments in the scale of operations, and the like on profitability and profit changes.

The main findings of our work can be summarized as follows. First, the econometric results showed that the average cost efficiency was at the level of 0.731, which means that on average the companies need

Table 6
Decomposition of profitability and TFP for concessionary water companies — average estimates.

	Output growth	Output price growth	Input price growth	Markup	Scale	Technical change	Efficiency change	Total factor productivity	Profit change
2010/11	0.135%	−0.446%	−0.548%	0.000%	−0.094%	−4.590%	3.589%	−1.095%	−0.859%
2011/12	−0.154%	0.308%	−1.480%	0.000%	−0.127%	−3.251%	1.183%	−2.195%	−0.559%
2012/13	0.271%	2.931%	1.085%	0.000%	−0.003%	−1.906%	−2.759%	−4.667%	−2.551%
2013/14	0.266%	2.904%	−2.398%	0.000%	0.041%	−0.339%	2.007%	1.709%	7.278%
2014/15	0.228%	−0.545%	0.664%	0.000%	0.043%	1.009%	−0.348%	0.704%	−0.277%
2015/16	0.506%	−2.151%	−0.719%	0.000%	0.518%	2.425%	0.861%	3.804%	2.878%
2016/17	0.243%	0.151%	0.041%	0.000%	0.214%	3.823%	−0.833%	3.204%	3.557%
2017/18	0.051%	−1.072%	−1.920%	0.000%	0.238%	5.376%	−1.708%	3.906%	4.804%
Average	0.193%	0.260%	−0.659%	0.000%	0.104%	0.318%	0.249%	0.671%	1.784%

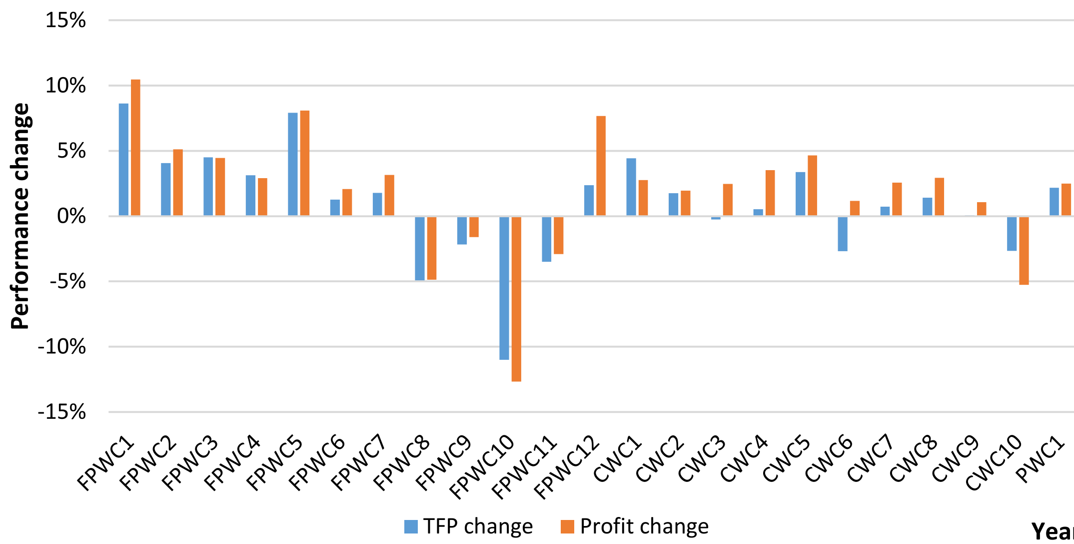

Fig. 3. Average total factor productivity (TFP) and profit change from 2010 to 2018 for each Chilean water company evaluated.

Table 7
Decomposition of profitability and TFP by water company — average estimates (2010–18).

	Output growth	Output price growth	Input price growth	Markup	Scale	Technical change	Efficiency change	Total factor productivity	Profit change
FPWC1	0.853%	−0.194%	−1.178%	0.000%	0.761%	6.960%	0.901%	8.622%	10.458%
FPWC2	−0.106%	0.025%	−1.145%	0.000%	0.547%	4.863%	−1.354%	4.056%	5.120%
FPWC3	0.031%	0.140%	0.206%	0.000%	0.464%	5.661%	−1.628%	4.497%	4.462%
FPWC4	0.341%	0.361%	0.915%	0.000%	0.267%	2.427%	0.437%	3.130%	2.917%
FPWC5	1.600%	−1.083%	0.347%	0.000%	0.435%	5.614%	1.864%	7.912%	8.082%
FPWC6	0.469%	0.111%	−0.216%	0.000%	−0.017%	−0.805%	2.097%	1.275%	2.072%
FPWC7	−0.277%	0.598%	−1.045%	0.000%	−0.038%	1.122%	0.706%	1.791%	3.156%
FPWC8	−0.032%	−1.403%	−1.484%	0.000%	−0.658%	−1.432%	−2.838%	−4.929%	−4.880%
FPWC9	−0.630%	0.047%	−1.050%	0.000%	−0.546%	−3.149%	1.524%	−2.171%	−1.598%
FPWC10	−1.302%	−1.774%	−1.392%	0.000%	−1.129%	−3.559%	−6.306%	−10.994%	−12.678%
FPWC11	−1.720%	0.491%	−1.828%	0.000%	−0.637%	−5.767%	2.906%	−3.498%	−2.899%
FPWC12	0.045%	4.392%	−0.864%	0.000%	−0.207%	−3.725%	6.294%	2.362%	7.663%
CWC1	0.441%	0.174%	2.291%	0.000%	0.509%	3.913%	0.017%	4.440%	2.764%
CWC2	−0.198%	0.250%	−0.137%	0.000%	0.388%	1.804%	−0.427%	1.765%	1.953%
CWC3	0.455%	1.210%	−1.049%	0.000%	0.248%	−1.384%	0.889%	−0.246%	2.467%
CWC4	−0.074%	1.524%	−1.554%	0.000%	0.142%	−0.780%	1.164%	0.526%	3.529%
CWC5	0.150%	0.500%	−0.624%	0.000%	0.204%	2.312%	0.872%	3.388%	4.661%
CWC6	−0.217%	0.861%	−3.202%	0.000%	0.070%	−0.173%	−2.579%	−2.681%	1.165%
CWC7	0.530%	0.342%	−0.970%	0.000%	0.074%	1.395%	−0.742%	0.727%	2.569%
CWC8	0.599%	0.830%	−0.090%	0.000%	−0.021%	0.363%	1.062%	1.404%	2.923%
CWC9	0.264%	−0.465%	−1.212%	0.000%	−0.585%	−3.341%	3.978%	0.051%	1.062%
CWC10	−0.017%	−2.624%	−0.049%	0.000%	0.007%	−0.925%	−1.743%	−2.661%	−5.254%
PWC1	−0.060%	−0.039%	−0.415%	0.000%	0.094%	2.828%	−0.744%	2.178%	2.493%

to reduce their costs by 27% to maintain the same level of output. There were several environmental variables that impacted on companies' costs and inefficiency such as serving customers in less densely populated areas and increased input requirements to improve drinking water and wastewater treatment quality standards. As far as profit and TFP changes are concerned, it was found that over time the rate of TFP and profitability change in the Chilean water industry was 1.062% and 1.967% per year on average, respectively. Technical progress and gains in efficiency were mainly accounted for the growth in TFP and profit, whereas the impact of scale effect on profit was immaterial. Increases in the prices charged to customers and a reduction in input prices also had a positive impact on profit.

The above findings are of great importance for researchers and policy makers for the following reasons. Firstly, technical change captures the shift in technology and is the key driver of profitability and productivity growth. Policy makers should therefore need to invest in research and development that supports innovation of new technology and improves technical change. Moreover, the study shows that there was a small efficiency change over the period of study. Less efficient companies continue to be lagging behind the best-practice companies. Thus, there is a need for less efficient companies to improve existing technologies. Our methodology aids a backward-looking view that allows conclusions to be drawn regarding the effectiveness of privatization. Furthermore, the decomposition of profit change into several components allows water utilities managers to identify the main factors on which they should act to increase the profits of the company.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.dajour.2022.100117.

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