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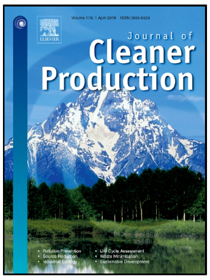

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Productivity change and its drivers for the Chilean water companies: A comparison of full private and concessionary companies.

María Molinos-Senante[1,2,3]*, Simon Porcher[4,5], Alexandros Maziotis[6]

[1] Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, Chile (E-mail: mmolinos@uc.cl)

[2] Escuela de Arquitectura e Instituto de Estudios Urbanos, Pontificia Universidad Católica de Chile, El Comendador 1916, Santiago, Chile.

[3] Centro de Desarrollo Urbano Sustentable CONICYT/FONDAP/15110020, Av. Vicuña Mackenna 4860, Santiago, Chile.

[4] Sorbonne Business School, 8 rue de la Croix de Jarry, 75013 Paris, France.

[5] Visiting Lecturer London School of Economics, Department of Management, Houghton Street WC2 2AE, London, UK.

[6] Fondazione Eni Enrico Mattei, Isola di San Giorgio Maggiore 8, Venice, Italy

* Corresponding author

Abstract:

The privatization of the water industry has aroused interest in comparing the performance of public vs. private water companies. However, little research has been conducted to compare the performances of full private (FPWCs) and concessionary water companies (CWCs). This study estimates and compares the productivity growth and its drivers (efficiency, technical and scale change) for a sample of Chilean FPWCs and CWCs over the 2007–2015 period using the input distance function. Both types of water companies showed deteriorations in productivity growth, with CWCs exhibiting higher rates of negative productivity growth than FPWCs. For FPWCs, any gains in efficiency and scale were outstripped by negative technical change. CWCs did not improve their performance in any of the three components of productivity change. The comparison of productivity change between FPWCs and CWCs is essential to support decision-making therefore, this study is of great interest for policymakers worldwide who are developing policies aimed at privatizing water companies.

Keywords: environmental factors; performance; privatization; productivity growth; quality of service; water and sanitation industry.

1. Introduction

Efficient management of water companies (WCs) is essential to ensure sustainable urban water activities. Performance assessments of WCs are relevant and have strong implications for regulators, utilities, customers, and stakeholders (Pinto et al., 2016; Dong et al., 2018). Since the 1980s, many studies have used different benchmarking methods to evaluate and compare the performances of water utility companies around the globe (Haider et al., 2016). Some research has focused on assessing the efficiency of water utility companies through static comparisons of their performance levels (Tutusaus et al., 2018). This approach provides information on WCs assessed at a given moment in time. Alternative studies have evaluated the change in productivity of WCs. Unlike efficiency studies, productivity change studies integrate the temporal component in the assessment (Portela et al., 2011) and focus on how the performance levels of WCs change over time (O'Donnell et al., 2017).

After the pioneering privatization of the English and Welsh water industry in 1989, several countries privatized some or all of their WCs. Since then, there has been controversial debate, politically and scientifically, about the appropriateness of privatizing utilities (Cheung and Chan, 2011). Case studies analyzed in the literature (Megginson and Netter, 2001) evidenced that private sector participation in the water industry is likely to result in improved managerial practices and higher operating efficiency. However, published literature also provides case studies where privatization of water utilities involved negative impacts on the society mainly due to increases in the water tariffs which led to water affordability problems (Al-Madfaei, 2017)[1]. Two major issues that have been investigated over the past 20 years include: i) the performance implications of public vs. private ownership

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[1] Porcher (2014) studies the impact of privatization on allocative efficiency in the French water industries and find no clear impact, i.e. margins are the same in the public and the private sector.

of WCs (Berg and Marques, 2011; Suárez-Varela et al., 2017), and ii) the change in productivity of WCs before and after their privatization (Saal et al., 2007). Most previous studies focusing on the second issue have referred to private WCs without taking into account that private WCs can be differentiated into two types, full private (FPWCs) and concessionary water companies (CWCs), depending on their approach towards privatization. For FPWCs, ownership, including infrastructure, is privatized, usually by selling strategic participations and shares to private consortia. For CWCs, water and sewerage services are privatized for a certain period of time, such that water regulators enter into long-term contracts with private entities (Petrova, 2006).

For urban planning and from a policy perspective, it is essential to compare not only the productivity change of public vs. private WCs but also of FPWCs vs. CWCs. This comparison will provide relevant information to policymakers regarding the proper approach for privatizing urban water industries. Despite the usefulness of assessing the productivity change of FPWCs and CWCs, to the best of the author's knowledge, only Molinos–Senante and Sala–Garrido (2015) have conducted an empirical case study on this topic. They evaluated the productivity change of 18 Chilean WCs, including FPWCs and CWCs, from 1997 to 2013 by estimating the Luenberger productivity indicator. Although these authors pioneered the estimation of productivity change for FPWCs and CWCs, their paper had several limitations.

To compute changes in the productivity of WCs, parametric or nonparametric methods can be used (Zhang, 2015). The first limitation of the study by Molinos–Senante and Sala–Garrido (2015) regards the use of the nonparametric Luenberger productivity indicator. This approach does not allow for the control of exogenous factors and quality of service. Several papers (see for instance Carvalho and Marques, 2011; Tanner et al., 2018) evidenced the importance of external variables in the performance assessment of WCs. The second limitation is that the authors decomposed the total factor productivity change (TFPC) into two drivers only: efficiency change (EC) and technical change (TC). This approach assumes that a change in the scale of a WC does not influence the change in productivity. A third limitation regards the presentation and interpretation of results. Molinos–Senante and Sala–Garrido (2015) presented results at the company level without any reference to the type of WC (i.e., FPWC or CWC). Moreover, no analysis was conducted to check the statistical significance of differences in productivity change between the two types of WCs.

Over the last 30 years, the Chilean water industry has implemented several major regulatory and institutional reforms to improve water and sewerage services (Hearne and Donoso, 2005). One of the most relevant reforms was the privatization of WCs, which began in 1998. Unlike in England and Wales, where all WCs were privatized at the same time following a common approach, the Chilean government privatized WCs in two stages following two different approaches (SISS, 2015). In the first stage (1998–2000), the five main Chilean WCs were privatized as FPWCs. Public WCs sold strategic participations to private consortia, with privatization of the public urban water infrastructure. In the second stage (2001–2004), public WCs transferred rights for the exploitation of water and sewerage services for 30 years, leading to CWCs. In 1998, 92.6% of urban customers were supplied by public WCs. In 2015, FPWCs and CWCs combined provided water and sewerage services to 95.8% of customers.

The main objective of this paper was to evaluate if there are any differences in the performance between FPWCs and CWCs. In doing so, we estimated and compared the TFPC values (and its drivers: EC, TC, and SC) of a sample of FPWCs and CWCs. An empirical application was carried out, which focused on the 22 main Chilean WCs (12 FPWCs and 10

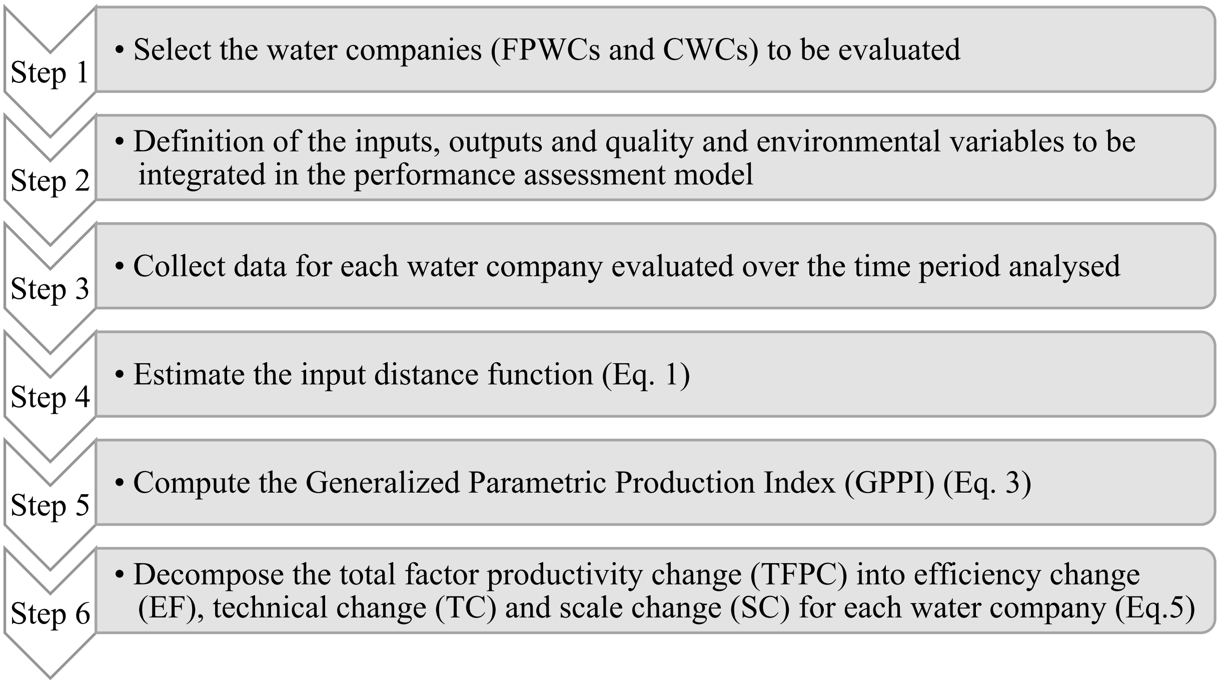
CWCs) over the 2007–2015 period which provide water and sewerage services to 98% of the urban population.

To the best of the knowledge of the authors, no study estimate and compared so far the TFPC of FPWCs and CWCs using a robust parametric method that allows for the control of exogenous factors and inclusion of quality of service issues that might influence productivity growth. Another innovation of the paper is the assessment of the impact of SC in the TFPC of FPWCs and CWCs.

Urban planners (local government) and water regulators are responsible for ensuring that the new urban developments have high quality drinking water and sewerage services (Gabrielsoon et al., 2018). Hence, the findings of this study contribute to better understand the dynamic of WCs by comparing the productivity change of FPWCs and CWCs. This information is essential to develop sound policies. Results about the comparison of TFPC and its drivers between FPWCs and CWCs are essential to support the decision-making process in selecting the approach to the privatization of WCs. In the year 2000 alone, 93 countries had municipalities that carried out some form of WC privatization (Petrova, 2006). Hence, it is essential that policymakers make informed decisions to promote the long-term technical and economic sustainability of WCs.

2. Methodology

To evaluate the TFPC of the analyzed WCs and the influence of the quality of services on TFPC, this research follows the methodological approach proposed by Saal et al. (2007) (Figure 1).



Step 1
- Select the water companies (FPWCs and CWCs) to be evaluated

Step 2
- Definition of the inputs, outputs and quality and environmental variables to be integrated in the performance assessment model

Step 3
- Collect data for each water company evaluated over the time period analysed

Step 4
- Estimate the input distance function (Eq. 1)

Step 5
- Compute the Generalized Parametric Production Index (GPPI) (Eq. 3)

Step 6
- Decompose the total factor productivity change (TFPC) into efficiency change (EF), technical change (TC) and scale change (SC) for each water company (Eq.5)

Figure 1. Main steps to evaluate and compare the TFPC and its driver for FPWCs and CWCs

Some previous papers (e.g., Antonioli and Filippini, 2001; Bottasso and Conti, 2009) estimated cost functions to evaluate both the productivity growth and profit change of WCs. By contrast, the present study applies the distance function approach, because there are no available data about all input prices to build a cost frontier and therefore, this study focused on assessing the TFPC of WCs. Following Orea (2002), Mugisha (2007), and Mellah and Ben Amor (2016), among others, this study uses the input distance function to characterize a production technology having multiple inputs and outputs.

The input distance function yields the maximum deflation factor that should be applied to an input set x to project it onto the efficient frontier of input set $(I^t(y))$. For output vector y at time t, the input distance function is defined as:

$$D_I(y,x,t) = max\left\{\delta : \frac{x}{\delta} \in I^t(y), \delta > 0\right\} \qquad (1)$$

This function enables computation of the technical efficiency of the WCs because $D_I(x,y,t) = (1/TE_I^{it}) \geq 1$, where TE_I^{it} is a Farrell measure of the input technical efficiency (Ferro and Mercadier, 2016). In accordance with previous studies, this paper uses an input-oriented approach to assess the performance of WCs (Worthington, 2014). This approach involves that performance improves by reducing the use of inputs for a given level of outputs. In the water industry, as in other network industries, the demand of outputs (i.e., drinking water and wastewater treatment services) is outside the control of managers, who mainly act on minimizing the use of inputs for water and sewerage services (Pinto et al., 2016).

Orea (2002) defined the Malmquist parametric productivity index (MPPI) as the weighted index of output change minus the weighted index of input change, employing input distance elasticities to estimate the weights of inputs and outputs. The MPPI is defined as follows:

$$\ln MPPI_I = -\frac{1}{2}\sum_{k=1}^{K}\left(\varepsilon_{kt+1} + \varepsilon_{kt}\right)\left(\ln\left(\frac{y_{kt+1}}{y_{kt}}\right)\right) - \frac{1}{2}\sum_{m=1}^{M}\left(\varepsilon_{mt+1} + \varepsilon_{mt}\right)\left(\ln\left(\frac{x_{mt+1}}{x_{mt}}\right)\right) \quad (2)$$

where $\varepsilon_{kt} = \partial lnD_I(t)/\partial lny_k$ and $\varepsilon_{mt} = \partial lnD_I(t)/\partial lnx_m$.

$D_I(x,y,t)$ is homogeneous of degree one in inputs; therefore, the weights of the input change must sum to unity. By contrast, the output weights do not sum to unity (Saal et al., 2007) due to the effects of non-constant returns to scale. Increasing returns to scale involve economies of scale because an expansion of output can be achieved with a less-than-proportionate increase in all inputs. If outputs increase by less than the proportional change in inputs, then there are decreasing returns to scale (Carvalho and Marques, 2015).

Saal et al. (2007) modified the MPPI so that the output weights were non-negative and summed to unity by definition, and the input weights were non-negative and summed to unity because of the homogeneity of degree one of the input distance function. Hence, it integrates in the assessment economies of scale. The generalized parametric productivity index (GPPI) which is defined as follows was applied in this study:

$$\ln GPPI_I = \ln MPPI_I + \frac{1}{2}\sum_{k=1}^{K}(\left(\frac{\varepsilon_{kt+1}}{\sum_{j=1}^{j=K}\varepsilon_{jt+1}}\right) + (\frac{\varepsilon_{kt}}{\sum_{j=1}^{j=K}\varepsilon_{kt}}))\left(\ln\left(\frac{y_{kt+1}}{y_{kt}}\right)\right) - \frac{1}{2}$$
$$\sum_{m=1}^{m=M}(\varepsilon_{mt+1} + \varepsilon_{mt})(\ln\left(x_{mt+1} + \varepsilon_{mt}\right)) \tag{3}$$

Following Caves et al. (1982), to implement the GPPI, the quadratic identity lemma is applied to the input distance function, as follows:

$$-\ln(\frac{D_I(y,x,t+1)}{D_I(y,x,t)} \equiv -\frac{1}{2}\sum_m\left(\varepsilon_{mt+1} + \varepsilon_{mt}\right)\left(\ln\left(\frac{x_m^{t+1}}{x_m^t}\right)\right) - \frac{1}{2}\sum_k\left(\varepsilon_{kt+1} + \varepsilon_{kt}\right)\left(\ln\left(\frac{y_k^{t+1}}{y_k^t}\right)\right) - \frac{1}{2}$$
$$\left[\frac{\partial lnD_I(y,x,t+1)}{\partial t} + \frac{\partial lnD_I(y,x,t)}{\partial t}\right] \tag{4}$$

Given that the input distance function is the inverse of the Farrell technical efficiency, then $-lnD_I(t) = lnTE_I(t)$, and the TFPC is decomposed into three components:

$$TFPC = EC + TC + SC \tag{5}$$

Following Saal et al. (2007), this paper uses the translog approach to estimate the input distance function, where i and t are units (WCs) and time indices, respectively. There are M inputs x_m, $m = 1 ... M$, and K outputs y_k, $k = 1 ... K$, and abbreviating $\tilde{x}_m \equiv ({}^{x_m}/{x_M})$:

$$-lnx_{M,i,t} = \alpha_i +$$
$$\sum_m^{M-1}\theta_m ln\tilde{x}_{m,i,t} + \frac{1}{2}\sum_m^{M-1}\sum_n^{M-1}\gamma_{m,n} ln\tilde{x}_{m,i,t} ln\tilde{x}_{n,i,t} + \sum_k \pi_k lny_{k,i,t} + \frac{1}{2}\sum_k\sum_l \beta_{k,l} lny_{k,i,t} lny_{l,i,t} + \sum_m^{M-1}\sum_k \phi_{m,k} l \tag{6}$$

$u_{i,t}$ are stochastic errors (assumed to measure inefficiency), drawn from an independent half-normal distribution that is truncated at zero. The term $\sum_p \xi_p z_{p,i,t}$ captures the impact of p environmental and quality variables on input requirements, allowing the estimated input distance function to capture better the true relationship between inputs and outputs (Saal et al., 2007).

Intercept parameter α_i accounts for heterogeneity of the analyzed WCs. This parameter is obtained through the true fixed effect method, proposed by Greene (2005), and it allows for the control of other factors influencing input requirements that have not been specifically controlled in the model. Following Greene (2005), maximum likelihood techniques are used to allow for firm-specific fixed effects and time-varying inefficiency specification. The unknown parameters to be estimated are as follows: α_i, θ_m, $\gamma_{m,n}$, λ_k, $\beta_{k,l}$, $\phi_{m,k}$, ψ_1, ψ_2, η_m, κ_k, and ξ_p.

3. Sample and Data Description

Statistical information from the WCs evaluated was extracted from the management reports of water and sewerage services published by the national urban water regulator (Superintendencia de Servicios Sanitarios, SISS) from 2007 to 2015.

Chilean WCs are multi-output producers, providing water supply and wastewater collection and treatment services. Following past evidence (Molinos–Senante et al., 2016a; Pinto et al., 2016; Li and Phillips, 2017), this study considered two outputs: i) the volume of water distributed, expressed in thousands of cubic meters of water produced annually, and ii) the number of customers with access to wastewater treatment services. Three inputs were assessed: i) the main length, defined as the sum of the water and sewerage networks (in km), which was used as a proxy for capital costs (Ananda, 2014, Ferro and Mercadier, 2016); ii) operating costs (Chilean pesos/year), defined as the total operating costs of the water and sewerage industries, deflated by the consumer price index taken from national statistics; and

iii) number of employees, which represents labor input expressed as the number, not cost, to impose the homogeneity assumption. Environmental and quality of service variables that are expected to influence TFPC were: i) customer density, defined as the number of customers per length pipe (customers/km); ii) nonrevenue water, defined as the percentage of water that was produced and not charged due to real and apparent losses (Neamtu, 2011); iii) drinking water quality; and iv) wastewater treatment quality. Nonrevenue water was included because Molinos–Senante et al. (2016b) found that most Chilean WCs have not solved their large nonrevenue water problems. The last two variables were measured by the water regulator as quality indicators between 0 and 1, with a value of 1 indicating that the water company met all legal requirements regarding the quality of drinking water (e.g., concentrations of pollutants) and the quality of wastewater treatment (e.g., sampling issues). Table 1 shows average values of data used to evaluate TFPC values for FPWCs, CWCs, and the whole sample of water companies from 2007 to 2015.

Table 1. Average of the inputs, outputs and environmental variables of the 22 Chilean water companies evaluated. Source: Own elaboration from Superintendencia de Servicios Sanitarios data.

		Inputs			**Outputs**		**Quality and environmental variables**			
	Year	**Operational costs (10^3 CLP/year)***	**Network length (km)**	**Number of employees**	**Water distributed (m^3/year)**	**Customers with access to wastewater treatment**	**Non-revenue water (%)**	**Customers density (Customer/km)**	**Drinking water quality**	**Wastewater treatment quality**
Full private water companies	2007	23,397,348	3,748	625	60,486	788,246	30	53	0.867	0.970
	2008	22,832,776	3,818	630	60,598	812,300	31	54	0.932	0.967
	2009	23,745,518	3,842	642	61,031	831,005	31	54	0.931	0.996
	2010	28,792,440	3,902	660	62,037	892,262	32	55	0.973	0.973
	2011	30,171,184	3,942	651	64,406	904,867	31	55	0.964	0.948
	2012	30,361,100	3,990	677	65,401	896,116	32	56	0.964	0.958
	2013	33,690,775	4,035	669	66,424	919,928	32	57	0.961	0.943
	2014	35,505,561	4,070	698	67,750	944,041	31	58	0.963	0.990
	2015	32,414,941	4,122	722	68,602	968,138	30	59	0.983	0.962
Concessionary water companies	2007	11,107,588	1,695	347	18,260	304,470	31	55	0.91	0.974
	2008	11,129,458	1,755	356	18,637	315,087	31	55	0.942	0.988
	2009	14,879,487	1,777	379	19,110	324,875	30	55	0.961	0.987
	2010	15,556,148	1,810	389	19,463	345,596	31	55	0.985	0.976
	2011	16,359,463	1,865	393	22,092	353,143	29	55	0.98	0.961
	2012	17,627,481	1,884	403	21,442	338,755	28	54	0.984	0.956
	2013	19,291,969	1,907	425	21,970	347,514	28	55	0.991	0.986
	2014	20,982,211	1,927	448	22,365	355,472	28	55	0.984	0.986
	2015	22,645,793	1,968	466	22,937	362,952	28	55	0.988	0.987
Total sample of water companies	2007	18,053,974	2,855	497	42,127	577,908	30	54	0.886	0.972
	2008	17,744,377	2,921	504	42,354	596,120	31	54	0.936	0.976
	2009	22,151,591	2,944	521	42,804	610,948	31	54	0.944	0.992
	2010	23,037,530	2,992	536	43,527	654,582	31	55	0.978	0.974
	2011	24,166,087	3,039	533	47,096	664,987	30	55	0.971	0.954
	2012	24,824,744	3,074	551	46,280	653,785	30	55	0.973	0.957
	2013	27,430,424	3,109	557	47,096	671,052	30	56	0.974	0.962
	2014	29,191,061	3,138	584	48,017	688,142	30	57	0.972	0.988
	2015	28,167,485	3,179	605	48,747	705,013	29	57	0.986	0.973

* Operational costs were adjusted to nominal CLP by the Chilean Consumer Price Indexes.

4. Results

Estimated results from the input distance function are reported in Table 2. Firm-specific effects i.e., the intercept parameter α_i, ranged from 3.299 to 3.663 for FPWCs and CWCs, respectively. The range of 0.364 suggested that the time-invariant heterogeneity of operating characteristics not otherwise controlled in the model accounted for small but important differences in the input requirements of the WCs.

Regarding monotonicity and curvature conditions, the estimated results confirmed that the input distance function was nondecreasing in inputs and nonincreasing in outputs, as shown by their first-order coefficients. The estimated input distance function was concave because the Hessian matrix of the translog input distance function with the second-order coefficients and the interaction term between inputs as elements was negative and semi-definite (Simon and Blume, 1994). There were some violations of the quasi-concavity assumption with respect to outputs. These violations did not imply the absence of an underlying cost-minimization process but may have reflected the inability of the translog input distance function to approximate the true input distance over the range of data (Wales, 1977). In particular, 79% (or 21%) of the observations satisfied (or violated) the quasi-concavity assumption in outputs. As Färe et al. (2010) and Wolf et al. (2010) noted, the translog function may lose flexibility when subjected to curvature restrictions.

Overall, the estimated translog input distance function was acceptable, and all variables were normalized around their means. Thus, the first-order coefficients of the outputs and inputs can be interpreted as the distance function output and input elasticities, respectively, for the average water company of the sample.

Estimated input elasticities were all positive and statistically different from zero, implying that the distance function was increasing with respect to inputs. Input elasticities of network length, operational costs, and labor were 0.767, 0.178, and 0.055, respectively. Number of employees was used as the normalized variable in the distance function. Its elasticity was recovered from the sum of the elasticities of the network length and operational costs. This finding suggested that network length and operating costs were the main drivers of increased input requirements to supply water and treat wastewater. Moreover, the high network length elasticity implied that the Chilean water and sewerage industry was capital-intensive.

Table 2. Estimated parameters of the input distance function. Labour input is the dependent variable.

Variables	Parameter	Coeff	St.Error	T-stat
Network length	θ_1	0.767	0.018	41.736*
Operational costs	θ_2	0.178	0.018	9.815*
Water distributed	π_1	-0.309	0.021	-14.537*
Wastewater customers treated	π_2	-0.664	0.022	-29.683*
Time	ψ_1	-0.010	0.002	-6.305*
Network length^2	$\gamma_{1,1}$	-0.693	0.027	-25.803*
Network Length * Operational costs	$\gamma_{1,2}$	-0.013	0.021	-0.594
Operational costs^2	$\gamma_{2,2}$	0.378	0.049	7.768*
Water distributed*Network length	$\phi_{1,1}$	-0.124	0.067	-1.848**
Wastewater treated * Network Length	$\phi_{2,1}$	0.280	0.066	4.214*
Water distributed*Operational costs	$\phi_{1,2}$	0.445	0.055	8.067*
Wastewater treated * Operational costs	$\phi_{2,2}$	-0.528	0.050	-10.619*
Water distributed^2	$\beta_{1,1}$	-0.286	0.031	-9.150*
Wastewater customers treated^2	$\beta_{2,2}$	-0.241	0.029	-8.200*
Water distributed*Wastewater treated	$\beta_{1,2}$	0.254	0.028	8.972*
Network Length * Time	η_1	-0.008	0.002	-4.096*
Operational costs * Time	η_2	-0.013	0.004	-3.101*
Water distributed*Time	κ_1	-0.017	0.004	-4.453*
Wastewater customers treated * Time	κ_2	0.021	0.003	6.377*
Time^2	ψ_2	0.003	0.001	3.693*
Customer density	ξ_1	-2.487	0.027	-92.730*
Customer density^2	ξ_2	0.404	0.007	58.568*
Wastewater treatment quality	ξ_3	-0.479	0.089	-5.356*
Drinking water quality	ξ_4	-0.208	0.027	-7.620*
Non-revenue water	ξ_5	-0.036	0.009	-4.137*
σ		0.144	0.002	48.979*
λ		5.841	0.469	12.435*
Log likelihood function	239.668			
Average technical efficiency	0.912			

* Coefficients are significant from zero at the 5% level

** Coefficients are significant from zero at the 10% level.

Output elasticities were statistically significant. Thus, providing wastewater treatment to more customers required more input than providing additional volumes of water. This is because increase in the volume of water supplied will take advantage of economies of scale whereas provide wastewater service to more customers will increase operational costs and number of employees (inputs) since the network will be bigger. The scale elasticity (i.e., sum of the inverses of the output elasticities) was 1.027 at the sample mean. In other words, a 1% increase in outputs would require an increase in inputs of 0.973%. Consistent with this result, Ferro and Mercadier (2016) reported increasing returns to scale in the Chilean urban water industry from 2005 to 2013. The second-order coefficient of customers provided with drinking water and wastewater treatment services was positive and significant, suggesting that these outputs were not complementary. This finding was consistent with the results of previous studies carried out in various settings (Saal and Parker, 2006).

Elasticities of network length and operational costs were negative and statistically significant over time. Thus, water companies increased capital-investment programs to improve the network, and the operational costs increased the input requirements over time. The estimated coefficient of the time factor was negative and statistically significant, suggesting that the average firm in the sample underwent technological regression at a small rate of 1%. Costs increased annually in part because of technical regress. However, the time-squared coefficient was relatively small and positive, suggesting that the estimated rate of technical change increased at 0.03% per year. Coefficients of time related to each of the input variables were negative and statistically significant, suggesting that water companies experienced technical regress resulting in increasing input requirements with respect to network length and operational costs. The statistically significant parameter of the interaction term between time and outputs suggested that technical change increased the relative magnitude of the number of customers of wastewater treatment services, whereas it decreased the relative magnitude of the elasticity of the amount of water supplied.

Density and density squared showed negative first-order and positive second-order terms. This result suggested that as population density increased, the input requirements increased. However, this effect would eventually be exhausted at sufficiently high levels of population density. Therefore, WCs operating in low-density areas might be less efficient than companies operating in high-density areas. In more densely populated areas, the input requirements may decrease because a company with a relatively high customer-to-network length ratio might use shorter pipes and, hence, have lower distribution costs (Torres and Morrison, 2006; Bottasso and Conti, 2009). This finding seemed to confirm the existence of economies of density in the Chilean water industry, consistent with past research in various settings (Kirkpatrick et al., 2006; Picazo–Tadeo et al., 2009; Mellah and Amor, 2016).

Elasticities of input requirements with respect to the drinking water quality and wastewater treatment quality were negative and statistically significant. This finding suggested that investments in improving the qualities of drinking water and wastewater treatment led to higher input requirements. Finally, increased nonrevenue water resulted in higher input requirements, which may be attributed to increased investments associated with the detection, repair, and control of water loss.

Average TFPC values for the Chilean WCs (Table 3) illustrated notable reductions in values for FPWCs and CWCs from 2007 to 2015. Although TFPC was negative in both cases, it was markedly larger for CWCs than for FPWCs. This finding was consistent with the results of Molinos–Senante and Sala-Garrido (2015), who suggested that Chilean FPWCs exhibited better performance across years than CWCs. For FPWCs, the worsening of productivity was due to the negative shift of the efficient frontier because the average EC and SC values were positive. By contrast, for CWCs, the three drivers of TFPC (i.e., efficiency change, technical change, and scale change) were negative. This result suggested that CWCs did not improve their performance in any of the three components of the TFPC.

Table 3. Average values of efficiency change, technical change, scale change and total factor productivity change from 2007 to 2015 expressed in percentage.

	Efficiency change (%)	**Technical change (%)**	**Scale change (%)**	**Total factor productivity change (%)**
Full private	0.75	-12.54	3.87	-7.93
Concessionary	-2.14	-5.94	-5.79	-13.89
Total sample	0.48	-9.47	-1.27	-10.26

To test whether the TFPC and its drivers differed significantly between FPWCs and CWCs, nonparametric Mann–Whitney and Kolmorov–Smirnov Z tests were carried out. The null hypothesis was that TFPC, EC, TC, and SC would not be significantly different between FPWCs and CWCs. The *p*-values for these tests (Table 4) illustrated that the null hypothesis could be rejected for TC and SC, but not for EC and TFPC. Distributions of the TC and SC values among CWCs and FPWCs were statistically significant. On the other hand, although large, the difference in the average TFPC values between FPWCs and CWCs was not statistically significant. Thus, it cannot be concluded that FPWCs generally presented better performance across years than CWCs. This finding revealed the importance of verifying results from a statistical perspective, to avoid obtaining biased conclusions.

Table 4. *p*-values of Mann-Whitney and Kolmorov-Smirnov tests

	Efficiency change	**Technical change**	**Scale change**	**Total factor productivity change**
Mann-Whitney	0.863	0.000	0.043	0.618

Kolmorov-Smirnov	0.503	0.001	0.031	0.753

Next, this paper sought to identify trends in the evolution of the productivity change across years. Figure 2 shows the average values of TFPC for the FPWCs, CWCs, and total sample of WCs evaluated year by year. Detailed results at the company level are reported as supplemental material. The TFPC of the Chilean water companies was positive for only one year, 2011/12. Thus, there was significant reduction of productivity during the period assessed. The increase in the use of inputs was not balanced by growth in the provision of water and sewerage services.

Two patterns can be differentiated for the productivity change of FPWCs and CWCs. From 2007 to 2011, although both types of water companies showed worsening productivity, CWCs exhibited worse performance (lower TFPC values) than FPWCs. In particular, from 2007 to 2011, TFPC declined by 12.5% and 6.5% for CWCs and FPWCs, respectively. By contrast, from 2011 to 2015, there was no clear pattern in the productivity change of the WCs. From 2012 to 2014, FPWCs and CWCs presented an opposite behavior. In the 2012/13 period, the TFPC of the FPWCs increased, whereas CWCs showed a reduction in productivity. During the next year, the opposite behavior was observed; the TFPC of the FPWCs declined, whereas the TFPC of the CWCs showed a positive behaviour.

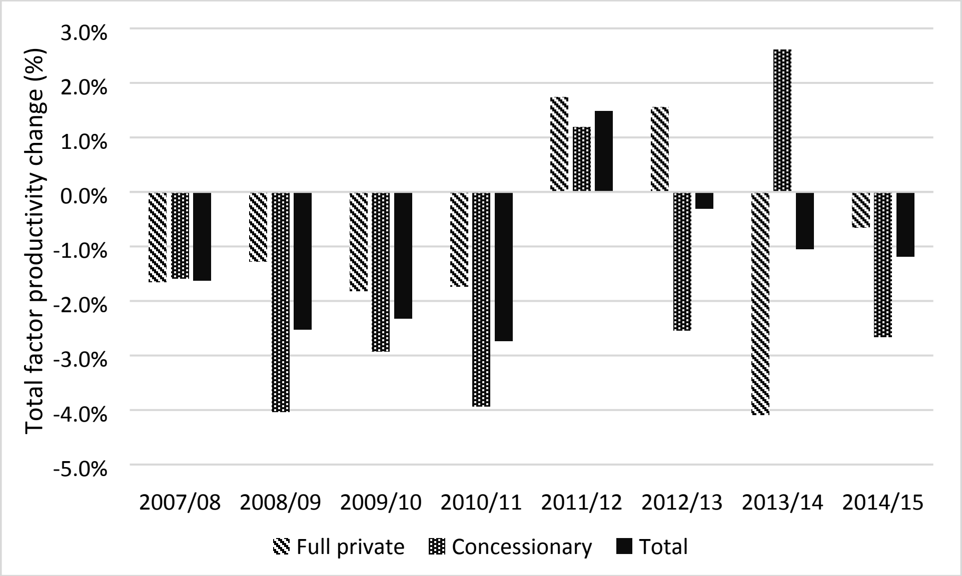


Figure 2. Average values of total factor productivity change for the total sample analyzed, for full private and concessionary water companies.

To understand better the drivers of productivity change of Chilean WCs, average values of EC, TC, and SC of the FPWCs and CWCs were plotted (Figures 3 and 4). The efficiency change, or catching-up index, reflected the capacity of water companies to be managed on the efficient frontier. Positive values of EC can be attributed mainly to managerial improvements (Simoes and Marques, 2012). For FPWCs, remarkable improvement of the EC was observed in the 2009/10 period (2.98%). This improvement compensated for the small decrease of this driver in subsequent years, leading a positive average value for the 2007–2015 period. EC showed greater variability for CWCs, with alternating positive and negative values across years. From a managerial perspective, this finding means that in average terms, FPWCs made more efforts to adopt better management practices than CWCs. Nevertheless, neither FPWCs nor CWCs exhibited positive values for EC in all of the years of the analyzed period. This finding suggested that Chilean WCs did not implement specific plans for improving management issues in the long term.

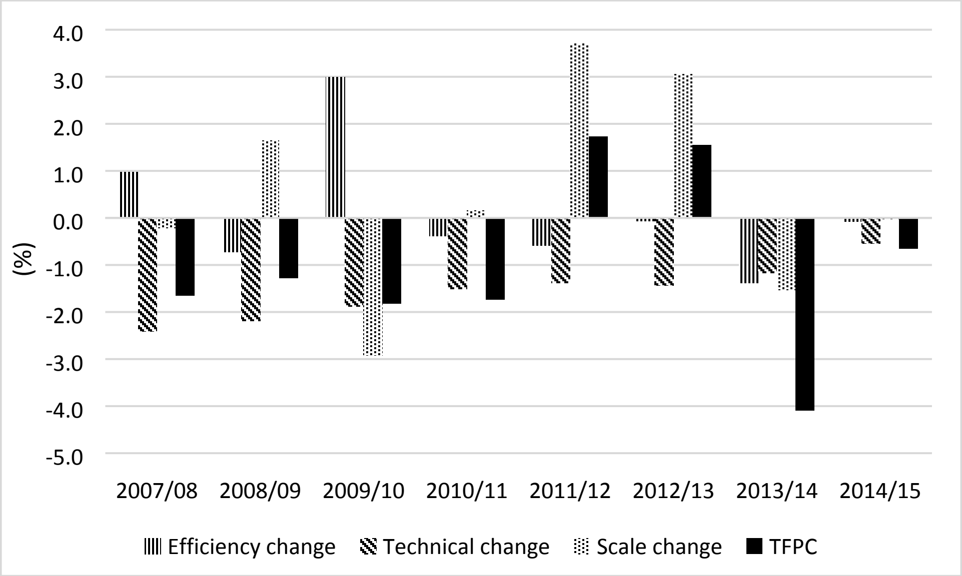


Figure 3. Drivers of the total factor productivity change (TFPC) for full private water companies

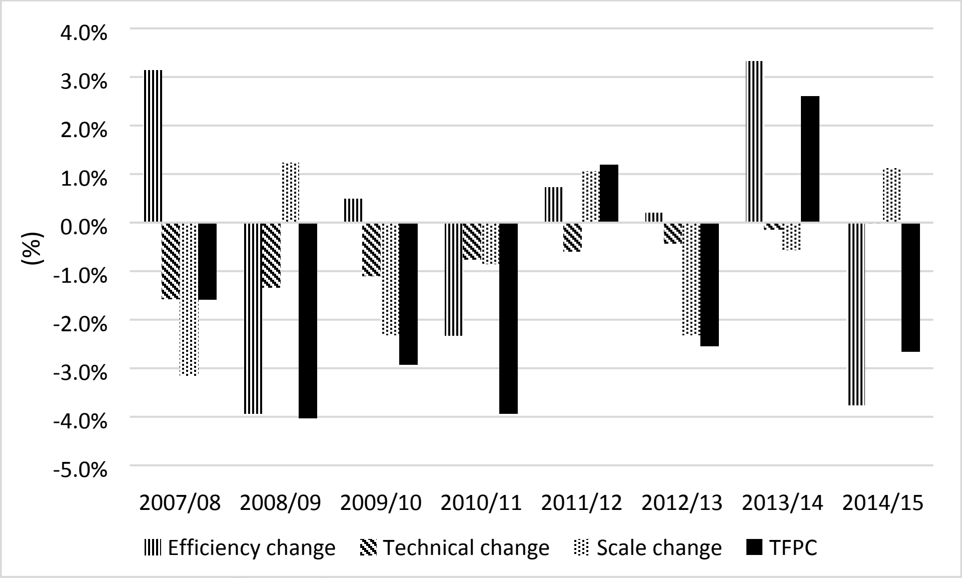


Figure 4. Drivers of the total factor productivity change (TFPC) for concessionary water companies

The second driver of TFPC, technical change measures the change in the efficient frontier between two periods (Molinos–Senante and Sala-Garrido, 2015). Average TC values of FPWCs and CWCs were negative for all 9 years evaluated (Figures 3 and 4). From 2007 to 2015, there was a steady regression of the efficient frontier. In the last years, the deterioration of TC was smaller than at the beginning of the period for both FPWCs and CWCs, but TC remained negative. Regulatory reform is one of the main driving forces to improve TC, making these findings very relevant for urban water regulators. Despite efforts made at the national level by regulators, reforms adopted in recent years were not sufficient to strengthen the Chilean water industry. This deficiency may be due to several reasons, with the small number of WCs providing water and sewerage services being among the most important. Twenty-two WCs supply water to 98% of the urban population. The eight largest Chilean WCs belong to two economic groups that provide water and sewerage services to 79% of urban customers. Under this ownership, it is difficult for regulators to introduce reforms to promote competitiveness, innovation, and, therefore, productivity among WCs.

The scale change reflects the type of returns to scale presented by the WCs. Positive SC values imply economies of scale, while negative SCs imply diseconomies of scale (Maziotis et al., 2014). Neither FPWCs nor CWCs presented a clear tendency regarding the presence of economies of scale (Figures 3 and 4). For both types of WCs, the SC contributed positively to TFPC in some years but negatively in others. FPWCs had larger variability in SC values than CWCs, as evidenced by the maximum and minimum average SC values of +3.7% and -2.9%, respectively. Such variability in SC is unusual worldwide. Nevertheless, our findings were consistent with previous studies focused on the Chilean water industry, which were inconclusive about the presence of economies of scale (SCL Econometrics 2009; Molinos–Senante et al., 2015; Ferro and Mercadier, 2016). In this context, Ferro and Mercadier (2016) concluded that the different results regarding economies of scale between previous studies were due to differences in methodology. However, the present study suggested that there was inconsistency in the presence of economies and diseconomies of scale for the Chilean WCs depending on the year. In some years, Chilean WCs presented increasing returns to scale, whereas they presented decreasing returns to scale in other years. This issue greatly complicates long-term planning by water regulators because there is no clear sign that favors or disfavors the horizontal integration of WCs.

5. Implications

Results (Figure 2) illustrate that the performance of the Chilean WCs changes across years, which may be due to several factors. In the framework of water governance, Berg (2016) identified seven elements affecting water sector performance: ideas, institutions, interests, information, incentives, ideals, and individuals. In the case of the Chilean water industry, FPWCs and CWCs share some of these factors, including institutions, incentives, interests, and ideals. Thus, according to Berg's (2016) methodological framework, the three main factors explaining performance differences between Chilean WCs are ideas, information, and individuals. Ideas are understood as the different conceptual frameworks to support decision-making processes. Data collection, verification, and analysis are essential to identify best practices and establish realistic targets. Finally, leadership is a relevant factor to improve water sector performance (Berg, 2016). Given that the Chilean WCs evaluated are private they do not share a common framework to support decision-making. Moreover, quality of service and efficiency targets are different among WCs. Both issues contributed unequivocally to the different performance between companies.

Based on the empirical application carried out in this study for the Chilean water industry, the following policy recommendations are proposed. Firstly, from this study it can be concluded that Chilean WCs (both FPWCs and CWCs) present notable economies of density. It indicates that significant cost savings can be achieved if WCs provide water and sewerage services in compact cities. This means that water companies to better understand the costs to deliver water and treat wastewater between urban and rural areas and develop strategies and make informed decisions to manage their assets more efficiently (e.g. more mains may need to be laid in rural than urban areas) so that they can achieve cost savings in those areas where significant costs exist. Secondly, the results of this study confirm that FPWCs present positive economies of scale which means that if WCs increase their size they can reduce their costs. The opposite occurs for CWCs. Hence, the water regulator should develop policies to encourage the merging of FPWCs forming larger WCs. However, at the same time the water regulator should promote innovation in order to increase the efficiency and quality of service of the WCs. Finally, CWCs have negative efficiency change across years whereas FPWCs presented positive values. This indicates that CWCs have not improved (or have done so to a lesser extent than FPWCs) their operational practices. Hence, the water regulator should introduce incentives for all water companies to adopt the water industry best practices.

6. Conclusions

This manuscript contributes to the current strand of literature in two main aspects. It evaluates and compares the productivity change for FPWCs and CWCs. Moreover, it assesses the impact of exogenous factors and quality of service on water companies´ efficiency. Finally, it evaluates the impact of efficiency change, technical change and economies of scale in the productivity performance of both types of WCs.

The empirical application conducted is this study to compare the performance of Chilean FPWCs and CWCs led to several interesting conclusions. First, FPWCs and CWCs showed reductions in their productivity growth, with CWCs exhibiting higher rates of negative TFP growth than FPWCs. Second, for FPWCs, any gains in EC and SC were outstripped by negative TC. Less efficient FPWCs improved their efficiency relative to the most frontier company, whereas the frontier company did not improve its performance over time. An average FPWC showed increasing returns to scale, suggesting that larger FPWCs can reduce their costs through scale effects (e.g., mergers among FPWCs). It evidenced that water regulators should target policies to encourage the merging of FPWCs forming larger WCs and promoting the adoption of best practices in the water industry. Moreover, CWCs did not improve their performance in any of the three components of productivity change. The major determinants in the deterioration of their productivity were the negative scale effect and TC. Effective long-term strategic planning and timely capital investment are needed to improve the technical efficiency. Hence, the study shows that national-level reforms that have been adopted in recent years have not been sufficient to strengthen the Chilean water industry. In conclusion, despite expending more efforts to adopt better management practices, FPWCs did not perform better than CWCs.

From a policy perspective, the findings of this study can be of great importance for researchers, urban planners, and policymakers for several reasons. First, the methodology employed allows the identification of factors that affect productivity change over time, which could aid regulators and managers to define measures that can be employed to improve performance in a regulated industry. Second, the comparison of different types of privatization will allow urban planners and policymakers to make decisions regarding the privatization approach to be taken. Finally, this study will improve understanding on the relative importance of various productivity components, which are essential to policymakers to make informed decisions for the sustainable and efficient management of water companies.

As a limitation to our study, we acknowledge that our case study only integrates four environmental and quality of service variables. This is due to the limited number of Chilean WCs. Future research should evaluate the TFPC on a larger sample of water companies which will allow to integrate additional environmental and quality of service variables that may affect the performance of both FPWCs and CWCs. Moreover, as future research we will extend our database by including information on prices for inputs so we can estimate and decompose productivity growth by using cost frontier approaches.

NOMENCLATURE

CWCs: concessionary water companies
EC: efficiency change
FPWCs: full private water companies
GPPI: generalized parametric productivity index
MPPI: Malmquist parametric productivity index
SC: scale change
TC: technical change
TFPC: total factor productivity change
WCs: water companies

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HIGHLIGHTS

The productivity of full private and concessionary water companies was compared over the 2007-2015 period.

Stochastic frontier techniques were used to compute productivity and its drivers

Drinking water and wastewater treatment quality along with non-revenue water contributed significantly to the productivity regression

Full private and concessionary water companies presented positive and negative economies of scale, respectively.