COSTS AND PERFORMANCE OF SOUTH AFRICAN WATER SERVICES PROVIDERS

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Abstract

Access to water is enshrined as a basic human right in the South African Constitution. Water Services Providers (WSPs) have a mandate to provide water at affordable tariffs. However, some of the WSPs can barely cover their operational costs through revenues. This study uses the stochastic cost frontier approach to estimate technical inefficiency in South African WSPs. Cross-sectional data for 147 WSPs obtained from the electronic database of Statistics South Africa (StatsSA) for the year 2013 is used. Firstly, the stochastic cost frontier was estimated using output, labour price, capital price and bulk water price. Secondly, the frontier was estimated using exogenous variables (number of customers, number of employees, free basic water and water services income). Finally, the cost frontier was estimated using all the eight independent variables. Results from all these three separate analyses, revealed no evidence of technical inefficiency in South African WSPs.

Keywords: Water utilities, stochastic cost, tariff, inefficiency, municipality.

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1. Introduction and Context

South Africa is a water scarce country with rainfall averaging 450mm per annum, a figure far below the world average of 860mm per annum (DWA, 2013). In order to meet the country's present and future water demand, both surface and ground water resources need to be sustainably managed. Access to water services is enshrined as a basic human right in the South African Constitution. According to law, each South African is entitled to 25 litres of free basic portable water per day, at a minimum flow rate of not less than 10 litres per minute, and within 200 meters of a household (DWAF, 2002). The government assumes that each poor household has eight members who will each receive 25 litres of free water per day, amounting to 6000 litres free basic water per month for each household (DWAF, 2007).

The DWAF (2002) defines water services as water supply and sanitation services the provision of which is a responsibility of a municipality. A municipality accorded the right to supply water services is called a Water Services Authority (WSA). Only municipalities can be WSAs and of the 278 South African municipalities only 152 are WSAs (DWA, 2013). In some cases, a WSA may contract a Water Services Provider (WSP) to provide water services on its behalf. The DWA (2014) describes a WSP as a WSA or any person who has a contract with a WSA to provide retail water services to consumers within a specific geographic area. Some WSAs appoint Water Boards to act as WSPs and offer retail water services to final users. A Water Board is a state-owned regional water services provider that may provide both bulk water services to more than one Water Services Authority area and retail services on behalf of WSAs (DWA, 2014).

WSPs have a mandate to provide water at affordable tariffs. However, evidence reveals that some of them can barely cover their operational costs through revenues due to lower tariffs and other reasons. Corruption, slack and ineptitude has been evident in South African municipalities with some even failing to efficiently provide basic services (Westhuizen and Dollery, 2009). To provide water services, WSPs incur several costs from the purchase of bulk water, water treatment, distribution of water and other activities. Since water qualifies as both a social good and social commodity, there is a great need for efficiency in its provision. Any form of technical inefficiency makes it hard for WSPs to recover the costs of providing water services.

It is now customary practice in several countries to benchmark the performance of utilities for regulatory purposes, the best known examples are Switzerland, the United Kingdom, the USA, Germany, the Netherlands and Italy (Baranzini, Faust and Maradan, 2010). Several indicators have been proposed to evaluate the performance of water utilities, from relatively simple ratios such as the number of workers per unit of water delivered, to more complex ones. In order to regulate water utilities, relevant information is needed, and this information can be derived through performance benchmarking. The better and more complete the information is, the more likely it is that the right problems are identified and appropriately addressed. Performance benchmarking techniques have become strategic tools for water regulators (De Witte and Marques, 2012). Benchmarking utilities promotes competition between the utilities, helps to identify the strengths and weaknesses of each utility, promotes information sharing and transparency, helps to identify performance trends, and provides consumers with information on the utilities (Gallego-Ayala, Dimene, Munhequete and Amos, 2014). Benchmarking techniques are either based on parametric methods that develop cost and production functions (such as stochastic cost functions) or nonparametric approaches that are based on data envelopment analysis (Baranzini et al., 2010).

This study uses the stochastic cost frontier approach to estimate technical inefficiency in South African Water Services Providers. The study assesses the impact of output, inputs and other exogenous variables outside the control of the WSPs on cost and efficiency. The varied nature of water provision in South Africa where consumers in different municipalities receive water services from diverse WSPs that range from water boards to WSAs makes it ideal to examine the performance of WSPs. Municipalities in South Africa are so diverse, ranging from metropolitan municipalities, local municipalities with a large town or city, local municipalities with a medium town or towns, local municipalities with a small town or towns, local municipalities with no urban core, to district municipalities. The cost performance of these municipalities regarding water provision should be assessed. To the best of the authors' knowledge, this is the first study to estimate the technical inefficiency in South African WSPs using the stochastic cost frontier approach.

The paper is organised into six sections. Section 2 reviews some empirical literature related to the study. Section 3 specifies the model and discusses the methodology. Section 4 defines the variables and gives the descriptive statistics of the sample. Section 5 discusses the results. Section 6 concludes the study.

2. Review of Some Empirical Literature

A plethora of studies that estimated the efficiency of water utilities using the stochastic cost function approach exist. Most of these studies are from developed countries, a few from developing countries and very few from South Africa. The scarcity of literature in developing countries is mainly due to the unavailability of data. This section reviews some empirical literature from developed countries (Baranzini, Faust and Maradan, 2010; and Filippini, Hrovatin and Zorić, 2007), developing countries (Souza, Faria and Moreira, 2007; and Estache and Martin, 1999), as well as South Africa (Tsegai, Linz and Kloos, 2009).

Baranzini, Faust and Maradan (2010) employed the stochastic cost function approach to estimate the cost inefficiency of 330 Swiss water utilities using a database that spans over six years (2000-2005). The study also investigated the impact of environmental characteristics outside the control of the water utilities on costs and inefficiency measures. To estimate cost efficiency Baranzini et al (2010) expressed total cost as a function of output, variable costs (labour price, energy price, material price and other costs), capital price and environmental factors (customer density, load factor, pumped water, type of customers and water adduction). Results from the study revealed that environmental factors affect the costs of water utilities and impact on estimated efficiency but less than traditional factors. The results further revealed that rankings of the water distribution utilities were very similar in the models that take environmental factors into account and in those which do not, but differ substantially between the variable and total cost models.

Filippini, Hrovatin and Zorić (2007) employed several stochastic frontier methods to estimate cost efficiency and economies of scale in Slovenian water distribution utilities using a panel data set for the period 1997-2003. Just like in the work of Baranzini et al (2010) the model expressed total cost as a function of water output, price of labour, price of material, price of capital, number of customers served, and the size of the service area. However, Filippini et al (2007) added other variables to those in Baranzini et al (2010), these were: water losses, water treatment, use of surface water, use of underground water, and changes in technology. Results from the study indicated that significant cost inefficiencies were present in the water utilities and the introduction of an incentive-based price regulation scheme was recommended as a possible solution. However, the inefficiency scores obtained from the different cost frontier models were not found to be robust. This was a result of the econometric model specification which could not separate unobserved heterogeneity from inefficiency. The true fixed effects model can be used because it performs better than the conventional panel data models with respect to distinguishing between unobserved heterogeneity and inefficiency (Greene, 2005a, b).

Souza, Faria and Moreira (2007) used a stochastic frontier model to assess the cost efficiency of Brazilian public and private water supply companies. The stochastic frontier model was derived from the translog family, a specification similar to a Cobb-Douglas including a quadratic term in log output. The model parameters were estimated by maximum likelihood using data of 279 firms for the year 2002. Unlike studies by Filippini et al (2007) and Baranzini et al (2010) that estimated total cost as the dependent variable, Souza et al (2007) used average cost as the dependent variable. Average cost was expressed as a function of water production output, price of capital, price of labour, capital, labour, average tariff and average profit. Except for the last two explanatory variables (average tariff and average profit), the other explanatory variables were similar to those used by Filippini et al (2007) and Baranzini et al (2010). Results from the study revealed no evidence that private firms and public firms are significantly different in terms of efficiency measurements.

In an old but quite relevant study, Estache and Martin (1999) compared the performance of public and private water companies in Asia and the Pacific Region. The study estimated the cost frontier for the Asian water companies using the 1995 data sample of 50 firms from the Asian Development Bank database. The estimation involved data on operational and maintenance costs, number of clients, daily production, population density in the area served, number of connections, percentage of water from surface sources, treatment capacity, market structure, number of hours of water availability, staff, salary, and a set of qualitative variables. Using the stochastic cost function, Estache and Martin (1999) expressed costs as a function of the level of output and the prices of inputs, generally agreeing in terms of variables with later studies by Filippini et al (2007), Souza et al (2007) and Baranzini et al (2010). Results from the study showed that the private operators were more efficient than public operators. This was not consistent with results from Souza et al (2007) that revealed no efficiency differences between private and public water firms in Brazil.

Using South African data for WSAs in the Middle Olifants sub-basin, Tsegai, Linz and Kloos (2009) applied the translog cost function method to estimate the structure of water supply costs and tariffs. The study used a panel data set of 50 WSAs for the years 2004 and 2006 with 100 observations. Total variable costs were estimated as a function of water output per year, price of bulk water, price of labour, price of materials, price of capital, and other variables such as population, poverty rate, and the backlogs rate. Despite using almost the same explanatory variables as Filippini et al (2007), Souza et al (2007) and Baranzini et al (2010), the work of Tsegai et al (2009) used total variable costs as the dependent variable. This was not consistent with the other studies that used total cost as dependent variable. Results from Tsegai et al (2009) indicated that marginal costs were higher than the actual tariffs that WSAs charged to consumers. The study recommended that charging a higher price will partly assist WSAs to recover the cost of supplying water. Tsegai et al (2009) used only total variable costs of providing water, for a certain part of South Africa, only for two years. A more comprehensive analysis of all South African WSAs is required. Additionally, a total cost function (not only total variable cost function) should be estimated.

Other studies that used the stochastic cost frontier approach to estimate efficiency in water utilities around the world include studies by Horn and Saito (2011); Vishwakarma and Kulshrestha (2010); as well as Aubert and Reynaud (2005). Horn and Saito (2011) estimated the cost efficiency of 831 Japanese water utilities using a panel data set for the period 1999 to 2008 and found that the average cost inefficiency was rather high at about 37 per cent, thereby recommending an incentive scheme to reduce cost and improve performance in the future. Vishwakarma and Kulshrestha (2010) estimated the technical efficiency of urban water utilities of selected 18 cities in the State of Madhya Pradesh in India and found some utilities performing better than others. Aubert and Reynaud (2005) estimated the impact of regulation on cost efficiency in France’s 211 Wisconsin water utilities for the years 1998 to 2000 and found that the utilities’ efficiency scores were partly explained by the regulatory framework.

In conclusion, all the studies reviewed in this section used the stochastic function approach to estimate the efficiency of various water utilities across the globe and revealed that inefficiencies do exist in water utilities. The majority of the reviewed studies expressed total cost as a function of water output, variable costs (such as price of labour, price of material, price of capital, price of energy) and other factors exogenous to water utilities (for example, customer density, load factor and type of customers). It was revealed in this section that there is a large gap in literature that uses the stochastic function approach to benchmark South African water utilities. This study will bridge the gap by applying the stochastic cost function approach to estimate the efficiency of South African Water Services Authorities. The model and methodology used in this study is discussed in the subsequent section. However, prior to the methodology, a summary of the empirical literature reviewed in this section is given in Table 1.

Table 1: Summary of the empirical literature reviewed in this section

Author(s)	Data sample	Model	Results
Souza, Faria and Moreira (2007)	279 Brazilian water supply utilities in 2002	Stochastic cost frontier	Efficiency measurements are not significantly different between private and public firms.
Baranzini, Faust and Maradan (2010)	330 Swiss water utilities for 2000-2005	Stochastic cost frontier	Exogenous factors affect the efficiency of water utilities less than endogenous factors.
Estache and Martin (1999)	50 Asian water companies in 1995	Stochastic cost frontier	Private water utilities were more efficient than public water utilities.
Tsegai, Linz and Kloos (2009)	50 South African WSAs from the Middle Olifants sub-basin using panel data for 2004 and 2006	Translog cost function	Marginal costs were higher than the actual tariffs that WSAs charged to consumers
Filippini,	52 Slovenian	Stochastic	Significant cost inefficiencies were

Hrovatin and Zorić (2007)	water utilities using panel data for 1997-2003	cost frontiers	present in the water utilities and an incentive-based price regulation scheme was recommended.
Horn and Saito (2011)	831 Japanese water utilities using panel data for 1999-2008	Stochastic cost frontier	Average cost inefficiency was high at about 37 per cent.
Vishwakarma and Kulshrestha (2010)	18 cities in the State of Madhya Pradesh, India	Stochastic cost frontier	Some utilities performing better than others.
Aubert and Reynaud (2005)	211 Wisconsin water utilities in France for 1998-2000	Stochastic cost frontier	Utilities' efficiency scores were partly explained by the regulatory framework.

3. Methodology and Model Specification

To estimate technical inefficiency in South African Water Services Providers, this study uses the stochastic cost frontier approach as developed by Aigner, Lovell, and Schmidt (1977). This is a parametric benchmarking method that assumes either a CobbDouglas, log-linear or translog functional form. Although most econometricians would prefer to use Data Envelopment Analysis (DEA) for benchmarking utilities, DEA does not account for noise. However, the stochastic frontier analysis overcomes the problem of unaccountability of noise and includes an error variable (u) in the function (Vishwakarma and Kulshrestha, 2010). The original formulation that serves as the foundation of the stochastic frontier model as developed by Aigner et al (1977) is:

$$y = \boldsymbol{\beta}'\mathbf{x} + v - u, \tag{1}$$

where y is the observed outcome (goal attainment), $\boldsymbol{\beta}'\mathbf{x} + v$ is the optimal frontier goal pursued by the individual (for example, maximum production output or minimum cost), $\boldsymbol{\beta}'\mathbf{x}$ is the deterministic part of the frontier and $v \sim \mathrm{N}[0, \sigma_v^2]$ is the stochastic part. The two parts together constitute the stochastic frontier. The amount by which the observed individual fails to reach the optimum (the frontier) is u, where:

$$u = |U| \text{ and } U \sim \mathrm{N}[0, \sigma_u^2] \tag{2}$$

(stochastic cost frontier changes to $v + u$). In this context, u represents the inefficiency. This is the normal-half normal model which forms the basic form of the stochastic frontier model (Aigner et al., 1977).

Water production is a process that consists of several activities such as water extraction and treatment, water transfer, water storage, pressurization of water pipelines, distribution of water to final customers, as well as quality monitoring and metering (Filippini, Hrovatin and Zorić, 2007). All these activities involve a lot of costs to WSAs and WSPs. To characterise the process of water provision and efficiency, it is essential to assume the existence of a mathematical relationship between inputs and output. South African WSPs have a legal obligation to serve all customers at a given water quality standard, thereby limiting their ability to produce output that maximises profit. WSPs are therefore assumed to take their main decisions predominantly regarding the optimal quantities of inputs.

The model used in this study estimates the stochastic frontier using total cost (TC), which is the total water related expenditure for the WSP. The total cost function comprises of water output (Q), labour price (LP), capital price (KP), bulk water price (BP) and exogenous variables (number of customers (NC), number of employees (NE), free basic water (FW) and water services income (Y)). Assuming that WSPs are in long run static equilibrium with respect to all inputs employed and that they minimise total cost, the total cost function will possesses the usual properties of monotonicity, concavity in factor price, and homogeneity of degree one with respect to factor prices and output. Therefore, the stochastic cost function used in this study assumes the following form:

$$TC_{it} = C(Q_{it},\ LP_{it},\ KP_{it},\ BP_{it},\ NC,\ NE,\ FW,\ Y,\ \beta)\exp(u_{it} + v_{it}) \tag{3}$$

Since the focus of the stochastic frontier analysis is not on estimating the frontier cost function but rather on the error term, which is the inefficiency component, the cost frontier function in Equation 3 is expressed in logarithms as follows:

$$\ln TC_{it} = \alpha_i + C(Q_{it},\ LP_{it},\ KP_{it},\ BP_{it},\ NC,\ NE,\ FW,\ Y,\ \beta)\exp(u_{it} + v_{it}) \tag{4}$$

where v_{it} is the noise term assumed to be in normal distribution $v_{it} \sim \mathrm{N}[0, \sigma_v^2]$. The u_{it} notation is the non-negative cost inefficient term (which is the distance from the observed cost to the minimum cost on the cost frontier). Like in the work of Horn and Saito (2011), this study assumes the cost inefficiency term to be in truncated normal distribution $u_{it} \sim \mathrm{N}[0, \sigma_u^2]$. The notation α_i represents time-invariant fixed effect, and β is the vector of the slope parameter.

The total cost inefficiency parameter is estimated as the ratio of observed total cost (TC_{it}) to frontier or minimum cost (TC^F). Therefore:

$$Inefficiency_{it} = \frac{TC_{it}}{TC_{it}^F} = \exp(u_{it}) \quad (5)$$

As discussed earlier in this study, the total cost frontier includes output, input prices, and some exogenous variables that can substantially affect the cost of South African WSPs. There is no general consensus in literature on the best approach to account for exogenous variables (Coelli, Perleman and Romano, 1999). However, this study follows the work of Baranzini, Faust and Maradan (2010) and assumes that the exogenous variables have a direct impact on the cost frontier, affecting the production structure, and subsequently the shape of the frontier, hence they should be included in the cost frontier. By including the exogenous variables directly in the frontier, one adapts the level of the cost frontier to the utility's environmental conditions (Baranzini et al., 2010). This approach was also used by other researchers such as Horn and Saito (2011) for the cost efficiency of 831 Japanese water utilities as well as Filippini, Hrovatin and Zorić (2007) for the cost efficiency of 52 Slovenian water distribution utilities.

It is empirically necessary to specify the form of the stochastic cost function to be estimated in the study. Forms of cost functions include the Cobb-Douglas function (Antonioli and Filippini, 2001), the log-linear cost function and the translog cost function (Horn and Saito, 2011). Due to the flexibility of the translog cost function, this study follows the work of Baranzini et al. (2010) and that of Horn and Saito (2011) to adopt the translog cost function as the basic model for estimating cost efficiency of South African WSPs. The translog cost function for South African WSPs as adopted in this study is specified as follows:

$$\ln\frac{TC_{it}}{KP_{it}} = \alpha_i + \beta_Q \ln Q_{it} + \beta_{BP}\ln BP_{it} + \beta_{LP}\ln\frac{LP_{it}}{KP_{it}} + \frac{1}{2}\beta_{Q,Q}\ln Q_{it}\ln Q_{it} + \frac{1}{2}\beta_{BP,BP}\ln BP_{it}\ln BP_{it}$$

$$+ \beta_{Q,BP}\ln Q_{it}\ln BP_{it} + \beta_{LP,LP}\ln\frac{LP_{it}}{KP_{it}}\ln\frac{LP_{it}}{KP_{it}} + \beta_{LP,Q}\ln\frac{LP_{it}}{KP_{it}}\ln Q_{it}$$

$$+ \beta_{LP,BP}\ln\frac{LP_{it}}{KP_{it}}\ln BP_{it} + \gamma_{NC}NC + \gamma_{NE}NE + \gamma_{FW}FW + \gamma_Y Y + u_{it} + v_{it} \quad (6)$$

The properties of the cost function are that it is concave and linearly homogenous in input prices, as well as non-decreasing in both input prices and output. To impose linear homogeneity in input prices, the normalisation of cost and input prices by one of the input prices is used (Horn and Saito, 2011). Henceforth, the total cost and the price of labour are divided by the price of capital.

4. Data, Variables and Descriptive Statistics

The study used cross-sectional data for 147 South African municipalities that are WSPs. Data for the year 2013 obtained from the electronic database of Statistics South Africa (StatsSA) was used. The datasets were for metropolitan, district and local municipalities (WSPs) across the nine (9) South African provinces[3]. Each WSP had datasets for: total cost (TC), output (Q), labour price (LP), capital price (KP), bulk water price (BP) and exogenous variables (number of customers (NC), number of employees (NE), free basic water (FW) and water services income (Y)). These variables are described as follows:

Total cost (TC) is the total water related expenditure for the municipality expressed in thousand Rands[4] (R'000)[5]. Descriptive statistics in Table 2 show that South African WSPs are very different in terms of water related total cost figures. The mean annual total cost for the 147 WSPs examined was R227 919 400 with a higher standard deviation R767 691 600. The WSP with the least total water provision cost had R2 346 000 while the highest total water provision cost was R6 018 366 000.

[3] List of the municipalities is given in Appendix 1

[4] Rand (R) is the South African currency. As of the 6th of August 2015, US$1 = R12.76.

[5] Components of the total costs are shown in Appendix 2

Water output (Q) is the total quantity of water supplied by the WSPs to both domestic and non-domestic customers during the year. The system input volume which is expressed in million cubic meters (m^3)/ per annum is used to account for water output. Table 2 shows that the mean quantity of water supplied by the 147 WSPs in 2013 was 23.4 million cubic meters with a standard deviation of 68.7 million cubic meters. The minimum quantity of water distributed by a WSP was 0.34 million cubic meters while the maximum distributed by a WSP was 536.3 million cubic meters.

Labour price (LP) is the average cost of labour per worker which is found by dividing water related employee costs by the number of water services employees including managers (full time and part time) within a WSP. This is expressed in Rands. Table 2 shows that the mean labour price for the 147 WSPs was R20 054.91 with a lower standard deviation of R18 870.72. The minimum price of labour for a WSP was R22.44 while the maximum price was R147 333.30.

Capital price (KP) is the price of capital investments on water provision. The provincial average capital cost per household expressed in Rands was used as proxy for capital price. This was used due to difficulties in obtaining data on the price of capital for each WSP. Data for the cost of capital was obtained from the DWA Cost Benchmark Guide. The mean of capital cost as shown in Table 2 was R19 141.08 with a standard deviation of R443.18. The minimum cost of capital was R18 478 while the maximum cost of capital was R20 795.

Bulk water price (BP) is the price of bulk water purchased from Water Boards and/or WSAs. The provincial average bulk water tariff expressed in Rands/per kilolitre (including VAT) was used. Descriptive statistics in Table 2 show that the mean bulk water price was R6.06 per kilolitre with a lower standard deviation of R1.04. The minimum bulk water price was R4.04 while the maximum price was R7.46 per kilolitre.

Number of customers (NC) shows the total number of domestic and non-domestic consumer units receiving water services from a WSP during the year. This variable highlights the vast differences in terms of size between the WSPs. Table 2 shows that the mean number of customers served by the 147 WSPs was 62 778 with a higher standard deviation of 150 539. The differences between the WSPs are shown by the minimum and maximum statistics where one WSP had as low as 1 246 customers while another had up to 963 886 customers.

Number of employees (NE) shows the number of full-time and part-time water services staff including managers within a WSP. Table 2 shows a mean of 1 446 water services employees with a higher standard deviation of 4 278. The minimum number of water services employees in one municipality was 52 employees while another had up to 28 361 water services employees.

Free basic water (FW) is the number of domestic consumer units receiving free basic water. Legally, an indigent South African is entitled to 25 litres of free basic portable water per day, at a minimum flow rate of not less than 10 litres per minute, and within 200 meters of a household (DWAF, 2002). Table 2 shows a mean of 23 912 domestic consumer units receiving free basic water in 2013 with a higher standard deviation of 66 070. The minimum number of domestic consumer units receiving free basic water was 225 in one municipality while another had up to 517 274 domestic consumer units receiving free basic water.

Water services income (Y) is the total water related revenue expressed in thousand Rands (R'000). There is concern that municipalities do not have cost reflective tariffs in place, and thus revenues from tariffs do not cover operations, maintenance, debt service and depreciation costs (MBI, 2014). Table 2 shows a mean water services income of R236 420 500 with a standard deviation of R755 194 700. One WSP received no income at all while another received income as high as R5 129 401 000. Some municipalities recorded deficits suggesting that appropriate tariff modelling is essential for municipalities to raise enough revenue.

Table 2: Descriptive statistics

Variable	Measurement unit	Obs	Mean	Std. Dev	Min	Max
TC	R'000/per annum	147	227919.4	767691.6	2346	6018366
Q	million m^3/per annum	147	23.37676	68.70225	.344412	536.312
LP	Rands	147	20054.91	18870.72	22.43959	147333.3
KP	Rands	147	19141.08	443.1819	18478	20795
BP	Rands/per kilo liter	147	6.05966	1.041088	4.04	7.46
NC	No.	147	62778.02	150539.4	1246	963886
NE	No.	147	1446.415	4278.287	52	28361
FW	No.	147	23911.64	66069.64	225	517274
Y	R'000/per annum	147	236420.5	755194.7	0	5129401

5. Results and Discussion

In this study, the first order coefficients were interpreted as frontier cost elasticities for the median WSP because all variables were in logarithms and were normalised at their sample median. The study estimated the normal/half-normal stochastic frontier model using the log likelihood-ratio test. In this study, the stochastic cost frontier for the 147 WSPs was estimated in three parts. Firstly, the stochastic cost frontier was estimated without including the exogenous variables, results of which are presented in Table 3. Secondly, the stochastic cost frontier was estimated with exogenous variables only and the results are presented in Table 4. Finally, the stochastic cost frontier was estimated with all variables (endogenous and exogenous) included. The work of Baranzini et al (2010) which followed almost the same approach inspired our study.

Table 3: Stochastic frontier normal/half-normal model results without exogenous variables

TC	Coef.	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Q	.9642377	.0400325	24.09	0.000	.8857754	1.0427
LP	.1721953	.0582621	2.96	0.003	.0580036	.2863869
KP	2.138737	2.709553	0.79	0.430	-3.171889	7.449363
BW	-.2918502	.355689	-0.82	0.412	-.9889879	.4052875
_cons	-12.62209	26.66287	-0.47	0.636	-64.88036	39.63618
/lnsig2v	-1.640811	.2595023	-6.32	0.000	-2.149426	-1.132195
/lnsig2u	-.4441758	.2713076	-1.64	0.102	-.9759289	.0875774
sigma_v	.4402532	.0571234			.3413958	.5677366
sigma_u	.800845	.1086377			.6138747	1.044762
sigma2	.8351756	.1493847			.542387	1.127964
lambda	1.819056	.1500145			1.525032	2.113079

Likelihood-ratio test of sigma_u = 0: *$chibar^2$ (01) = 9.32* *Prob> = $chibar^2$ = 0.001*

Table 3 shows that the coefficients of output (Q), labour price (LP) and capital price (KP) have the expected positive sign, with output and labour being statistically significant at 5 per cent significance level. This is consistent with theory and results from other studies (see Horn and Saito, 2011; Baranzini et al., 2010; and Souza et al., 2007). The positive relationship between total cost and output suggests that total cost increases as output increases. A unit increase in output increases total cost by approximately 0.964. Similarly, an increase in the price of labour leads to an increase in total cost. A unit increase in the price of labour increases total cost by approximately 0.172. In the same way, a unit increase in the price of capital increases total cost by approximately 2.139. Contrary to theory, the coefficient of bulk water price (BW) has a negative sign, suggesting an inverse relationship between total cost and the bulk water price. A unit increase in the bulk water price would reduce the total cost by approximately 0.292.

Aigner et al (1977) suggested that the amount by which the observed individual fails to reach the optimum (the frontier) is error term (u) which represents the inefficiency. The null hypothesis tested in this study was that inefficiencies exist in South African WSPs. However, the stochastic cost frontier results without exogenous variables (Table 3) revealed that the Likelihood-ratio test of sigma_u (u) is equal to 0, therefore rejecting the null hypothesis that inefficiencies exist in South African WSPs. Therefore, the stochastic cost frontier results without exogenous variables suggest that there is no technical inefficiency in the provision of water services by WSPs.

The stochastic cost frontier was also estimated using only exogenous variables. These variables have an impact on the total cost of WSPs. Four exogenous variables were used to estimate the stochastic cost frontier, these are: number of customers (NC), number of employees (NE), free basic water (FW) and water services income (Y). The selection of these variables was guided by literature (Horn and Saito, 2011; as well as Baranzini et al., 2010). Table 4 presents the estimation results for the stochastic cost frontier with exogenous variables only.

Table 4: Stochastic frontier normal/half-normal model results for exogenous variables

TC	Coef.	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
NC	.3049637	.0476354	6.40	0.000	.2116	.3983274
NE	.0845381	.0503239	1.68	0.093	-.0140949	.1831711
FW	.0739681	.0261486	2.83	0.005	.0227177	.1252185
Y	.6239532	.03337	18.70	0.000	.5585492	.6893573
_cons	-.2093569	.4015342	-0.52	0.602	-.9963495	.5776356
/lnsig2v	-2.423023	.1170357	-20.70	0.000	-2.652408	-2.193637
/lnsig2u	-11.77795	305.2807	-0.04	0.969	-610.1172	586.5613
sigma_v	.297747	.0174235			.2654831	.3339318
sigma_u	.0027698	.4227853			3.3e-133	2.3e+127
sigma2	.0886609	.0104481			.0681831	.1091388
lambda	.0093026	.4245661			-.8228316	.8414368

Likelihood-ratio test of sigma_u = 0: chibar^2 (01) = 0.00 Prob> = chibar^2 = 1.000

The coefficients of all the exogenous variables in Table 4 have positive signs as was expected. Positive signs indicate a positive relationship between total cost and the particular independent variable (Baranzini et al., 2010), suggesting that an increase in the particular independent variable would lead to an increase in total cost. As shown in Table 4, a unit increase in the number of customers will increase total cost by approximately 0.305. This is theoretically correct because WSPs will have to spend more on capital, labour and other operational activities as the number of customers increase. The results also show that a unit increase in the number of employees would increase total cost by approximately 0.085. This is also theoretically consistent because an increase in the number of water related employees means more wages, salaries and other employee associated costs which will increase the total cost figures. Furthermore, the results revealed that a unit increase in the quantity of free basic water provided would increase total cost by approximately 0.074. Since free basic water is provided to indigent households free of charge, the WSP will have to foot the water provision costs, therefore, the more the free basic water provided, the higher the cost to the WSP. Finally, water related revenue also revealed a positive relationship with the total cost of providing water, where a unit increase in revenue results in a 0.623 increase in total cost. The estimation results are statistically significant at 5 per cent significance level. Aigner et al. (1977) interpreted these normal-half normal model coefficients as the frontier cost elasticities.

The error term (u) in stochastic frontier analysis represents the inefficiency component (Aigner et al., 1977). The Likelihood-ratio test of sigma_u (u) is equal to 0 suggesting that the null hypothesis that technical inefficiency exist in South African WSPs can be rejected. This result was attained at a probability of 1.00, suggesting that the result can be reliable. Based on these results, it can be concluded that there is no technical inefficiency in South African WSPs when the total cost frontier is estimated using exogenous variables only. Finally, the stochastic cost frontier was estimated with all variables (endogenous and exogenous) included. Results are presented in Table 5.

Table 5: Stochastic frontier normal/half-normal model results with all variables

TC	Coef.	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Q	.0357114	.0543046	0.66	0.511	-.0707237	.1421465
LP	.0934054	.0281498	3.32	0.001	.0382328	.1485779
KP	1.551816	1.187181	1.31	0.191	-.775016	3.878649
BW	-.0412868	.1628368	-0.25	0.800	-.3604411	.2778674
NC	.2587981	.0607853	4.26	0.000	.1396612	.377935
NE	.111031	.052846	2.10	0.036	.0074548	.2146072
FW	.0656096	.0254861	2.57	0.010	.0156579	.1155614
Y	.6090696	.0326016	18.68	0.000	.5451715	.6729676
_cons	-15.86327	11.68653	-1.36	0.175	-38.76844	7.04191
/lnsig2v	-2.502541	.1184056	-21.14	0.000	-2.734612	-2.270471
/lnsig2u	-11.10596	305.9506	-0.04	0.971	-610.7581	588.5461
sigma_v	.286141	.0169403			.2547924	.3213465
sigma_u	.0038759	.5929142			2.4e-133	6.3e+127
sigma2	.0818917	.0099911			.0623095	.1014739
lambda	.0135454	.5960541			-1.154699	1.18179

Likelihood-ratio test of sigma_u = 0: chibar^2 (01) = 0.00 Prob> = chibar^2 = 1.000

All coefficients in Table 5 had the same signs as those in Tables 3 and 4. Results were statistically significant at 5 per cent significant level and the Likelihood-ratio test of sigma_u (u) was equal to 0 at a probability value of 1.00, suggesting that there is no evidence of technical inefficiency in South African Water Services Providers.

6. Conclusion

This study used the stochastic cost frontier approach to estimate technical inefficiency in South African municipalities that are WSPs. Cross-sectional data for 147 WSPs for the year were used. These datasets were obtained from the electronic database of Statistics South Africa (StatsSA). Each of the 147 WSPs had data for total cost (TC), output (Q), labour price (LP), capital price (KP), bulk water price (BP) and exogenous variables (number of customers (NC), number of employees (NE), free basic water (FW) and water services income (Y)).

Estimation for the stochastic cost frontier was performed in three parts. Firstly; the total cost frontier was estimated using output, the price of labour, the price of capital and the price of bulk water. Results from the estimation revealed no evidence of technical inefficiency in the WSPs. Secondly; the total cost frontier was estimated using exogenous variables (number of customers, number of employees, free basic water and water services income) and the results also revealed no evidence of the existence of technical inefficiency. Thirdly; the stochastic cost frontier was estimated with both endogenous and exogenous variables included and still there was no evidence of technical inefficiency. Therefore, it can be concluded that there is no technical inefficiency in South African Water Services Providers. However, there is need for tariff modelling because some municipalities cannot cover operational costs through revenue. There is also a need to correctly ascertain the indigent so as to avoid the provision of free basic water to individuals that can actually afford to pay.

This study grouped all the municipalities together and estimated technical inefficiency irrespective of their sizes and diversity. For future research, it is recommended that the stochastic cost frontier be used to separately estimate technical inefficiency in each group of municipalities, for example, metropolitans should be assessed separately from district municipalities, local municipalities and vis-versa. Furthermore, technical inefficiency of municipality in each province should be assessed separately. All this can be done subject to the availability of data.

7. References

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8. Appendix

1. List of the municipalities (WSPs used in the study)

Mun Code	Municipality	Mun Category	Mun Code	Municipality	Mun Category
NMA	Nelson Mandela Bay Metro	A	NC061	Richtersveld	B3
BUF	Buffalo City	A	NC062	Nama Khoi	B3
EC101	Camdeboo	B3	NC064	Kamiesberg	B3
EC102	Blue Crane Route	B3	NC065	Hantam	B3
EC103	Ikwezi	B3	NC066	Karoo Hoogland	B3
EC104	Makana	B2	NC067	Khai-Ma	B3
EC105	Ndlambe	B3	NC071	Ubuntu	B3
EC106	Sunday's River Valley	B3	NC072	Umsobomvu	B3
EC107	Baviaans	B3	NC073	Enthanjeni	B3
EC108	Kouga	B3	NC074	Kareeberg	B3
EC109	Kou-kamma	B3	NC075	Renosterberg	B3
EC131	Inxuba Yethemba	B3	NC076	Thembelihle	B3
EC132	Tsolwana	B3	NC077	Siyathemba	B3
EC133	Inkwanca	B3	NC078	Siyancuma	B3
EC134	Lukhanji	B2	NC081	Mier	B3
EC136	Emalahleni	B4	NC082	!Kai! Garib	B3
EC137	Engcobo	B4	NC083	Khara Hais	B2
EC138	Sakhisizwe	B3	NC084	!Kheis	B3
EC144	Gariep	B3	NC085	Tsantsabane	B3

MAN	Mangaung	A
FS161	Letsemeng	B3
FS162	Kopanong	B3
FS163	Mohokare	B3
FS171	Naledi	B3
FS181	Masilonyana	B3
FS182	Tokologo	B3
FS183	Tswelopele	B3
FS184	Matjhabeng	B1
FS185	Nala	B3
FS191	Setsoto	B3
FS192	Dihlabeng	B2
FS193	Nketoana	B3
FS194	Maluti a Phofung	B3
FS195	Phumelela	B3
FS196	Mantsopa	B3
FS201	Moqhaka	B2
FS203	Ngwathe	B3
FS204	Metsimaholo	B2
FS205	Mafube	B3
JHB	City of Johannesburg Metro	A
TSH	City of Tshwane Metro	A
EKU	Ekurhuleni Metro	A
GT421	Emfuleni	B1
GT422	Midvaal	B2
GT423	Lesedi	B3
GT481	Mogale City	B1
GT482	Randfontein	B2
GT483	Westonaria	B2
GT484	Merafong	B2
ETH	eThekwini Metro	A
KZN225	The Msunduzi	B1
KZN252	Newcastle	B1
KZN263	Abaqulusi	B3
LIM354	Polokwane	B1
LIM361	Thabazimbi	B3
LIM362	Lephalale	B3
LIM364	Mookgopong	B3
LIM365	Modimolle	B3
LIM366	Bela Bela	B3
LIM367	Mogalakwena	B2
MP301	Albert Luthuli	B4
MP302	Msukaligwa	B2
NC086	Kgatelopele	B3
NC091	Sol Plaatjie	B1
NC092	Dikgatlong	B3
NC093	Magareng	B3
NC094	Phokwane	B3
NC451	Joe Morolong	B4
NC452	Ga-Segonyana	B3
NC453	Gamagara	B3
NW371	Moretele	B4
NW372	Madibeng	B1
NW373	Rustenburg	B1
NW374	Kgetlengrivier	B3
NW375	Moses Kotane	B4
NW382	Tswaing	B3
NW383	Mafikeng	B2
NW384	Ditsobotla	B3
NW385	Ramotshere Moiloa	B3
NW392	Naledi	B3
NW393	Mamusa	B3
NW394	Greater Taung	B4
NW396	Lekwa-Teemane	B3
NW401	Ventersdorp	B3
NW402	Tlokwe	B1
NW403	City of Matlosana Municipality	B1
NW404	Maquassi Hills	B3
CPT	City of Cape Town Metro	A
WC011	Matzikama	B3
WC012	Cederberg	B3
WC013	Bergrivier	B3
WC014	Saldanha Bay	B2
WC015	Swartland	B3
WC022	Witzenberg	B3
WC023	Drakenstein	B1
WC024	Stellenbosch	B1
WC025	Breede Valley	B2
WC026	Langeberg (Breede River)	B3
WC031	Theewaterskloof	B3
WC032	Overstrand	B2
WC033	Cape Agulhas	B3
WC034	Swellendam	B3
WC041	Kannaland	B3
WC042	Hessequa	B3
WC043	Mossel Bay	B2

MP303	Mkhondo	B3	WC044	George	B1
MP304	Pixley Ka Seme	B3	WC045	Oudtshoorn	B2
MP305	Lekwa	B3	WC047	Bitou	B3
MP306	Dipaleseng	B3	WC048	Knysna	B2
MP307	Govan Mbeki	B1	WC051	Laingsburg	B3
MP311	Delmas (Victor Khanye)	B3	WC052	Prince Albert	B3
MP312	Emalahleni	B1	WC053	Beaufort West	B3
MP313	Steve Tshwete	B1			
MP314	Emakhazeni	B2			
MP315	Thembisile	B4			
MP316	Dr J S Moroka	B4			
MP321	Thaba Chweu	B3			
MP322	Mbombela	B1			
MP323	Umjindi	B3			
MP324	Nkomazi	B4			
MP325	Bushbuckridge	B4			

2. Components of the total water related costs

Employee related costs
Interest paid
Loss on disposal of property, plant and equipment
Bad debts
Contracted services
Collection costs
Depreciation and amortisation
Impairment loss (PPE)
Repairs and maintenance
Bulk purchases:
Purchases of water
Purchases of electricity
Other bulk purchases
Grants and subsidies paid to:
Other local government institutions
Tertiary institutions of higher learning
Households or individuals
Non-profit institutions serving households
Other
General expenditure:
Accommodation, travelling and subsistence
Advertising, promotions, and marketing
Audit fees
Bank charges

Cleaning services
Consultancy and professional fees
Entertainment costs
Fuel and oil
Hiring of plant and equipment
Insurance costs
Pharmaceutical
Postal and courier services
Printing and stationery
Rebates for service charges
Rental of land, buildings and other structures
Rental of office equipment
Security services
Subscriptions and membership fees
Telecommunication services
Training and education
Transport costs
Other expenditure