ZEF Bonn
Zentrum für Entwicklungsforschung
Center for Development Research
Universität Bonn

Daniel W. Tsegai,
Teresa Linz,
Julia Kloos

Number
129

Economic analysis of water supply cost structure in the Middle Olifants sub-basin of South Africa

ZEF – Discussion Papers on Development Policy
Bonn, April 2009

The CENTER FOR DEVELOPMENT RESEARCH (ZEF) was established in 1995 as an international, interdisciplinary research institute at the University of Bonn. Research and teaching at ZEF aims to contribute to resolving political, economic and ecological development problems. ZEF closely cooperates with national and international partners in research and development organizations. For information, see: http://www.zef.de.

ZEF – DISCUSSION PAPERS ON DEVELOPMENT POLICY are intended to stimulate discussion among researchers, practitioners and policy makers on current and emerging development issues. Each paper has been exposed to an internal discussion within the Center for Development Research (ZEF) and an external review. The papers mostly reflect work in progress.

Daniel W. Tsegai, Teresa Linz and Julia Kloos: Economic analysis of water supply cost structure in the Middle Olifants sub-basin of South Africa, ZEF – Discussion Papers On Development Policy No. 129, Center for Development Research, Bonn, April 2009, pp.20.

ISSN: 1436-9931

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Walter-Flex-Strasse 3
D – 53113 Bonn
Germany
Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
http://www.zef.de

The authors:
Daniel W. Tsegai, Center for Development Research (ZEF), University of Bonn, Germany
(contact: dtsegai@uni-bonn.de)
Teresa Linz, Center for Development Research (ZEF), University of Bonn, Germany
(contact: tlinz@uni-bonn.de)
Julia Kloos, Center for Development Research (ZEF), University of Bonn, Germany
(contact: jkloos@uni-bonn.de)

Contents

List of Tables

List of Figures

Acknowledgements

This work is part of the BMBF-funded project on “Integrated Water Resources Management Pilot Project in the Middle Olifants Sub-basin of South Africa”. We would like to thank Dr. Celine Nauges [National Institute for Research in Agriculture (INRA) and Toulouse School of Economics, France] and Dr. Johannes Sauer (Imperial College London) for their review and insightful comments on the earlier versions of the manuscript.

Abstract

Using data gathered from the National Treasury of South Africa, we examine the structure of water supply costs and tariffs of Water Service Authorities (WSAs) in the Middle Olifants sub-basin of South Africa. Using the translog cost function method, the marginal cost of water supply and economies of scale are estimated. Comparison of tariffs and marginal costs show that the estimated marginal cost is higher than the actual tariff paid by consumers. This implies that WSAs in the Middle Olifants are not charging enough to recover the costs of the water services. Thus, among other things, pricing of water at its marginal cost would partly assist in solving the cost recovery problem. Raised tariffs would in turn contribute to improved efficiency of water use. As evidenced by estimation results of returns to scale (greater than one), merger of WSAs would be economically advantageous. Hence, reversing the process of transferring water services' authority to 'local' municipality level and thus up-scaling WSAs into the 'district' municipality level is an important policy option for improving water services efficiency in the Middle Olifants sub-basin of South Africa.

Kurzfassung

Die vorliegende Studie untersucht, anhand von Datensammlungen des nationalen Finanzministeriums Südafrikas, die Struktur der Wasserversorgungskosten und Tarife der Wasseranbieter (WSAs) im Wassermanagementgebiet mittlerer Olifants in Südafrika. Mit Hilfe eines ökometrischen Ansatzes unter der Verwendung einer Translogkostenfunktion werden die Grenzkosten der Wasserversorgung sowie Skaleneffekte geschätzt. Der Vergleich von Wassertarifen und Grenzkosten zeigt, dass die geschätzten Grenzkosten höher sind als der tatsächlich bezahlte Tarif der Konsumenten. Dies bedeutet wiederum, dass die WSAs im Mittleren Olifants nicht genügend Gebühren verlangen, um die Kosten für die Wasserversorgung zu decken. Demnach würde eine Preiseinstufung anhand der Grenzkosten, neben anderen Maßnahmen, dazu beitragen, das Problem der Kostendeckung wenigstens teilweise zu lösen.
Höhere Tarife würden im Gegenzug die Effizienz der Wassernutzung verbessern. Die Schätzungen der Skalenerträge (größer als eins) belegen, dass ein Zusammenschluss der WSAs ökonomisch vorteilhaft wäre. Demzufolge ist der Zusammenschluss von lokal verwalteten WSAs auf Bezirksebene eine wichtige politische Option, um die Effizienz der Wasserversorgung im Mittleren Olifants in Südafrika zu verbessern.

1 Introduction

South Africa is a water-scarce country. According to UNESCO (2003), it is one of the 30 most water-stressed countries in the world. Located in a predominantly semi-arid part of the world, the country has an average rainfall of 450 mm per year, well below the world average of 860 mm per year (NWRS, 2002). South Africa's rainfall is also prone to erratic extremes in the form of floods and droughts. Coupled with these are low run-off rate (nine per cent), few natural lakes, and high annual evaporation, in which in most cases it exceeds the average rainfall. The total flow of all the rivers in the country combined amounts to approximately 49,200 million cubic meters (m^3) per year (NWRS, 2002). Impact assessments of climate change predict a worsening of the natural conditions in this regard (IPCC, 2007).

Basic water services in South Africa in general and in the Olifants basin in particular are unreliable and inadequate to meet basic human needs. Although the South African National Water Act (1998) guarantees free basic water of six kilo liters per month per household[1] for all in South Africa, this has not been fully implemented yet. In Limpopo and Mpumalanga provinces (which account for the major part of the Olifants basin), only 60 per cent[2] of the local municipalities are receiving the free basic water (computed from Otterman et al., 2007).

In Limpopo and Mpumalanga provinces, 18 per cent of the total population depends on unreliable water source including boreholes, spring, rainwater, dams or pools, river/stream water and water vendors (estimated from Census South Africa, 2001). Especially when compared to the country's average of 15 per cent with unreliable water supply, the water service in the Olifants basin is not satisfactory. As 22 per cent of the population in the Olifants basin lies below the RDP[3] water, 50 per cent lie below RDP sanitation. With respect to RDP water, 24 per cent of the rural population and 21per cent of the urban population lie below RDP water. In terms of sanitation, 52 per cent of the rural population and 50 per cent of the urban population lies below RDP, respectively. All the above figures demonstrate that the water and sanitation services in the Olifants basin are generally weak.

Assuring the supply of water to the end user is becoming increasingly difficult to water service providers. Added to this is the challenge of providing water services sustainably. Sustaining the water supply services requires, among other things, to recover the money costs

1 This is equivalent to 25 liters per person per day

2 Even though it is better than the national average of 54 per cent, it is still not good enough in view of the government's aim of reaching every one.

3 RDP (Reconstruction and Development Program) is a South African socio-economic policy framework implemented by the African National Congress (ANC) in 1994. The aim was to address the socioeconomic problems and especially to alleviate poverty and massive short falls of services brought about by the consequences of Apartheid Regime. Among these is providing basic water and sanitation services to the whole population. Thus, being below RDP is equivalent to be below this basic access.

associated with supplying water at an acceptable level of assurance, quality and accessibility to the end user. The cost can be in terms of capital investment in water infrastructure (reservoir and pipes) and/or operating and maintenance costs like bulk water distribution, treatment, and reticulation within human settlements.

In South Africa, water services provision is the task of Water Service Authorities (WSAs), Water Boards, Irrigation Boards and Community-based organizations (in rural areas). The water boards are the most dominant, providing bulk water supply services and limited retail water services. Irrigation boards are responsible for supplying water for large-scale irrigation purposes. WSAs have the constitutional mandate to provide water services by purchasing bulk water from water boards for retail and reticulation. WSAs can be metropolitan cities, local municipalities and/or district municipalities which provide water retail function within their area of jurisdiction. A simple illustration of the water services provision and the pricing chain is described in Figure 1.

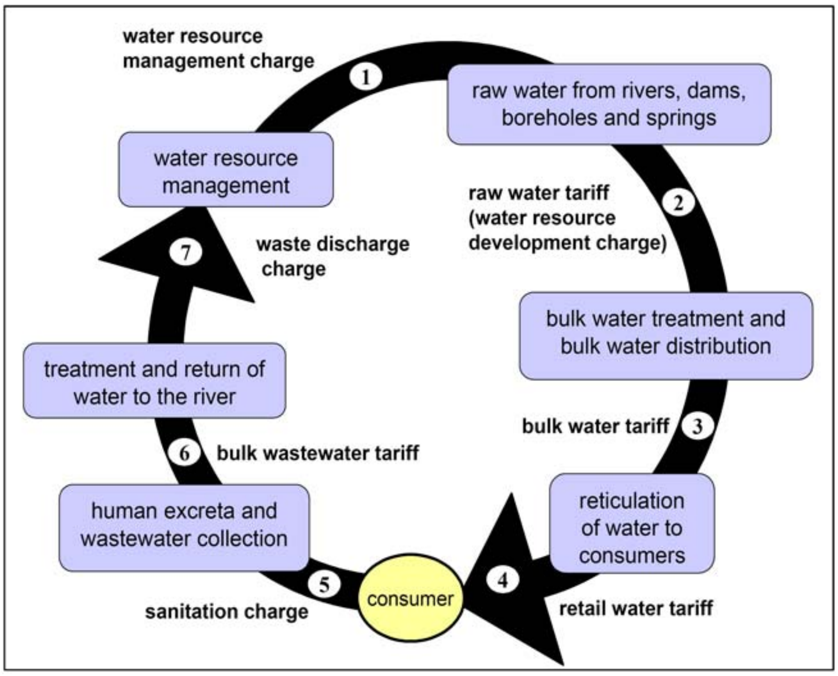

Figure 1: Pricing chain for water use charges
Source: Ottermann et al., 2007

Recovering the cost and providing water services in a sustainable and efficient way is far from satisfactory in South Africa. According to Ottermann et al. (2007), water tariff values are set based on production cost (treatment and pumping) and some cross subsidization schemes to meet socio-political objectives. The tariffs rarely reflect the actual value of water which accounts for full sustainability and conservation features like scarcity, social and environmental values. The assumption here is that WSAs do not recover the cost of supplying water since the price charged to consumers is too low. This paper aims to contribute to policy by coming up with a marginal cost estimation which will point to WSAs to set the price of water based on the estimated marginal cost ("marginal cost pricing").

The government of South Africa is endeavoring to tackle the problem of water scarcity, improving water use efficiency and water supply services. This is demonstrated, among others, by the provision of the Water Allocation Reform (WAR) which includes the process of compulsory licensing for registering all water uses, the Water Services Act (1997), National Water Act (1998), as well as the National pricing strategy for raw water use.

Using data gathered from National Treasury of South Africa, this paper examines the structure of water supply costs in the Middle Olifants sub-basin of South Africa. This paper attempts to compare the actual tariffs with the estimated marginal cost. Using the translog cost function method, the marginal cost of water supply is estimated. A comparison of the estimated marginal cost and the actual water tariff that households pay will give an insight into the water pricing options for policy makers. Policy options for economies of scale are also conducted to examine the possibilities of amalgamation or separation of WSAs.

The paper is structured as follows. Following a general introductory remark, the second section reviews the previous literature on the estimation of water supply cost structure in developed and developing countries. In section three, the theoretical framework for the translog cost function is discussed. Section four presents the empirical model specification and the estimation techniques. Data source and study area description are elaborated in section five while section six discusses estimation results. Section seven concludes.

2 Previous Literature

Several studies have dealt with the analysis of water supply cost structure viewing it from different perspectives. Using a cross sectional data of 162 water undertakings, Ford and Warford (1969) derived a cost function in order to determine the unit cost of water supply industry in England and Wales. Results demonstrated that amalgamation of undertakings does not necessarily decrease costs and effect of amalgamation was shown to differ from case to case. Hayes (1987) examined the cost structure of the water utility industry in the USA by considering the water industry as multi-product firm for "wholesale" and "retail" product and examined if sufficient cost complementarity exists to justify joint "retail" and "wholesale" production. Results showed that joint retail and wholesale production should continue and the degree of economies of scope tends to fall over time for the largest firms and increase for smaller firms. Renzetti (1999) assessed the municipal water supply and sewerage treatment utilities in Ontario, Canada. His findings suggest that prices charged to residential customers are too low that they amount to only one third of the estimated marginal cost for water supply. Kim (1995) investigated the U.S water utilities by regarding the utilities as multi-product firm for "residential" and "non-residential" services and examined the pricing strategy of water services relative to marginal cost and second-best pricing. Results confirmed that the pricing structure and the marginal cost are quite different while the second best optimum is quite close to the then existing pricing structure. Fabbri and Fraquelli (2000) looked at the cost structure of the Italian water industry and demonstrated that evidence to returns to scale relies upon the functional form adopted and variables included. Garcia and Thomas (2001) analyzed the structure of municipal water supply costs in France taking 165 water utilities and using a time series data (1995 –1997). They regarded water industry as multi-product firm but unlike other multi-product views, here the multi product is "losses" and the "actual water produced". Their results provide evidence of significant economies of scale which indicates local communities' benefit from merger into water districts.

All the above studies and many others are within the context of developed countries. Relatively, analyzing the cost of providing water as such has not been an important concern in the developing countries' water economics literature. There are some, for example, Estache and Rossi (1999) compared the performance of public and private water companies in the Asia and Pacific region; Corton (2003) analyzed the implementation of benchmarking of the water sector in Peru. While Kirkpatrick et al. (2004) contrasted the water services efficiency between public and private utilities using data from developing countries; Nauges and van den Berg (2008) compared economies of density, scale and scope in four developing and transition countries namely Brazil, Moldova Romania and Vietnam.

However, these studies are not conclusive in terms of explicit accounting for the cost of water supply and to our knowledge no such attempt is made to estimate marginal cost of water supply and economies of scale of the water industry in South Africa. The contribution of the paper into the literature of water economics of South Africa is twofold: the estimation of marginal cost of water supply for WSAs, which could serve as important element in the water pricing strategy for WSA's. Another contribution is the returns to scale estimation which will perhaps impact the ongoing process of decentralizing WSAs from "district" to a "local" municipality level.

3 Theoretical Framework

In this section, the theoretical framework behind the translog cost function and the scale economies' estimates for the WSAs are explained.

Reflecting on the tradeoff between flexibility and globality, Guilkey et al. (1983) explained that when selecting a functional form, the choice is between flexible functional forms which are relatively complex but having the flexibility of modeling fairly sophisticated technology and those that exhibit good behavior globally as well as relatively simple but cannot model sophisticated technologies. Among the choices available are the Cobb-Douglas, Quadratic, Translog and generalized Leontief cost functions. The translog function currently enjoys widespread popularity among economists (Chung, 1994) and it can be considered as a second-order Taylor's series approximation in logarithms to an arbitrary cost function (Christensen et al., 1973). The translog function is the most flexible functional form. Furthermore, it does not require *a priori* the assumptions of homotheticity, separability, neutrality, constant returns to scale or unitary elasticities of substitution. In this study, following many other studies (Christensen and Greene, 1976; Babin et al., 1982; Renzetti, 1992; Kim, 1995; Fabbri and Fraquelli, 2000; Garcia and Thomas, 2001), the translog cost function is employed.

Let us assume that the cost of producing water (C_i) is represented by

$$C_i = C_i\ (p, y) \tag{1}$$

i = 1, …, n where i indexes refer to WSAs; p is the vector of strictly positive input prices, y is the output. Thus, the cost function is given by

$$C_i\ (p, y) = \min\ p.x,\ x \in v(y) \tag{2}$$

Where x is a vector of inputs and v(y) is the input requirement set. From the cost function, it is possible to derive the cost minimizing factor demand equations using Shephard's Lemma (Chambers, 1989)

$$\frac{\partial C(p,y)}{\partial p_i} = X_i(p,y) \tag{3}$$

Scale economies (returns to scale) (R_s) are important measurements for examining the potential for amalgamation and/or separation of industries in view of the economic benefits. This is especially vital for public industries. If there are economies of scale, larger firms can produce at lower average costs than smaller ones. Scale economies are defined as the relative increase in output as a result of a proportionate increase in all inputs. In a nutshell, scale economies are measured by the relationship between average and marginal cost (Kim, 1987).

Returns to scale (R_S) are the inverse of the elasticity of output ε_{CY} :

$$R_S = \frac{c(p,y)}{MC*Y} = \frac{1}{\varepsilon_{cy}} \tag{4}$$

Where $\varepsilon_{CY} = \partial \ln C / \partial \ln Y_i$, MC is the marginal cost $MC_i = C/Y_i \times \varepsilon_{CY}$ in which C is the fitted value of the cost function.

Economies of scale exist when $R_s > 1$, constant returns to scale exist, if $R_s = 1$, and decreasing returns to scale exist if $R_s < 1$. The important implication of this is that marginal cost pricing is not sufficient to recover costs for industries with economies of scale (Kim, 1987).

It is also essential to estimate the degree to which the marginal cost responds to changes in the variables affecting it. Following Kim (1987), the marginal cost elasticity of output Y, in relation to the own output is given by:

$$\frac{\partial \ln MC}{\partial \ln Y} = \frac{1}{\varepsilon_{CY}}\left[\alpha_{ii} + \varepsilon_{CY}(\varepsilon_{CY} - 1)\right] \tag{5}$$

The marginal cost elasticity of output Y in relation to input price P_j is expressed as

$$\frac{\partial \ln MC}{\partial \ln P_i} = \frac{\alpha_{Yi}}{\varepsilon_{CY}} + S_j \tag{6}$$

Where S_j is the cost share of input j

The calculation of own price elasticity is given by $\varepsilon_{ii} = \frac{\alpha_{ii}}{S_i} + (S_i - 1)$ (7)

And that of cross price elasticity is given by $\varepsilon_{ij} = \frac{\alpha_{ij}}{S_i} + S_j \quad i \neq j$ (8)

4 Empirical model Specification and estimation procedure

4.1. Model specification

In this section, we present the empirical model. The translog cost function and the factor share functions derived from the translog cost function are also demonstrated in some detail.

Given a cost minimizing behavior, the underlying technology of water supply is represented uniquely by a cost function. Translog cost function has been extensively used as it has proved to be the most flexible form in bridging the gap between theoretical and empirical research and more so it provides a second order approximation to any unknown cost function (Chung, 1994 and Christensen et al., 1973). The specification of the translog cost function proceeds as follows:

$$\ln C = \alpha_o + \alpha_Y \ln Y + \sum_i \alpha_i \ln P_i + \frac{1}{2}\alpha_{YY}(\ln Y)^2 + \frac{1}{2}\sum_i \sum_j \alpha_{ij} \ln P_i \ln P_j + \sum_i \alpha_{Yi} \ln Y \ln P_i + \in$$

$$i, j = 1,\ldots, n \qquad (9)$$

Where C is the total variable cost, Y is the output and P_i is the price of inputs. Extending the above equation (equation 9), yields the following:

$$\ln C = \alpha_o + \alpha_Y \ln Y + \alpha_L \ln P_L + \alpha_M \ln P_M + \alpha_K \ln P_K + \frac{1}{2}\alpha_{YY}(\ln Y)^2 +$$
$$\alpha_{LM} \ln P_L \ln P_M + \alpha_{LK} \ln P_L \ln P_K + \alpha_{MK} \ln P_M \ln P_K + \alpha_{YL} \ln Y \ln P_L + \alpha_{YM} \ln Y \ln P_M +$$
$$\alpha_{YK} \ln Y \ln P_K + \frac{1}{2}\alpha_{LL}(\ln P_L)^2 + \frac{1}{2}\alpha_{MM}(\ln P_M)^2 + \frac{1}{2}\alpha_{KK}(\ln P_K)^2 + \in \qquad (10)$$

Where P_L, P_M and P_K refer to the input price of labor, materials and capital, respectively.

The translog function is homothetic if $\alpha_{Yi} = 0$; homogenous of degree one in input prices if $\alpha_{YY} = \alpha_{Yi} = 0$ and linearly homogenous if $(\alpha_Y - 1) = \alpha_{YY} = \alpha_{Yi} = 0$. All the above constraints are verified at each data point4. Following Garcia and Thomas (2001) and Nauges and van den Berg (2008), we have imposed the above constraints by dividing the variable cost and input prices by the price of one input (in our case, price of capital is taken).

[4] Since the translog cost function does not satisfy the regularity conditions globally, it is necessary to check local properties at each data point (Kim, 1987).

In order for a dual cost function to be a well behaved function, it has to be non-decreasing in input prices (Chambers, 1989). The condition for the non-decreasing in input prices holds if $\partial C/\partial P > 0$ which is satisfied in our case (Table 2 in the results section). Theory also requires concavity in input prices such that matrix of coefficients (α_{ij}) is negative semi-definite and fitted values of cost shares are non-negative. This means that the bordered Hessian Matrix $(-1)^n\left|H_n\right| > 0$ or $\left[\partial^2 C/\partial P_i P_j\right] < 0$. The fitted cost shares are checked at each data point for their positivity to satisfy the monotonicity condition and all are found to be positive confirming the concavity and monotonicity conditions holding for the estimated function. Symmetry condition requires that $\alpha_{ij} = \alpha_{ji}, \forall_i \neq j$. In the estimated translog cost function, symmetry condition is already assumed *a priori*. Hence, it is already imposed in the system, thus we do not need to impose it during estimation.

Under the assumption that perfect competition prevails, P_i and Y are exogenous. Differentiating equation 2 with respect to each of P_i's, the left hand side of the resulting equation is given by:

$$\frac{\partial \ln C}{\partial \ln P_i} = X_i * \frac{P_i}{C} = S_i \tag{11}$$

Application of Shephard's Lemma yields the input share equations given by:

$$S_i = \frac{\partial \ln C}{\partial \ln P_i} = \alpha_i + \sum_j \alpha_{ij} \ln P_j + \sum_i \alpha_{Yi} \ln Y \tag{12}$$

Where $S_i = P_i X_i/C = \partial \ln C/\partial \ln P_i$, the share of total variable cost accruing to input i.

The cost share equation for the three inputs is specified as follows:

$$S_L = \frac{\partial \ln C}{\partial \ln P_L} = \alpha_L + \alpha_{LL} \ln P_L + \alpha_{LM} \ln P_M + \alpha_{LK} \ln P_K + \alpha_{LY} \ln Y + \in$$

$$S_M = \frac{\partial \ln C}{\partial \ln P_M} = \alpha_M + \alpha_{ML} \ln P_L + \alpha_{MM} \ln P_M + \alpha_{MK} \ln P_K + \alpha_{MY} \ln Y + \in$$

$$S_K = \frac{\partial \ln C}{\partial \ln P_K} = \alpha_K + \alpha_{KL} \ln P_L + \alpha_{KM} \ln P_M + \alpha_{KK} \ln P_K + \alpha_{KY} \ln Y + \in \tag{13}$$

Implied by the linear homogeneity in input prices, the share equation system (13) possesses the property that for each observation the sum of the cost shares (S_i) overall equations equals to 1 ($\sum_{i=1}^{n} S_i = 1$). Thus, if there are n factor share equations, only n-1 of them are linearly independent. One of the advantages of translog cost function is that for the translog functional form, homotheticity is not assumed *a priori*, and thus the factor share (S_i) of the cost is not independent of total output. The important econometric implication of the adding-up condition is that (Berndt, 1991) sum of the disturbances across equations must always equal zero such that the disturbance covariance matrix is singular and non-diagonal. More so, because the disturbance covariance and residual cross products will both be singular, Maximum Likelihood (ML) estimation will not be feasible. Thus, according to Berndt (1991), the most common procedure for handling this singularity problem is to drop an arbitrary equation and then estimate the remaining n-1 share equations by ML.

Arbitrarily dropping the S_k[5] equation, thus reducing the P_K , we get the following

$$S_L = \alpha_L + \alpha_{WL} \ln\left(\frac{P_W}{P_K}\right) + \alpha_{LL} \ln\left(\frac{P_L}{P_K}\right) + \alpha_{LM} \ln\left(\frac{P_M}{P_K}\right) + \alpha_{LY} \ln Y$$

$$S_M = \alpha_M + \alpha_{WM} \ln\left(\frac{P_W}{P_K}\right) + \alpha_{ML} \ln\left(\frac{P_L}{P_K}\right) + \alpha_{MM} \ln\left(\frac{P_M}{P_K}\right) + \alpha_{MY} \ln Y \qquad (14)$$

4.2 Estimation Procedure

Using Zellner's Iterative efficient method, we employ a system of Seemingly Unrelated Regression (SUR) procedure to obtain maximum likelihood estimates. Estimating only the translog cost function (equation 10) is possible; however information contained on cost shares would be neglected (Garcia and Thomas, 2001). Therefore, the translog cost function (equation 10) is estimated jointly with the cost share equations (equation 14).

[5] "As long as ML estimation procedures are employed on the n-1 share equations, all parameter estimates, log-likelihood values, and estimated standard errors will be invariant to the choice of which n-1 equations are directly estimated" (Berndt, E.R, 1991)

5 Data

The data is available at local municipality level for the years 2004 and 2006. The municipalities within the Middle Olifants and municipalities which lie partly in the Middle Olifants are included in the estimation. With a total of 50 WSAs examined for the two years, the total number of observations is 100. The main source of data for this study is the Treasury department of the Ministry of Finance of South Africa. Other sources include the Water tariff report of DWAF and the Census (2001) data. Unfortunately, the costs and revenues of water services are not ring-fenced in most municipalities of South Africa. Thus, data for some variables were difficult to disentangle from other general services of the Municipality and thus proxy variables were used instead, as will be explained below.

Data extracted from the Treasury Department include annual bulk in water purchase expenditure, annual water reservation and reticulation costs, number of water supply staff and the annual water staff expenditure (budget) and the rest costs of the service of water (for energy, materials and other recoverable costs).

Total variable cost (C) is the sum of "labor" (L); "capital" (K), which includes water reservoir and reticulation costs as well as other "material "costs (M) which include energy and other materials costs. Other variables include the unit price of labor (P_L), water output (Y), price of capital (P_K), and price of materials (P_M). P_L is computed by dividing staff cost involved in water supply over the number of staff in the WSA engaged in water services, which gives us the average expenditure per person per year. Y is defined as the volume of water available for distribution (sale) to final customers by WSAs, obtained by dividing annual bulk in water purchase expenditure by P_w. P_K is defined as the ratio of the total annual expenditure for water reservoir and reticulation to the total volume of water output available for sale/distribution (Y). Other costs (M) consists of heterogeneous costs and thus unit price (P_M) is difficult to achieve. Hence, following Garcia and Thomas (2001), we construct a price index as a unit cost per cubic meter of water delivered.

Descriptive statistics for the data are shown in Table 1. On average, the annual cost per year for water services amounts to about 29 million Rands[6]. The volume of water purchased by the WSAs is equivalent to about 58 liters per person and day which exceeds the free basic water

[6] This cost excludes the annual average expenditure for bulk water purchase of about 10 million Rands. It was excluded from the calculation of total variable cost because it is also used for the calculation of the water output by dividing it to price of water and thus it was excluded to avoid simultaneity problem (National Treasury South Africa (2006).

entitlements [7](25 liters per person and day) according to the National Water Act. The cost share is also higher for capital followed by materials; labor cost accounting the least share. The average tariff for bulk water purchase by WSAs is also 3.6 Rands per cubic meters. The backlogs rate, which illustrates the percentage of the population with no basic access to basic water services, accounts for 26 per cent of the population.

Table 1: Descriptive Statistics

Variables	Notation	Mean	Std. error	Minimum	Maximum
Total variable Cost (R'000) per year	c	28649.49	2117.115	24447.05	32851.94
Water output (m^3 '000) per year	Y	3090.57	345.652	2404.45	3776.68
Price of bulk water (R/m^3): [charged to WSAs]	P_w	3.62	0.033	3.55	3.68
Price of labor (R'000/person/year)	P_L	77.91	1.821	74.30	81.53
Price of materials (R/m^3)	P_M	25.86	2.753	20.39	31.32
Price of capital (R/m^3)	P_K	31.48	10.394	10.84	52.11
Labor share	S_L	0.16	0.008	0.14	0.17
Capital share	S_k	0.47	0.018	0.44	0.51
Materials share	S_M	0.37	0.022	0.32	0.41
Population (in '000s)	Pop	264.21	27.316	209.98	318.43
Poverty rate	Pov	0.54	1.279	51.66	56.74
Backlogs rate	Brate	0.26	0.017	0.22	0.29
Per capita water (l/P/day)	ppw	58.74	6.95	44.96	72.53

Source: Own estimation (based on Data from National Treasury – South Africa and Census SA, 2001 data)

7 In South Africa, the National Water Act (1998) entitles every individual living in South Africa a free basic water of 25 liters per person per day or 6 kilo liters per month per household (It is also mentioned in the introduction section).

6 Empirical Results

This section describes the estimation results. Parameter estimates of the translog cost function are reported in Table 2. A well-behaved function must satisfy certain conditions including positivity, linear homogeneity in prices, concavity and monotonicity. Linear homogeneity in input prices was imposed during estimation. The eigenvalues of the Hessian Matrix, evaluated at the sample means, are all negative satisfying the concavity condition. The fitted values of the cost share equations are also all positive confirming the monotonicity condition fulfilled.

The coefficient of the output variable (α_y) has the expected positive sign. Estimation result of 0.542 means that a ten percent increase in the volume of water induces a 5.42 percent increase in variable cost. A ten percent increase in price of labor and capital cause of 4.7 percent $(\alpha_L)$and 3.4 percent (α_K) increase in the variable cost respectively. In order to control for the time effect, a dummy variable was included in the estimation. It was insignificant indicating there was no significant technology change that can influence the cost structure between years 2004 and 2006. With a 0.99 R^2, the model is robust and the explanatory variables can explain the dependent variable well.

Table 2: Estimates of Translog and cost share equations using Iterated Zellner's efficient method

Parameter	Coefficient
α_o	2.270 (0.227)***
α_y	0.542 (0.077)***
α_{yy}	0.069 (0.013)***
α_L	0.469 (0.056)***
α_K	0.339 (0.030)***
α_M	0.193 (0.060)***
α_{LM}	-0.045 (0.010)***
α_{LK}	-0.029 (0.004)***
α_{LL}	0.075 (0.010)***
α_{KM}	-0.121 (0.004)***
α_{KK}	-0.151 (0.004)***
α_{MM}	0.166 (0.011)***
α_{YL}	-0.071 (0.010)***
α_{YK}	0.046 (0.011)***
α_{YM}	0.246 (0.005)***
Year (dummy)#	0.016 (0.015)
R^2	0.997

Standard errors in parentheses *** significance at 99% level

#Year 2004 =1, Year 2006 = 0

Source: Own estimation (based on Data from National Treasury – South Africa)

Table 3 shows the own and cross price elasticity estimations. In line with theory, we have negative and significant signs for the own price elasticities which shows that an increase in input price decreases the demand. The own price elasticity of -0.373 for labor, for example, means a ten percent increase in the price of labor will bring about 3.73 per cent decrease in the demand for labor. The same interpretation applies to the other variables as well.

Table 3: Own and cross price elasticities

	E_M	E_L	E_K
E_M	-0.180(0.029)***	0.038(0.026)	0.142(0.011)***
E_L	0.088 (0.061)	-0.373 (0.061)***	0.284 (0.023)***
E_K	0.112(0.009)***	0.097 (0.008)***	-0.851 (0.008)***

Standard errors in parenthesis *** significant at 99% level
Source: Own estimation (based on Data from National Treasury – South Africa)

Table 4 presents the average cost, average price paid by consumers, marginal cost, returns to scale, elasticity of output and marginal cost elasticities, calculated at the sample mean. The marginal cost of 8.17 R/m^3 demonstrates that providing an additional m^3 of water needs an investment of 8.17 Rands. A comparison of price paid by consumers of 3.05 R/m^3 (in Table 5) and the marginal cost shows that there is a huge difference of what it costs the WSAs to supply an additional m^3 of water and the price paid by consumers. Thus scaling-up the price to the level of marginal cost would partly assist WSAs in recovering the cost of water supply. The cost elasticity of output also shows that a ten percent increase in water output brings about an increase of 8.6 per cent in the total costs. The returns to scale of 1.16 also mean that an increase in input by ten per cent brings about 11.6 per cent increase in output reflecting the advantage of economies of scale. This has important policy implication that merging WSAs will have the benefit of cutting WSAs' costs. This is especially relevant in the context of South Africa in which the authority of supplying water is being decentralized and in the process of being scaled down to local municipalities' level.

The own marginal cost elasticity of output has a value of -0.056 (Table 4) which means that a ten percent increase in output brings about 0.5 per cent decrease in marginal cost of supplying water. As expected, the marginal cost elasticities with respect to input prices are all positive (Table 4) which implies that when the price of inputs increase, the marginal cost of an output tends to increase.

Table 4: Estimation results of Average Cost, Marginal Cost, Elasticity and Returns to scale

Average cost (in R/m^3)	31.87
Average price paid by domestic users* (R/ m^3)	3.05
Marginal Cost (MC) in R/m^3	8.17
Cost Elasticity of output	0.86
Returns to scale	1.16
MC Elasticity w.r.t. Labor price	0.077
MC Elasticity w.r.t. Capital price	0.655
MC Elasticity w.r.t. Materials price	0.523

* Computed from water tariffs document of DWAF taking the total water supplied (inclusive of the free water 6 kilo liters per month per household)

Source: Own estimation (based on Data from National Treasury – South Africa)

The measures included in Table 4 are further considered as we regard three groups[8] of WSAs, based on the volume of water distributed (Table 5). The average cost tends to decline with the increase in the size of the WSA characterizing the advantages of saving costs because of economies of scale. The declining marginal cost with the increase in the size of the WSA is further evidence to the prevalence of the economies of scale. Marginal cost is at its lowest in the "Large" WSA group though the marginal cost figures are similar in the "Medium" and "Large" groups, while the returns to scale are at its highest for the "Medium" group.

[8] By ordering the WSAs according to the volume of water distributed annually (from low to high) three groups are made thus taking the first tercile as "small", the second being "medium" and the last as "large" WSA in that order.

Table 5: Elasticities and returns to scale for WSAs ranked with respect to the size of the WSA [Volume of water distributed annually (Y)]

	Small (Y < 1.2 mm³/year) N=26	Medium (1.2 ≤ Y < 3.4 mm³/year) N=35	Large (Y ≥ 3.4 mm³/year) N=32
Average Cost (R/m³)	58.2068	11.3437	6.2173
	(9.7312)*	(1.7116)	(0.9316)
Marginal Cost (R/m³)	13.2551	6.6868	6.5233
	(9.0887)	(2.1600)	(2.7036)
Cost elasticity of output	0.8744	0.8519	0.8673
	(0.0111)	(0.0073)	(0.0082)
Returns to scale	1.1485	1.1769	1.1563
	(0.0154)	(0.1025)	(0.0111)

Source: Own estimation (based on Data from National Treasury – South Africa) Figures in parentheses are standard errors

7 Conclusions and Policy implications

The study presents the marginal cost and returns to scale estimates for water supply calculated at mean levels as well as disaggregated across three size groups of WSAs. Estimation results have indicated that marginal costs are higher than the actual tariffs that WSAs charge to consumers. Thus, we conclude that setting a water price at a value somewhat equal to the marginal cost would bring about two positive effects. The first is that charging a higher price will partly assist WSAs in recovering the cost of supplying water (on the condition that the extra cash generated from the higher price will be invested in water infrastructure). Furthermore, higher price would translate into an improved water use efficiency assuming that people will be more careful about the water use if the charges for water are set at a relatively higher price. According to the estimation results calculated at mean levels, increasing returns to scale prevail indicating that merging WSAs would be economically advantageous. Thus, reversing the existing trend of supplying water at the local municipality level and up-scaling WSAs to the district level is an important policy option for water services efficiency. Categorizing WSAs into three groups according to size (volume of water distributed) also shows that the "Large" group yielded a relatively smaller marginal cost and the "Medium" group returned the highest returns to scale estimates indicating that the optimal size of WSA should lie somewhere within the "Large" and/or "Medium" group.

References

Babin, F.G., C.E. Wills and P.G. Allen. 1982. Estimation of substitution possibilities between water and other production inputs. American Journal of Agricultural Economics. Vol. 64. No. 1 Pages 148 – 151.

Berndt , E. R. 1991. The practice of Econometrics: Classic and contemporary. Addison Wesley Publishing Company.

Christensen, L.R. and W.H. Greene. 1976. The Journal of Political Economy. Vol. 84. No. 4. Pages 655- 676.

Christensen, L.R., D.W. Jorgensen and L.J. Lau, 1973. Transcedental Logarithmic Production frontiers. Review of Economics and Statistics. Vol. 55. Page 28-45.

Chambers, R. K. 1989. Applied production analysis: A dual approach. Cambridge University Press.

Chung, J.W. 1994. Utility and Production functions: Theory and applications. Blackwell Publishers. Cambridge, Massachusetts, USA.

Corton, M.L. 2003. Benchmarking in the Latin American water sector: The case of Peru. Utilities Policy. Vol. 11. Page 133 – 142.

DWAF. 2000. Directorate Water Resource planning. Economic Information System: An Associated Economic reports by Province and Water management Area. CD Version 1.1

DWAF. 2003. Directorate: Water Resources Planning Internal Strategic Perspective. Olifants River WMA Version 1. March 2004.

Estache, A. and M.A. Rossi. 1999. Comparing the performance of public and private water companies in the Asia and Pacific Region: What a stochastic frontier shows. Policy Research working paper. The World Bank.

Fabbri, P. and G. Fraquelli. 2000. Costs and structure of technology in the Italian water industry. Empirica 27: 65-82.

Free Encyclopedia. 2007. Water Supply ad Sanitation in South Africa.

Ford, J.L. and J.J. Warford. 1969. Cost functions for the Water Industry. The journal of Industrial economics. Vol. 18. No. 1. Pages 53-63.

Garcia, S. and A. Thomas. 2001. The structure of municipal water supply costs: Application to a panel of French local Communities. Journal of Productivity analysis. 16. 5-29

Greene, W. 2006. Econometric analysis, 5th edition. Prentice hall. Pearson Education International

Guilkey , D. K., C.A. Knox and R.C. Sickles. 1983. A comparison of the performance of three flexible functional forms. International economic review. Vol. 24. No. 3 591 – 616.

Hayes, K. 1987. Cost structure of the water utility industry. Applied Economics. Vol. 19. No. 3. 417- 425

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change and water. IPCC Technical report number 4.

Kim, H.Y. 1995. Marginal Cost and second best pricing for water services. Department of Economics, Western Kentucky University, Bowling Green, KY 42101-3576. USA.

Kim, H.Y. 1987. Economies of scale in multi-product firms: an empirical analysis. Economica, New series. Vol. 54. No 214 pp 185-206.

Kirkpatrick, C., D. parker and Y. Zhang. 2004. State versus private sector provision of water services in Africa: An empirical analysis. Centre on Regulation and Competition

Institute for Development Policy and Management University of Manchester UK and School of Management Cranfield University Cranfield, UK

National Water Resources Strategy (NWRS), 2002. Chapter 2: South African Water situation and strategies to balance water supply and demand.

National Treasury. 2006. Local government budgets and expenditure review 2001/2 – 2007/8.

National Water Act. 1998.. Republic of South Africa Government Gazette. Cape Town. South Africa

Nauges, C. and C. van den Berg. 2008. Economies of density, scale and scope in the water supply and sewerage sector: A study of four developing and transition economies. Journal of Regulatory Economics. Vol. 34. Number 2. 144 - 163

Ottermann, A., G. Blecher, J. du Plessis and the BI Support team. 2007. Water Services Tariffs 2006/2007. Prepared for DWAF's Water Services Planning & information (Mr Allestair Wensley).

Renzetti, S. 1992. Estimating the structure of Industrial water demands: The case of Canadian Manufacturing. Land Economics. Volume 69. No. 4 Pages 396 - 404

Renzetti, S. 1999. Municipal water supply and sewerage treatment: Costs, prices, and distortions. The Canadian journal of economics. Vol. 32. No. 3. Pages 688 - 704

UNESCO. 2003. World Water Assessment Program (WWAP). The United Nations World Water Development Report. UNESCO Publishing, Paris.

WRP. 2007. Towards the establishment of water market institutions for effective and efficient water market allocation, WRC K5/1569.