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The Upshot of Autonomy and Efficiency of Urban Water Service Providers in Uganda and Tanzania

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Abstract

The theoretical and empirical debate on the effect of managerial autonomy on the efficiency of urban utilities is still ongoing, yet limited research has been conducted in the water sector in developing countries. To address the gap, this paper gives empirical evidence on the effect of managerial autonomy on the efficiency of urban water service providers in Uganda and Tanzania.

Using the managerial autonomy index and Data Envelopment Analysis (DEA), information from performance and management contracts, utility annual financial reports, partnership deed agreements, water policy statements, and results of 66 respondents was used to determine the level of managerial autonomy and efficiency in the 30 Decision Making Units (DMUs) of NWSC in Uganda and DAWASCO in Tanzania. The effect of managerial autonomy on efficiency was determined using Tobit regression analysis.

The results show the mean managerial autonomy level of 47% implying that Head Office (HO) of water utilities has given limited autonomy to the different Decision Making Units (DMUs). Most of the DMUs have no or limited autonomy on procuring assets for their units, entering loan agreements, approving the annual report, and determining staff compensation. The fully efficient towns (1.00) are four and the mean efficiency level is 0.63. The Tobit regression model indicates that the adoption of managerial autonomy significantly (Prob>chi2 = 0.0006) contributes to efficiency.

The findings indicate a high likelihood of managerial autonomy causing a change in the efficiency of urban water utilities. The position that an increase in managerial autonomy will cause the likelihood for technical efficiency to decrease, could be expected in the event that the principal (HO) who grants autonomy may not keenly and continuously supervise and monitor the activities of the agent (DMU). Urban water utility managers should put in place an appropriate structural framework to govern the relationship between the water utility HO and the DMU. Besides this, the utility head office should delegate decision making powers to the DMUs based on a clear framework.

Keywords: Autonomy; Public sector reforms; Efficiency; DEA; Decision making; Water reforms

Introduction

Water utilities globally, and in developing countries specifically, have been undergoing significant reforms since the 1990s with a view to efficiency improvement. One dimension of the reforms is fostering managerial autonomy at various levels of service delivery [1]. Autonomy is one of the key aspects of public sector service reform that focuses on decentralization of authority and empowering people at lower levels to take full responsibility of what they control [1]. Based on evidence collected in the early 90s suggesting that autonomy improves performance, many water utilities were restructured to foster autonomy. To date, water utilities like National Water and Sewerage Corporation (NWSC) and Dar es Salaam Water and Sewerage Corporation (DAWASCO) are fostering managerial autonomy of their Decision Making Units (DMUs). Limited empirical evidence has been collected on whether fostering autonomy between the water utility Head Office (HO) and the DMUs improves efficiency. Using responses from 66 respondents, a managerial autonomy score for each DMU was determined. Also DEA efficiency scores computed using Operating Expenses as a composite input variable and water billed and Non Revenue Water as output variables. A link between managerial autonomy and efficiency was determined by regressing the autonomy scores against the efficiency score. The conclusion of this study is that that the adoption of managerial autonomy significantly (Prob>chi2 = 0.0006) contributes to efficiency.

Water service delivery reforms with persistent challenges

Despite the reforms in the water sector [2,3], water services provided especially in developing economies are still inadequate [4-7]. Nearly I billion of the world's people, especially in developing countries, do not have adequate[1] supply of water [8].

[1] adequate" defined as a single water tap shared among hundreds of people.

The inadequate services are illustrated by low coverage which in Sub-Saharan Africa ranges between 50-75% [8]. Indeed in Sub-Saharan Africa only 15% of the total population access piped water, and 48% use improved sources. Other water service problems are high NRW [9], inefficient billing and collection practices [10], poorly maintained infrastructure [11] and unaffordable water tariffs especially by low income earners are attributes of inadequate services.

The inadequate water services offered have serious financial, productivity and health costs [8]. Such consequences are faced by especially low-income earners who are usually the victims of this type of service. Every year 2 million people, mostly children, die due to diarrheal diseases associated with inadequate water supply, sanitation and hygiene [8]. Mara [6] acknowledges that inadequate water supplies are responsible for a large proportion of disease transmission in rural and peri -urban areas in developing countries.

Kagiri [12], reported that Mityana town in Uganda with the estimated population of 38,700 people spent days without water forcing hotels and offices to close and residents to trek long distances in search for water. Kagiri continues that the cause of the problem was the breakdown of the transformer and the main water pump that was vandalized. Commenting on the status of the water sector, Semberya [13] reports that 46% of Tanzanians don't have access to water.

Clearly the water problems of insufficient service delivery are eminent in NWSC in Uganda and DAWASCO in Tanzania despite the reforms adopted.

The above problems and challenges have led to poor technical and financial performance of water utilities as illustrated in Table 1.

Performance Dimension	Uganda (NWSC)	Tanzania (DAWASCO)	Bench Indicator
Number of connections	2,85,418	1,30,964	
Coverage rate	80%	40.70%	>90%
Staff / 1,000 connections	6	6.2	<5 to 7
NRW	33.60%	55.50%	<20%
Water production per day (m^3)	2,60,595	2,57,835	
Annual turnover	Ushs. 168.7.4billion	TZS 39.73billions	

Table 1: Technical and financial performance of major water service providers in Uganda and Tanzania. Source: NWSC [14]; EWURA [15].

As shown in Table 1, the performance of the major water service providers indicated above is still below the benchmark indicators[2] of well performing water utilities in Africa particularly on coverage and NRW.

Theoretical and Empirical Trend of Managerial Autonomy and Efficiency

The public administration literature asserts that autonomy is central to performance. Autonomy of state owned enterprises was a key factor in the 1980s [16]. Ayub and Hegstad [16] asserted that lack of autonomy in managing public utilities leads to weak financing discipline and low productivity. Subsequent studies in the 1990s also drew related conclusions that greater managerial autonomy from government is associated with better performance [17,18]. Hoffer's [19] in-depth analysis of four water utilities led him to conclude that autonomy is a key determining variable for effective urban water supply. Based on evidence supporting the view that increased managerial autonomy improves performance, a number of countries embarked on reforms aimed at increasing autonomy of water utilities. Such reforms tended to focus on changing the legal status of organisations. The assumption was that by segregating the functions of oversight and service delivery, autonomy would be enhanced.

Verhoest et al. [20] using data of 84 organisations concludes that autonomy is not linked to the formal legal status in a straightforward way. The researchers were a bit pessimistic on the positive autonomy performance link. They conclude that there is little observable correlation between the legal form and mode of operation.

The consensus view is that autonomy matters for the performance of public service providers. However, there is considerable debate on the autonomy efficiency relationship [1,21]. Several issues complicate research on autonomy efficiency relationship. Defining performance especially in the public sector is a challenge where there is no consensus on proxy indicators of performance. Also, autonomy has managerial (internal autonomy) and structural (external autonomy) dimensions [22]. This makes it problematic to measure. While some researchers have identified autonomy as one of the key factors that influence performance other researchers [23] could not attribute efficiency improvements to autonomy.

Autonomy and performance

A number of countries have embarked on reforms aiming to improve performance of public sector organization by enhancing their autonomy. These reforms have focused on changing the legal status of organizations embedded in the public sector. The belief was that unbundling organizations would create an arms' length relationship between organizations delivering the service and oversight organizations. From a study of 84 organisations, Verhoest et al. [20] conclude that autonomy is multidimensional and that it is not directly linked to the legal status. This implies that attempts to measure autonomy must rely on observations of managerial decision making. For purposes of this research autonomy has been defined as the degree of managerial discretion, that is, the executive ability to affect organizational outcomes.

Batley [22] conducted a cross country research and found out that greater managerial autonomy from government is associated with better performance. This is because, where managers have the freedom to manage, they are freed from bureaucratic rules and controls. Indeed Hoffer's [19] study of four water utility companies leads him to a conclusion that autonomy is a key determining variable for effective urban water supply. Groves et al. [24] and Chang et al. [18] conducted quantitative research on Chinese public enterprises that led then to a conclusion that autonomy increases staff productivity.

Some researchers have shown that improvement of performance can be found in increased financial autonomy of a service provider

[2] The indicators used are from Nwasco report of 2012. These are the indicators used in Zambia to assess the performance of different water service providers.

[1,19,22-24]. These researchers take a limited view of autonomy. Other aspects of autonomy like employment, procurement and customer management were not considered.

Managerial autonomy

The structural autonomy is supported by managerial autonomy where people at lower levels in the utility are allowed to take decisions. Well structured performance agreements encourage increased managerial and operational autonomy through the decentralization of decision making to the business units serving the customers [25]. Performance agreements hence target improved performance by breaking down overall strategic goals into specific operational processes and output oriented targets in exchange for increased operational autonomy and performance-related remuneration. Performance related remuneration motivates the operator to become more accountable for delivering on targets and for improving services in a cost-effective manner.

Attributes of managerial autonomy

Researchers [1,20] have developed various dimensions of managerial autonomy as shown in Table 2.

Dimension of managerial autonomy	Relevant powers
Employment policies and practices	Powers to determine rules that govern employee salary levels, promotion/demotion, personnel evaluation, and staff appointment.
Operational autonomy concerning human resource management.	Power to confer secondary employment benefits, to promote / demote, to appoint staff, and to evaluate staff.
Financial management	Power to borrow, determine charges, participate in private law entities, shift budget between budget lines, and shift financial resources between accounting periods.
Procurement	Power to procure goods and services, and non-current assets.
Customer management	Power to bill and collect water service revenues, terminate water service delivery

Table 2: The managerial autonomy construct [1]. Source: Verhoest et al. [20].

In their study, Braadbaart et al. [1] developed a managerial autonomy index, which the researchers say displays a high degree of internal consistency. From their research of 22 utility organizations, the researchers conclude that there is an association between autonomy and key performance variables (service coverage, revenue water, water tariff, bill collection ratio, labour productivity and the quality of financial reporting). The results indicated strong positive associations between autonomy and key performance indicators of a water utility. The conclusion drawn was that managerial autonomy is central to the performance of a water utility.

Method

Both quantitative [26] and qualitative designs [27] have been used. This design was selected because the study involves an empirical investigation of "a contemporary phenomenon within its real context using multiple sources of evidence". Additionally, the boundaries between the phenomenon being studied and the context within which it is being studied are not clearly evident [27]. This choice is also based on consideration of the research questions, existing knowledge on autonomy and efficiency [28].

Choice of two utilities

NWSC in Uganda and DAWASCO in Tanzania were selected because both cases were initially typical public utilities and now both are following the principles of New Public Management that advocate for managerial autonomy among other considerations. However, over the ten years (2000–2009), the two corporations have followed different reform routes. All the towns of NWSC were managed by the corporation apart from Kampala which was managed by private international operators from 1998 to 2005. Dar es Salaam water on the other hand was managed under a lease agreement between 2003 and 2005. When the lease contract was terminated before its maturity DAWASCO was formed to manage water services in Dar es Salaam.

Apart from the differences in the reform routes taken, the performance of the two utilities varies greatly. NWSC is being referred to as a high performing water utility in Sub-Saharan Africa [9,23]. In contrast DAWASA/DAWASCO is commonly identified as a below average performing water utility [4,29,30]. Kisanga for instance reported Dar es salaam Water and Sewerage Company (Dawasco) has been named the worst water utility firm in the country, having failed to curb water loss, theft, improve services and infrastructures.

Table 3 shows the general characteristics of NWSC and DAWASCO in terms of service coverage, population in the service area, quantity of water produced, staff per 1000 connections, network length and Non Revenue Water percentage.

Utility name	Service coverage	Service area (pop)	Drinking water production (m3/ day)	Staff / 1000 connections	Network length (m)	NRW %
NWSC	80%	2,986,773	260,595	6	5,499.40	33.6
DAWASCO	40.70%	3,236,961	257,845	8	2,634	55.5

Table 3: Performance characteristics of NWSC and DAWASCO for 2013. Source: NWSC Report [14]; Water Sector Status Report.

Decision Making Units (DMUs) of NWSC and DAWASCO have been used as units of analysis. Data for 20 DMUs of NWSC and 12 from DAWASCO for the year ending June 2013 has been used. The new DMUs of NWSC that were taken on by the utility in recent years have not been included.

Measuring managerial autonomy

Measuring managerial autonomy is a daunting task. Based on strategic leadership literature, Hambrick and Finkelstein [31] defined managerial autonomy as the level of managerial discretion viewed in terms of the latitude of managerial action. Carpenter and Golden [32] build on this notion by defining managerial autonomy as the executives' ability to effect important organizational outcomes. For this study managerial autonomy is conceptualized as the level of managerial discretion for a particular decision making unit. The conceptualisation is similar to that adopted by Braadbaart et al. [1] and

Mukokoma and Van Dijk [10] while assessing the level of managerial autonomy.

Information from performance and management contracts, utility annual financial reports, partnership deed agreements, water policy statements, and findings from 66 respondents was used to determine the level of managerial autonomy in the 30 DMUs. The current management of each DMU was asked about the degree of autonomy on fifteen (15) items. For each item, management was asked to indicate whether the decision is or can be made; exclusively by the DMU, by the DMU in consultation with Head Office, or by Head Office entirely. The response to the questions was used to construct a managerial autonomy index. A score of 1 was assigned for a decision made exclusively by the DMU, 0.5 for a decision made by the DMU in consultation with Head Office, and 0 for a decision made exclusively by Head Office.

Interpreting and explaining DEA efficiency results

As a linear programming technique, DEA finds a weighting system that allows inputs and outputs each to be aggregated and efficiency scores to be calculated. No single set of weights is required. Rather, by repeated solutions, DEA finds a set of weights for each DMU. The weights are those that are most favourable to the unit. The maximum efficiency score that can be obtained is 1(highly efficient) while the lowest score is 0 (not efficient). At its simplest, an efficiency score of 0.8 indicates that the unit could (by following practices of selected efficient DMUs) reduce each of its inputs by 20% and maintain the current level of output.

Tobin suggested the Tobit regression model as an appropriate multivariate statistical tool in the second stage to consider the characteristics of the distribution of the efficiency measure. The Tobit describes the relationship between a non-negative dependent variable which in this study are the DEA efficiency scores and an independent variable which is the NPM reform. This is considered to be an appropriate analysis for this study because the DEA efficiency scores are characterized of censored data which cannot be higher than unity. The DEA scores are limited to the interval of 0 to 1 and accordingly only have a positive probability to attain one of the two corner values. Second stage DEA seeks to relate such efficiency scores for a given group of DMUs to a number of exogenous variables believed to influence the level of efficiency. De Borger et al. [33] proved that Tobit regression can also account for truncated data. Hoff [34] compared Tobit and OLS regressions for modeling DEA scores in the second stage analysis. He concludes that Tobit approach will in most cases be sufficient in representing a linear approximation of the models. Hoff [34] explains further that OLS model will clearly predict scores outside the interval (0;1), thus for this study Tobit regression has been used and OLS simply used as a benchmark analysis. Indeed quite a number of studies have of recent have used Tobit approach at the second stage analysis of the efficiencies. For example Coelli [35], Garcia [36], Kirkpatrick et al. [37], Ndandiko [38] have used a similar approach to assess efficiency in water utilities.

The general Tobit model formulation with limited dependent variable as proposed by Greene (2003) is given by:

$$y_i^* = X_i \beta + \varepsilon_i \qquad (1)$$

Where y_i^* is the latent variable; X_i represents the vector of explanatory variables; and β are the parameters to be estimated. It is assumed that the errors are normally distributed, with mean zero and variance σ^2, $\varepsilon_i \sim N(0,\sigma^2)$.

Considering that in the study efficiency scores were defined by DEA, where the limit for a unit to be efficient is 1, the observed variables (y_i) are defined as follows:

$y_i = 1$ if $y_i^* > 0$,

0 if $y_i^* \leq 0$ .y_i else

The Tobit coefficients can be interpreted in terms of the magnitude, direction, and significance of the coefficients. Such interpretations can verify theory, confirm prior research, or provide information of the effect on an independent variable across all dependent variables.

Efficiency scores can be analysed using descriptive statistics and trend analysis. Garcia and Muniz [39] used three Spanish Municipalities to assess their efficiency over six years with a view to guide regulation in the water sector.

This study has used descriptive statistics, trend analysis, and Tobit regressions to explore and explain efficiency. As a preliminary stage an explanation of the descriptive and trend data of the efficiency scores has been made. Thereafter a regression of the NPM dimensions of segregation of functions, market orientation, customer orientation, managerial autonomy and accountability for results against the DEA efficiency score has been run.

Findings, Analysis and Implication

Level of managerial autonomy in NWSC and DAWASCO

Contracts between Head Office (HO) and Decision Making Units (DMUs) are intended to increase managerial autonomy through the decentralization of decision making to the DMUs. The focus of this study was on the extent to which powers have shifted from HO to the DMUs as shown in Table 4.

The current management of each DMU was asked about the degree of autonomy in each of the 15 decisions areas. For each decision, management was asked to indicate whether the decision is or can be made; exclusively by the DMU, by the DMU in consultation with Head Office, by Head Office entirely. The response to the questions was used to construct a managerial autonomy index. A score of 1 was assigned for a decision made exclusively by the DMU, 0.5 for a decision made by the DMU in consultation with Head Office, and 0 for a decision made exclusively by Head Office.

Table 5 shows autonomy scores of the 30 DMUs used in this study on the 15 autonomy index items. The results indicate that most of the DMUs have no or limited autonomy on procuring assets for their units, entering loan agreements, approving the annual report, and determining staff compensation.

Using SPSS 19 the managerial autonomy scores for the 30 DMUs were computed. Also the technical efficiency scores for 30 DMUs (18 for NWSC and 12 for DAWASCO) were calculated using DEA Banxia Frontier Analyst 4 Software to identify the most and least efficient DMUs based on the chosen relevant multiple inputs and outputs. Table 6 gives the descriptive statistics of managerial autonomy showing the minimum, maximum, mean and standard deviation.

The results in Table 6 show the mean managerial autonomy level of 47% implying that HO has given limited autonomy to the different DMUs. Interviews with the management of NWSC indicated that since 2006 there has been an increase in the level of internal autonomy by powers being shifted from HO to DMUs through Internally Delegated Area Management Contracts (IDAMCs).

	Low autonomy		High autonomy	
Autonomy dimension	HO	DMU	HO	DMU
Employment policies and practices	Hire and fire, promote/ demote, determine staff compensation system, internal work processes and standards.	Produce records on employment practices.	Sets policies with secondment for hiring, promotion and pay increments.	Hire and fire, promote/ demote, determine staff compensation system, internal work processes and standards for some levels.
Financial management	Power to set water tariff structure and level, enter loan agreements, approve annual financial report.	Account for funds disbursed	Power to set water tariff structure	
			approve annual financial report, investment decisions, financial flow control, operational costs like power, chemicals, maintenance and salaries of seconded staff.	Prepare business plans
				Identify funding opportunities, influence some operational costs.
Procurement	Budget for items to be procured.	Requisition and Receive procured items.	Provision of logistics Procurement of non-current assets.	procure routine operational goods and services.
Customer management	Power to bill and collect water service revenues, terminate water service delivery.	Produce customer records as needed by HO	Conducting customer audits, customer data management .	Power to bill and collect water service revenues, terminate water service delivery.

Table 4: Shift of powers from Head Office (HO) to the DMU.

The adoption of the IDAMC concept effectively transformed NWSC's towns into a series of quasi-private, ring-fenced, and autonomous business units.

A follow-up interview with the managing director of NWSC on the level of autonomy revealed that, "there is need to balance the level of autonomy with the need to centralize so as to foster efficiency especially in the procurement of inputs". Nevertheless a lot has changed since the year 2000.

Before the year 2000 managers at the DMUs had powers to procure simple items like sugar and tea. All major goods and services were procured centrally by HO. DMUs had no control over prices, quality of goods, delivery cycles, etc.

Autonomy index item	SCALE		
	1 (DMU)	0.5 (DMU and HO)	0 (HO)
1. Billing and collection	11	15	4
2. Offering customer care services	19	7	4
3. Termination of water service provision	8	17	5
4. Entering loan agreements	0	2	28
5. Procuring goods and services	13	14	3
6. Procuring assets			30
7. Hiring and firing staff	3	15	12
8. Determining staff compensation		10	20
9. Determine internal work standards	10	11	9
10. Determine internal work processes	13	12	5
11. Appraise employee performance	17	10	3
12. Monitoring leakages and thefts	19	11	
13. Preparation of work plans	22	7	1
14. Preparing performance reports	23	5	2
15. Approve annual report	0	6	24

Table 5: Raw scores for managerial autonomy index items for 30 DMUs.

Item	Level of Autonomy (N = 30)
Min	33%
Max	70%
Mean	47%
SD	0.12
NO.	30

Table 6: Descriptive statistics of level of managerial autonomy and DEA efficiency.

To change this, in line with the procurement legislation, NWSC and DAWASCO appointed delegated contracts committees at the DMUs to oversee the decentralized procurements. For NWSC the decentralization process was most effective during the era of Area Performance Contracts (APCs) and Internally Delegated Area Management Contracts (IDAMCs). DAWASCO by 2009 did not have

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effective procurement committees at the DMU level. In an interview, the managing director of DAWASCO said that, "autonomy of the DMUs has to be matched with the level of trust and professionalism of the managers in the DMUs".

Interviews with managers at the DMUs of NWSC and DAWASCO indicated that there are some autonomy challenges. Some managers at the HO could not let go of their cherished powers. Indeed there is perceived interference from the HO managers under the guise of strategic guidance. Responses from Head Office (HO) of the two water utilities indicated that some managers at DMUs tended to abuse portions of delegated powers through irregularities in staff recruitment and illicit activities (corrupt staff, illegal connections, adulteration of revenues in the field), and mysterious expenses related to delegated investment activities. Corrective action was taken on the culprits and DMU management teams disbanded.

Assessing efficiency of NWSC and DAWASCO using DEA

The decision process on variable selection for this study was guided by an analysis of the cost drivers in the industry; review of empirical studies using DEA methodology; knowledge of data available from the NWSC and DAWASCO annual reports and reports from the water ministries in Uganda and Tanzania and by the degrees of freedom constraint faced by the study when using a small sample.

Specifying the inputs

According to the standard production theory, labour, capital and intermediate products are key inputs. The production process of the water supply service relies on the stock of capital comprising of the plants, reservoir tanks, and the network of pipes without detracting the importance of labour as well as the usable materials such as chemical, energy and other usable materials. It is noted from the review of empirical studies that the input variables were proxies of the factors of production reflected by the elements of the cost structure comprising of labour, materials, energy, and capital costs; thus operating expense (OPEX) was itemized. In this study such detailed breakdown is not possible due to data availability constraints and sample size limitations.

For this study, Operating expenses (OPEX) as a single input measure has been adopted since it encompasses the compensation to labour, chemicals, energy, maintenance, and depreciation as a proxy for capital used in the production process as illustrated in Figure 1. OPEX Sums up all variable resources expended in producing and delivering the service for the public client and thus provides a clear picture of what resources are being used and what is being achieved by expending them.

Length of network

Some empirical studies have used network length as an input variable [36,40] while others have used it as an output variable [39,41]. Clearly there is no consistency as to whether network length should be treated as an input or output variable. For this study network length is not used as it is reflected in OPEX. This is so because the longer the network, the more a utility firm spends more on maintenance, repairs, energy, and leaks. Another reason for not including network length is information availability gaps in some of the DMUs of DAWASCO.

Number of staff (labour cost)

Number of staff is one of the common input variables that researchers used [37,42,43]. The studies that have used it as an input variable had large samples that enabled them to itemize elements of OPEX which is not the case for this study given the sample size used. Besides this, there is a high significant correlation (r=0.986, p=.000) between OPEX and number of staff as shown in Table 9.

Specifying the output variables

The outputs must reflect the key results water service providers deliver to their clients. Figure 1 below depicts the major inputs and outputs in urban water service delivery in Uganda and Tanzania. The figure shows that when water is distributed, a certain proportion is delivered to units connected to the network grid (water delivered) while the other proportion is lost via bursts and leaks arising from defective pipelines and inadequacy in maintenance and repairs of the ageing networks. Furthermore, while some of the water delivered reaches its anticipated destination, that is, clients legally connected on the grid and therefore are billed; another proportion is lost via illegal connections. The water that reaches the legally connected clients represents water sold and clients are billed for it while the water that is lost via network bursts, leaks and illegal connections represents Non Revenue Water (NRW).

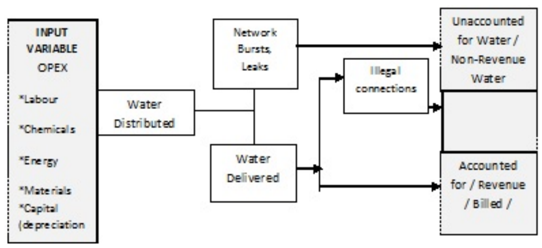

Figure 1: Major inputs and outputs in urban water service delivery. Source: Adapted from Nalwoga [44].

Volume of Water Billed (VoWB)

Volume of water delivered is the most commonly used single output variable in the water efficiency measurement. This is so since volume of water delivered is a reasonable performance result indicator of what water utility firms deliver to clients. Indeed volume of water delivered has a lot of influence on the level of OPEX. However, quite often in developing countries and particularly in the context of Uganda and Tanzania, the total amount of water delivered is not actually known since it includes NRW arising from water lost due to illegal connections and non-metered water. The better option would be to use VoWB which is implied in bills, as it best represents the actual amount of water delivered to the client. In this research VoWB was chosen as a quantitative measure in the DEA model.

Non Revenue Water [leakage, losses and illegal connections]

As illustrated in Figure 1 above, the production and distribution of water supply technology results into both accounted for (water sold) and unaccounted for water (water loss) as outputs. Kirkpatrick et al. [37] considered water loss as an indicator of the technical quality of service, which has been ignored by many studies.

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Tynan and Kingdom [45] point out, that the NRW ratio captures commercial losses attributable to inefficient billing or illegal connections, as well as physical losses. Thus high levels of NRW (or low levels of accounted-for water) indicate poor system management and/or poor commercial practice as well as inadequate pipeline maintenance. Garcia [36] utilized NRW as an output that is 'produced' jointly with water delivered to customers. They argued that the occurrence of network leaks, losses and illegal connections as part of the production and distribution can be considered as part of the overall inefficiency of the system. Hence, analyzing the water production process by incorporating water network losses generates essential and positive indications for water utility and public policy managers [38]. The researchers further note that overlooking water losses in the analysis may produce unreliable results if water utility managers' decisions regarding production are not independent from network water losses; a situation prevalent in Uganda and Tanzania.

Water Coverage – measure of access

Water coverage is defined as population with access to water services (either with direct service connection or within reach of a public water point) as a percentage of the total population under the utility's nominal responsibility. Picazo [46] correctly observes that in some developing countries with low coverage and unreliable water supply, service coverage, and service continuity are adequate variables to measure water quality. In contrast, in industrialized countries where water services cover nearly all the population and water quality reaches higher standards, alternative measures of quality are required. Lin et al. [47] and Garcia [36] used coverage as an indicator of service quality because it is a direct measure of water availability to citizens in municipalities. Hence, in the case of Uganda and Tanzania where urban safe water coverage stands at 80% and 40.7% [14,15] respectively, increasing coverage is a key performance and development indicator. However, all coverage indicators are impacted by whether the data on population and household size is up to date and accurate (Uganda's Census figures are for 2002). The need to estimate the population served by public water points and/or the number of households per connection may affect the confidence that can be placed in the water coverage measure. Because of this limitation, this variable has not been commonly adopted for the DEA analysis.

Hours in a day when water is available (Service Continuity)

As observed in the study by Kirkpatrick et al. [37], hours in a day when water is available, was utilized as a proxy for quality of service – service continuity. Whereas this indicator is worthwhile, it is regarded not so relevant in the perspective of Uganda and Tanzania where erratic supply of power (electricity) and Fuel are beyond the control of utility managers at the DMU level. These disrupts in electricity supply often times are the cause of unreliable water supply.

Descriptive statistics of potential water supply statistics

The descriptive statistics in Table 7 is for the 30 DMUs of NWSC (18) and DAWASCO (12) for the year 2013. The variables described are annual operating expenditure (OPEX), Volume of Water Billed, NRW, water coverage, number of staff and continuity of service. The statistics is given in terms of the minimum, maximum, mean, and standard deviation.

Statistical validation of the input and output variables

The linearity for DEA variables should be assessed to confirm that the variables fulfill the isotonic property that requires no negative linearity between inputs and outputs [48]. Assessing linearity of variables helps in detecting factors with the same significance. For this study the bi-variate relationship between the different proposed variables was tested using Pearson's coefficient as shown in Table 8. The results indicate that operational expenditure and number of staff as input variables are highly correlated with a score of 0.986.

NWSC (2013)					
Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Annual Operational Expenditure UGX "000"	18	593,611	38,287,672	3,617,314	8,726,020
Volume of Water billed per annum (in meters^3)	18	228,611	28,790,851	2,559,405	6,597,320
Non Revenue Water (%)	18	8.6	37.8	20.6	8
Water coverage (%)	18	44.7	85	62	14
Number of staff	18	13	660	69	149
Continuity (avg hrs in a day water is available)	18	7	23	17	5
DAWASCO (2013)					
Annual Operational Expenditure TZX "000"	12	489,386	8,216,886	3,453,207	2,250,666
Volume of Water billed per annum (in meters^3)	12	1,949,763	32,736,756	13,757,862	8,966,839
Non Revenue Water (%)	12	37	69	53	9
Water coverage (%)	12	44	70	61	9
Number of staff	12	5	83	34	22
Continuity (avg hrs in a day water is available)	12	6	16	10	3

Table 7: Descriptive Statistics of Potential Water Supply Variables for 2013.

Model specification and choice of variables

Banker et al. [48], suggests that DEA model specification is one of the critical issues to be considered. The logic used for variable selection is usually based on the consumed resources to produce output. This implies that the input and output variables should have isotonicity mathematical property [49] meaning that an increase in the input should result in an increase in the output and vice versa. Generally, the DEA formulation requires that the input and output variables be positive which is the case for this present data base as indicated in Table 8. The results indicate that most input variables are significantly correlated to the output variables with the scores ranging between 0.81 and 0.11.

Variable	Potential Inputs		Potential Outputs			
	Operational Expenditure Shs "000	Total No. of staff in a year	Volume of Water billed per annum (in cubic meters	Non Revenue Water (%)	Continuity (average hours in a day water is available	Water coverage (%)
Operational Expenditure Shs "000"	1					
Total No. of staff in a year	.986*	1				
Volume of Water billed per annum (in cubic meters)	.643*	.811**	1			
Non Revenue Water (%)	.229*	.109*	0.514	1		
Continuity (average hours in a day water is available	.108*	.189*	.257*	-.679*	1	
Water coverage (%)	.186*	.225*	.218*	-.431*	.497*	1
N =	30	30	30	30	30	30

Table 8: Potential water supply variables correlation Matrix. **Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Input	Outputs
	Volume of water billed
Operating Expenses	Non Revenue Water

Table 9: The DEA model used.

For this study one input and two outputs were chosen n>9; as shown in Table 9. Based on the above arguments, it is believed that the three variables used in the analysis satisfy the rule of thumb suggested by Banker et al. [48].

Descriptive statistics of NWSC's and DAWASCO's efficiency scores

To develop an understanding of the comparative efficiency of each DMU in NWSC and DAWASCO, data for the year end 2013 was run to determine the efficiency scores that are used in the descriptive statistics. It is acknowledged that DEA is only an exploratory tool for efficiency measurement and indicates directions for further investigations into how to enhance efficiency. Table 10 shows the number of highly efficient towns, and mean, maximum, minimum and standard deviation of the efficiency scores for NWSC and DAWASCO.

Number of fully eff. Units	4
Min	0.26
Max	1
Mean	0.63
STDEV	0.24
No. observation	30

Table 10: Descriptive statistics for DEA efficiency scores.

Number of fully efficient towns and mean technical efficiency scores

The fully efficient towns are four; two from NWSC namely; Entebbe and Kampala; and two from DAWASCO namely; City center and Boko. The fully efficient towns on the frontier have also been distinguished by identifying the number of comparators to distinguish real benchmarks and firms that are classified as being fully efficient due to lack of comparable firms [50]. The results show that all firms are real benchmarks of at least one other firm. The mean efficiency level is 0.63.

Efficiency clusters

Efficiency clusters have been used to categorise the DMUs into those that are high, moderate, and least efficient. Though assessing the performance of the DMUs by considering averages can be informative especially for the DMUs not on the best practice frontier. It is challenging when assessing the performance of the DMUs on the frontier. The challenge is distinguishing the performance of the highly efficient DMUs. A common approach is to distinguish the highly efficient DMUs by considering the number of times a particular DMU has been chosen as a peer.

Using DEA efficiency scores, the fully efficient DMUs have been differentiated based on the number of benchmarks as suggested by Sinuany-Stern et al. [51]. Using this approach, an efficient DMU is highly ranked if it is chosen as a useful target by many other inefficient units. The efficient units are ranked by counting the number of times they appear in the reference sets of inefficient units. The inefficient units are ranked by counting the number of DMUs that need to be removed from the analysis before they are considered efficient. The DMUs have been ranked on a scale of 1(highly efficient) to 18 (least efficient) for NWSC and up to 12 (least efficient) for DAWASCO as indicated in Table 11. Each DMU has been ranked on a yearly basis and an overall rank has been determined to identify the top (10) highly efficient, moderately efficient (10) and the least (10) efficient towns.

Efficiency clusters for NWSC

In this cluster Entebbe and Kampala emerge as the top two. This means that the best practices of these two DMUs might be useful to other DMUs to improve their operational efficiency. Two (Entebbe and Fort portal) of the top highly efficient towns have been under the jurisdiction of NWSC way before the year 2000. The other three, Kampala, Mubende, and Masindi were initially managed by private operators. Still in the highly efficient category apart from Mubende and Masindi, the rest were constituted into partnerships; Greater Entebbe water Partnership for Entebbe, Rwenzori Water partnership for Fortportal and Kampala Water Partnership since the year 2009. Another attribute that can be considered for this cluster is the profitability performance. The financial statements for the year ending June 2013 indicate that Kampala was the most profitable segment followed by Entebbe. However, using the NRW performance indicator, Kampala had the highest score of 37.8% while Entebbe had a score of 21.6%.

Highly efficient		**Moderately efficient**		**Least efficient**	
DMU	Rank	DMU	Rank	DMU	Rank
NWSC					
Entebbe	1	Hoima	7	Masaka	13
Kampala	2	Gulu	8	Mbale	13
Mubende	3	Jinja	9	Tororo	15
Masindi	4	Lira	10	Kabale	16
Fortportal	5	Kasese	11	Bushenyi	17
Arua	6	Mbarara	12	Soroti	18
DAWASCO					
Gerezani	1	Kibaha	5	Bagamoyo	9
City Centre	2	Magomeni	5	Ilala	10
Boko	3	Kawe	5	Kimara	11
Kinondoni	4	Kisutu	8	Temeke	12

Table 11: Efficiency clusters of DMUs.

In the least efficient category Soroti was initially managed by private operators while the rest have been under NWSC jurisdiction. In this category, it is only Mbale that has been constituted into a partnership known as Elgon water partnership. Using the profitability indicator for the year ended June 2009, Soroti, Bushenyi, and Kabale were loss making DMUs, though their NRW scores were 15.5%, 22.1% and 13.4% respectively. The other towns in this cluster their performance is average.

Efficiency clusters for DAWASCO

Considering the clusters for DAWASCO, the highly efficient cluster is composed of DMUs like Gerezani, City centre, and Boko. These are averagely planned settlements. According to the Water Aid Report, 2013, a sizeable number of residents in these areas are connected to the DAWASCO water network. Gerezani is viewed as the global leader, thus the best practices of Gerezani might be useful to other DMU in a bid to improve technical efficiency. In contrast the least efficient clusters especially the DMUs of Temeke and Ilala have unplanned settlements. According to Napacho and Mayele [52] many of the residents are not connected to piped water. Indeed Water Aid [53] gives a percentage of 8% of the residents in Temeke as those connected to DAWASCO water directly, 21% connect to DAWASCO through their neighbours. This offers a high chance of illegal connections, unmetered water and water theft. It is not surprising the in these areas that NRW scores range between 50% and 67%.

Managerial autonomy and the efficiency link

Efficiency scores were regressed against the managerial autonomy scores with the utility as a dummy. Table 12 shows the results for the Tobit regression model.

	(n=30)		
Variable	Coef	T	P>t
Autonomy	-0.612	-2.38*	0.001***
Dummy Utility	19.83	3	0.003**
Constant	80.62	10.07	.000***
	Prob>chi2 = 0.0006		

Table 12: Tobit regression model for NPM and efficiency. *significant at 10% level, **significant at 5% level, ***significant at 1% level.

As shown in Table 12, the Tobit regression model indicates that the adoption of managerial autonomy significantly (Prob>chi2 = 0.0006) contributes to efficiency. The results show that the parameter estimate for managerial autonomy is negative and statistically significant at 1% level including a dummy for utility in the analysis showed that the variable is statistically significant, implying that there are significant differences between DAWASCO and NWSC.

The results imply that an increase in managerial autonomy will cause the likelihood for technical efficiency to decrease, thus the hypothesis that managerial autonomy does not improve with technical efficiency is upheld. This is in agreement with the findings of Berman and Bosert [54] who concluded that managerial autonomy in the public hospitals in developing countries has not improved technical efficiency. The same conclusion was drawn by Nalwoga [44] that analysed managerial autonomy and efficiency of water utilities over ten years.

The position that an increase in managerial autonomy will cause the likelihood for technical efficiency to decrease, could be expected in the event that the principal (HO) who grants autonomy may not keenly and continuously supervise and monitor the activities of the agent (DMU). Besides this, it could also be that the cost of supervising and monitoring the delegated tasks increases operational costs hence reducing technical efficiency. Another reason would be that some managers in the DMUs could be seeking their personal objectives at the expense of the utility objectives as Emile et al. [55-57] concluded that the effect of managerial autonomy on efficiency depended on the establishment of practical principles to ensure that the methods are exercised in an ethical manner [58].

Managers at the utility head office and those at the DMUs should develop competences in contract management, monitoring and evaluation with a view to ensuring that the agent (DMUs) acts in the interest of the principal (the utility Head Office). Urban water utility managers should put in place an appropriate structural framework to govern the relationship between the water utility head office and the DMU. Besides this, the utility head office should delegate decision making powers to the DMUs based on a clear framework.

A caution though is that the efficiency scores used in this study are relative not absolute values since DEA has been used that is a tool for benchmarking relative performance. Also a composite measure (OPEX) was used for the input variables. Subsequent studies with bigger samples could itemize the elements of OPEX.

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