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Managerial ownership and urban water utilities efficiency in Uganda

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July 2011

Abstract

This paper assesses the impact of the early 1980s neoliberalistic reform strategies in urban water distribution in developing countries. It examines in particular, the technical efficiency of two heterogeneous urban water utility-groups in Uganda. Performance is considered in light of the key urban water sector objectives that are to universally increase qualitative water coverage and enhance utility revenue. Using a two-staged bias-corrected metafrontier based on the data envelopment analysis estimators, the *public-private* (than the *public-public*) owned utilities are found less efficient. Efficiency differences between both groups are further linked to utilities scale of operation and market capture capabilities among other factors. The paper urges policy makers to strengthen public sector capabilities as a development policy solution for inclusive quality water services access among other basic public utility services in Uganda, Africa and the developing countries in general.

Keywords: Efficiency, managerial ownership, non-parametric, Uganda, urban water supply.

JEL classification: C14, H41, L95, Q25

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1 Introduction

Safe drinking water access in Africa remains a key developmental issue. Sub-Saharan Africa and Oceania regions are particularly lagging behind their millennium development target of halving the population without access to safe drinking water by 2015 (UNESCO and Earthscan, 2009). This exceptional gap in safe water coverage calls for strengthened infrastructure development but firstly, water provider's efficiency advancement.

In overcoming water service providers' (hereafter water utilities i.e., WUs) technical inefficiency reflected in low revenue collection, declined (re)investments and limited quality water coverage, the government of Uganda embarked on a number of organizational and institutional sector reforms in the late 1990s (MWLE, 2001). Sector investment and development plans for the rural water supply, urban water supply, water resource management and water for production were designed and endorsed (MWLE, 2000: 2001: 2005a: 2005b). Among other strategies, the urban water supply sector reforms advanced increased private sector participation in infrastructure development and service provision as well as, universal safe water coverage with sufficient cost recovery (MWLE, 2001). This study focuses on the urban water sector that consists of both large and small town's WUs.

Following the neoliberalistic urban water sector reforms, service provision mandate for gazetted large and small urban towns was delegated respectively, to the National Water and Sewerage Corporation (hereafter, NWSC) and the local governments (MWLE, 2001). Both NWSC and the local governments (i) sign a renewable three year performance contract with the government (Ministry of Water and Environment, hereafter, MWE), (ii) own respective water distribution assets on behalf of the government and (iii) engage self-procured WUs through renewable management contracts,[3] to supply water on their behalf across towns under their mandate (MWLE, 2001).[4] Nonetheless, WUs under NWSC's oversight are publicly owned while those under the local governments are privately owned as provided respectively, by the NWSC Act Cap 317 (RoU, 1995) and the Local Government Act, Cap 243 (RoU, 2008). The MWE regulates and provides technical support to all urban WUs in Uganda (MWLE, 2008). Regulation is based on prior agreed partial performance indicators provided in the respective management contracts.

In advancing universal safe water coverage for all urban population in Uganda as provided by the National Water Policy (MWLE, 1999), it is important to examine the influence of these

[3] Short term management contracts than long-term concession arrangements (i) permit regular competitive bidding that helps improve WUs operational efficiency and, (ii) are less prone to future renegotiation risks among other contract incompleteness-related problems (Seppala, *et al.*, 2001).

[4] Following Bayliss (2003), unbundling asset ownership from services provision not only permits improved transparency and accountability but isolates also, operation areas that are easy to privatize.

differently advanced managerial ownership types on WU's technical efficiency. Normally, traditional production frontier models (parametric or non-parametric) are used to link observed output production to some optimal production defined by the best-practice frontier (Fried, *et al.*, 2008). This is particularly the case when observed firms (or groups of firms) are homogenous in nature (e.g., in terms of technology use). However, urban WU-groups in Uganda are heterogeneous with respect to their managerial ownership and inherently, their scales of operation. This implicitly implies that production frontier differences between both WU-groups are inherently influenced by the existing managerial ownership arrangement.

We use the metafrontier technique based on the Data Envelopment Analysis (hereafter, DEA) estimators (Rao, *et al.,* 2003; O'Donnell, *et al.,* 2007). The technique allows the study to estimate first, specific utilities distance to the specific group frontier (technical efficiency measure) and second, specific group frontier's distance to the best-practice technology available across the urban water supply sector (defined by the metafrontier). This allows us to capture (i) WUs technical efficiency (relative to specific group frontier) and (ii) technology differences (gaps) between WU-groups while taking into account any utilities heterogeneity.

Despite their advantages over econometric frontier techniques, two-stage DEA estimators face several statistical limitations including serial correlation (especially in finite samples) of estimated efficiencies. This results in incorrect and misleading estimates. To overcome these limitations, the two-stage double bootstrap truncated regression technique (Simar and Wilson, 2007) is used. The technique permits the study to extend the deterministic metafrontier technique and allow for consistent inferencing while controlling for any data noise impacts. This further allows us to examine whether WUs' efficiency is different across the distinct managerial ownership arrangements and more so, whether other utility and sector specific environmental factors explain group's efficiency differences.

Through the rest parts of the paper, WUs under NWSC are referred to as *public-public* owned while those under the local governments are referred to as *public-private* owned. Managerial ownership is defined as the transfer by the government of service provision responsibilities through management contracts. Safe water coverage is defined to include mainly piped water supplies within 200 meters from observed households (MWLE, 2006: 2007). Self-collected operational data from urban WUs across both groups over a three-year period (2005-2007) is used. In Uganda alike other utilities across the developing world, technical inefficiency is reflected in terms of market penetration constraints (service coverage gaps) owing to limited revenue collection and reinvestment among other factors. These restrain staff capacity advancement and regular mains maintenance works among other aspects, resulting for example, in increased non-revenue water (NRW). Between 2004 and 2007, about 21 percent of the distributed water was lost on average across the *public-public* owned (17 percent) and the *public-private* owned (25 percent) WUs in Uganda (MWLE, 2007).

Limited systematic country productivity assessments given the sector reforms exists across the African region (see Annex 1), largely owing to inexistent or/and inconsistent utility operational data constraints (Parker and Kirkpatrick, 2005). Accessibility of specific country data, in this case, from the Ugandan urban water sector, allows valuable within-country analyses. These provide useful insights in the design of future restructuring policy strategies especially, across the African region. Since the late 1990s when the MWE initiated reforms across the urban water sector in Uganda, limited performance analyses that incorporate the sector's complexity (in terms of multiple-input use and multi-output production), exist. Available annual performance assessment reports use partial than multidimensional performance indicators such as, the share of people with or without access to safe water systems (see MWLE, 2006: 2007: 2008). This study attempts to bridge these gaps. Resultant findings will help utility managers and sector regulators to objectively identify scopes for improving specific WUs performance as well as, the entire urban water supply sector within existing technological constraints.

The following section explores the role of managerial ownership on WUs performance. Section three develops the analytical framework while section four describes the Ugandan water sector. The empirical methodology and data used for the study are defined in section five. Section six and seven provides the study results and conclusion, respectively.

2 Managerial ownership and water utilities performance

Common to the 1990s restructuring programmes rolled out across most infrastructural public utilities (including electricity, gas, telecommunications and water supply utilities) in the developing economies in particular, is the change in the ownership of assets and management of service provision rights (Seppala, *et al.*, 2001; Parker and Kirkpatrick, 2005; Boubakri, *et al.*, 2008). However, both *publicly* and *privately* owned utilities differ in a number of ways that potentially influence their performance. Governments (tax-payers through for example, public companies or corporations) own public utilities while private shareholders own private utilities. Government's control over the means of production and service delivery (through input prices for example) guarantees (or it is meant to guarantee) inclusive quality services provision (optimized social welfare). This is particularly relevant for the urban water supply industry that is geographically monopolistic, characterized by high initial investment sunk costs, and hardly competitive (due to the non-detachability of water production and distribution networks within a specific service area) in nature (Waterson, 1988; Seppala, *et al.*, 2001; Joskow, 2007; Spronk, 2010).

Nonetheless, direct government control and subsidization of state-owned utilities results in unwarranted cost overruns owing to weak budget oversights, conflicting trade union interests and the inexistence of market take-over risks in case of bankruptcy (Boubakri, *et al.*, 2008; Marques, 2008; Lin, *et al.*, 2009). Coupled with public utility property right's non-transferability (Crain and Zardkoohi, 1978) in addition other inefficiencies due to public choice and principal-agent problems (see Byrnes, 1985; Vining and Boardman, 1992), public ownership lends itself to attenuated activities specialization, foresightedness and innovativeness (Tisdell and Hartley, 2008).

Private utility managers face persistent pursuit for profits with limited multi-tasking and free-riding problems (Seppala, *et al.*, 2001; Anwandter and Ozuna, 2002). This pursuit for profits coupled with depoliticized shareholder performance-based monitoring results in improved resource allocation efficiency, innovativeness and responsiveness to consumer demands (Tisdell and Hartley, 2008; Spronk, 2010).

Literature counts a number of empirical studies that found *privately* (than *publicly*) owned urban WUs more efficient (Crain and Zardkoohi, 1978: 1980; Raffiee, *et al.*, 1993; Bhattacharyya, *et al.*, 1995; Estache and Rossi, 2002; Bitran and Valenzuela, 2003; Moreira, *et al.*, 2005; Andrés, *et al.*, 2008; Gassner, *et al.*, 2009; Picazo-Tadeo, *et al.*, 2009; Correia and Marques, 2011). Compared to *publicly* owned urban WUs, *privately* owned utilities were found more cost effective, responsive to costumer demands, less corrupt, well governed and more likely to exploit possible scale, scope and costumer density economies (see Annex 1).

Nonetheless, *private* (than *public*) urban WU ownership is often flawed by increased information asymmetry, exclusive service provision, operations downsizing and increased output prices with minimal capital investments among other problems (see Lynk, 1993; Bhattacharyya, *et al.*, 1994; Shaoul, 1997; Saal and Parker, 2000: 2001; Estache and Trujillo, 2003; Saal, *et al.*, 2007; Marques, 2008; Souza, *et al.*, 2008, see Annex 1). This reduces services quality and customer satisfaction (Seppala, *et al.*, 2001). Besides, a few empirical studies found no significant differences between *privately* and *publicly* owned urban WUs in both developed and developing countries (see Feigenbaum, *et al.*, 1983; Hausman, *et al.*, 1986; Byrnes, *et al.*, 1986; Teeples and Glyer, 1987; Lambert, *et al.*, 1993; Estache and Rossi, 2002; Saal and Parker, 2004; Kirkpatrick, *et al.*, 2006; Souza, *et al.*, 2007).

Earlier studies on the role of ownership on urban WUs' performance use different approaches (mainly parametric) based on a priori defined assumptions and provide mixed evidence. The increasingly inconclusive debate since the 1970s coupled with the imperfectly contestable urban water market (Vining and Boardman, 1992) reflects the continued relevance of the issue. This is true for most African countries that are presently implementing (e.g. Cote d'Ivoire, Gambia, Ghana, Guinea, Kenya, Lesotho, Mozambique, Senegal, Uganda, Zambia) or in the process of initiating (e.g., Democratic Republic of Congo) neoliberalistic reform programmes in their urban water sectors (ECA, 2005; AMCW *et al.*, 2006; Osumanu, 2008). Key to these water reform programmes is the advancement of private sector participation in services delivery - a highly debated political issue. This paper provides new evidence on the role of service provision ownership on urban WUs technical efficiency with the use of bias-corrected non-parametric techniques.

3 Analytical framework

DEA takes into account most service sectors complexity in terms of multi-input utilization to produce multi-outputs. It estimates efficiency scalars based on external rather than average values (Fried, *et al.,* 2008). While the deterministic approach compares favourably with econometric approaches (Chalos and Cherian, 1995), it nevertheless avoids a priori production function specifications. The metafrontier technique (Rao, *et al.*, 2003; O'Donnell, *et al.,* 2007) in particular, permits efficiency measurements across more that one dissimilar groups relative to a common metafrontier.

Metafrontier is defined as the boundary of an unrestricted technology set that envelopes observed group frontiers. This allows for the estimation of (i) individual utilities' technical efficiency relative to the individual's best-practice group frontier derived from each group's observations, and (ii) specific group's technology gaps relative to the metafrontier (reflecting the overall available technology accessible across observed groups). Technical efficiency estimates represent the ratio of the minimal inputs required to the actual inputs used given a certain output level (resource saving objective) or, the ratio of the maximal achievable outputs to the actual attained output given a certain input mix (service-expanding objective) (Fried, *et al.,* 2008). They (technical efficiency estimates) help inform performance improvement designs within and across observed groups.

Both WU-groups observed in this study share similar water distribution technology. They distribute potable water through piped network systems (MWLE, 2006: 2007). Nonetheless, they differ in two main aspects that potentially influence their resource usage among other choices. Firstly, they differ in their managerial ownership nature. Secondly, they operate under different scales. In 2006 for example, the *public-public* owned utilities served about 1,669,182 (out of a total of 2,384,546) population with piped water systems within their licensed jurisdiction. The *public-private* owned utilities on the other hand, served estimated 451,823 (out of a total of 996,335) persons with piped water systems within their licensed jurisdiction. There existed in 2006 a total of 18 (*public-public)* and 71 (*public-private)* urban towns (utilities) with functional piped water systems in Uganda (MWLE, 2006). The paper at hand uses the managerial ownership dummy variable under variable return to scale (hereafter, VRS) assumption, to capture any unobserved structural disparities due to differences in ownership structure that is fixed for each firm in the same group (Bhattacharyya, *et al.*, 1995).

A metatechnology set (T_{MF}) is associated with technologically feasible input and output sets based on non-negative input (x) and output (y) vectors of the dimension $M \times 1$ and $N \times 1$ respectively.

$$T_{MF} = \{(x, y) : x \geq 0 \,;\, y \geq 0 \,;\, x \text{ can produce } y\} \qquad [1]$$

In the case of the urban water sector in most developing countries, demand for improved water services remains unmatched by WUs. More so, owing to the performance-based regulation arrangements following the urban sector reforms, utilities limitedly alter their input mixes including capital stock (i.e., often fixed at least in the short-term) and preset tariffs but have the liberty to change their output mixes. Such allows them attain a priori set performance targets with sufficient cost-recovery (Estache and Rossi, 2002). We thus, adopt an output oriented technological specification. To estimate technical efficiency (θ_{MF}) across utility groups, an *output metadistance function* $\{D^o_{MF}(x, y)\}$ is defined (on the output set representing the metafrontier technology set) as:

$$D^o_{MF}(x, y) = \inf_{\theta_{MF}} \{\theta_{MF} > 0 : (y/\theta_{MF}) \in P_{MF}(x)\} \qquad [2]$$

where $D_{MF}(x, y)$ is the maximal radial expansion of unit outputs given existing input resources. $P_{MF}(x)$ is the output set defined for any input vector as $P_{MF}(x) = \{y : (x, y) \in T_{MF}\}$ while, 'inf' stands for 'infimum[5]'.

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[5] It allows for the possibility that the minimum may not exist. That is, $(\theta_{MF}) = +\infty$ is possible (see Coelli, *et al.*, 2005).

In the absence of price information (input *costs* and/or output *revenue*), distance functions permit the specification of multiple-input and multiple-output technology sets (Coelli and Perelman, 1999). Under an output-oriented assumption, estimated distance functions are by nature non-decreasing in *y*, decreasing in *x*, linearly homogenous in *y* and convex in *y* (Coelli, *et al.*, 2005). Relative to the metafrontier, a given utility (x, y) is technically efficient if the *output metadistance function* equals unity. This implies that it is located on the outer boundary of the production possibility set.

To further estimate individual utility's technical efficiency scores relative to each group's best-practice frontier, an n^{th} group-specific technology set (T_{GF}^{n}) is defined and represented in terms of its *group-specific distance function* $\{D_{GF}^{n}(x, y)\}$ as:

$$T_{GF}^{n} = \{(x, y): x \geq 0 \, ; y \geq 0 \, ; x \text{ can be used by WUs in group } n \text{ to produce } y\} \quad [3]$$

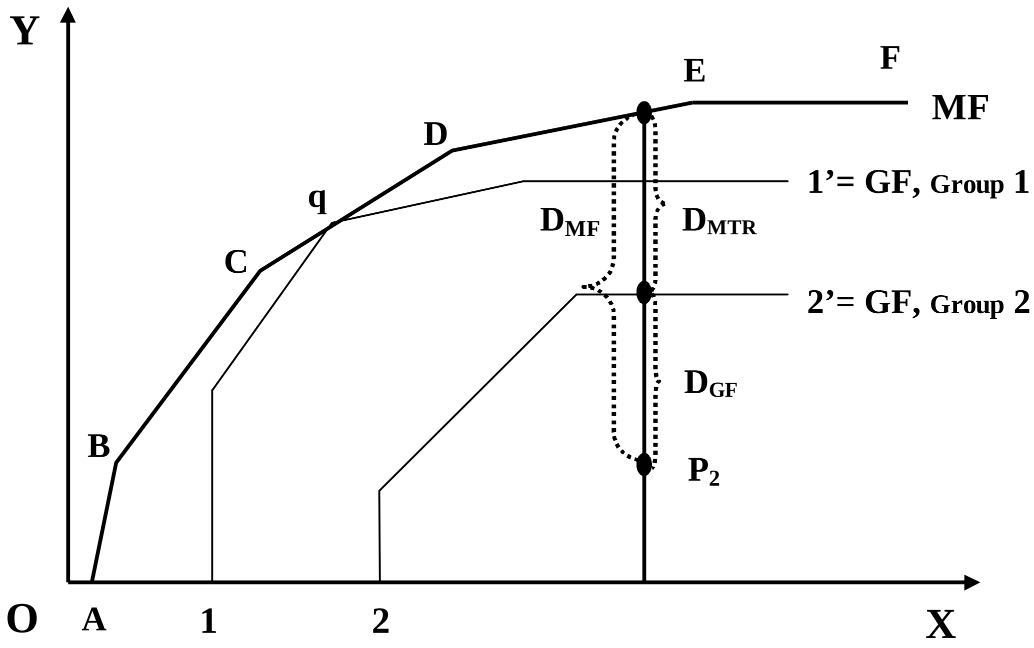
$$D_{GF}^{n}(x, y) = \inf_{\theta_{GF}^{n}} \{\theta_{GF}^{n} > 0 : (y/\theta_{GF}^{n}) \in P_{GF}^{n}(x)\}, \, n = 1, 2, 3 \ldots N \quad [4]$$

where $P_{GF}^{n}(x)$ represents the group specific output set whose boundaries define the group frontier. $P_{GF}^{n}(x) = \{y : (x, y) \in T_{GF}^{n}\}, \, n = 1, 2, 3 \ldots N$. WU *i* is technically efficient relative to its group best-practice frontier if its group specific distance function is equal to one. The technical efficiency score of a given WU $(TE_{GF_i}^{n})$ is thus related to the distance, computed relative to the group frontier $(TE_{GF_i}^{n} = D_{GF_i}^{n})$.

Figure 1 provides an illustration of a convex metafrontier *ABCDEF*[6] that envelopes *group 11'* and *22'* frontiers. The distance between the metafrontier (D_{MF}^{N}) and either group's frontiers (D_{GF}^{n}) provides a measure of the *technology gap ratio* (D_{MTR}). The farther a specific group's average efficiency is to one, the farther (in terms of output production) to the maximum potential output given the technology available across the urban water sector, WUs within the specific group are.

[6] Non-convexity assumption (resulting for e.g., in A-B-C-q-1', in figure 1) results to higher group efficiency and technology-gap ratio estimates, relative to the metafrontier (O'Donnell, *et al.,* 2007).

Figure 1: Metafrontier technique illustration*



* For a utility producing unit output with unit input. An output orientation under VRS is assumed.
Source: Authors illustration

Technology gap (D_{MTR}) measures the ratio of group-*n*'s output (defined by the best-practice group frontier) relative to the potentially attainable output defined by the metafrontier, given observed input units. The technology gap for the *public-private* owned utility group is for example computed as (Rao, *et al.,* 2003; O'Donnell, *et al.,* 2007):

$$MTR_{Ppr}(x,y) = D_{MF}^{Ppr}(x,y) / D_{GF}^{Ppr}(x,y) \qquad [5]$$

The two stage double bootstrap truncated regression technique (see Simar and Wilson, 2007) based on the DEA efficiency estimators is used to construct both group frontiers and the metafrontier (by pooling all groups observations). DEA VRS considers the following optimization problem (that is solved for each observation) for *N* firms *(i = 1,2,3…N)* in *T* periods *(t = 1, 2, 3… T)*:

$$\max_{\phi_{it},\lambda_{it}} \quad \phi_{it} \qquad [6]$$

$$\text{subject to:} \quad \phi_{it}\,\boldsymbol{y}_{it} - \boldsymbol{Y}\lambda_{it} \le 0,$$

$$\boldsymbol{X}\lambda_{it} - \boldsymbol{x}_{it} \le 0,$$

$$\text{and} \quad \lambda_{it} \ge 0; \quad \sum \lambda_{it} = 1$$

where $\phi_{\mathbf{it}}$ is a scalar that provides information on the n^{th} utility's technical efficiency estimates in the t^{th} period. $\boldsymbol{y}_{\mathbf{it}}$ is a M x *1* vector of output quantities for the i^{th} firm in the t^{th} period. $\boldsymbol{Y}$ is the M x $L_n T$ *matrix* of output quantities for all L_n firms in all T periods and $\lambda_{\mathbf{it}}$ the $L_n T$ x 1 vector of non-negative weights. $\boldsymbol{X}$ is the Q x $L_n T$ vector of input quantities for all L_n firms in all T periods while $x_{\mathbf{it}}$ is the Q x 1 vector of input quantities for the i^{th} firm in period t. $\sum \lambda_{it} = 1$ imposes VRS to the linear program while $\mathbf{1/}\phi_{\mathbf{it}}$ gives the output-oriented technical efficiency estimates of either the group frontier (s) or, the metafrontier.

4 The Ugandan water sector

Unlike many African countries, Uganda is relatively well endowed with adequate water resources. The country has a mean annual rainfall of 1300 millimetres (mm) that ranges from 100 mm in the semi-arid parts of Karamoja to 3000 mm in the Northeastern region (UN-Water and WWAP, 2006). Uganda's renewable water resource is estimated at 66 km^3per year. By 2007, this was equivalent to about 1412 cubic meters per inhabitant per year (m3/inh/y) annual internal renewable water resources. This endowment exceeds by far internal renewable fresh water resources in some (30 percent) African countries with quantities below 1000 m3/inh/y including, Algeria (342 m3/inh/y), Burkina Faso (906 m3/inh/y), Egypt (24 m3/inh/y), Libya (104 m3/inh/y), Kenya (630 m3/inh/y) and Tunisia (418 m3/inh/y) (AfDB, 2010). Prominent fresh water reservoirs in Africa including the Nile basin (the world's longest); rivers Ruizi, Katonga, Kafu, Mpologoma and Aswa; and lakes Kyoga, Albert, George, Edward and Victoria (the world's second largest freshwater lake, and the source of the River Nile) pass through or are found in Uganda (UN-Water and WWAP, 2006). Consequently, 82 percent of the country's land is arable (UN-Water and WWAP, 2006).

More than 40 percent of the urban population (about 1.7 million out a total of 4.4 million urban residents) lacks access to improved water supply systems (MWLE, 2008). The number is projected to rise with increased urbanization and population growth rates, among other factors. More so, sewerage service provision remains an enormous challenge constrained by low infrastructural development. By 2007, only about 10 percent of the population living in the large urban towns was served with improved sewerage services (Mugisha, 2007). While improved sewerage service provision is equally indispensable for a healthy productive population, this paper focuses only on improved water supply provision.

Besides catchment-level institutions that protect fresh water reservoirs, WUs constitute a major actor in sustainable water resource and supply management. They invest in infrastructural development including the construction and maintenance of dams, treatment plants, storage tanks, desalination and recycling systems and distribution piped network systems. Infrastructural investment not only ensures sustained quality services delivery but guarantees water resources sustainability against inevitable water shortages from seasonal and sometimes shared surface and underground water catchments.

5 Empirical specification and data

Water distribution technology across the Ugandan urban water sector is described, in the current analysis, in terms of one input; operational expenditures and two outputs; the volumetric amount of water sold and the number of served population with piped water systems (i.e., within utilities' licensed jurisdiction). Volumetric water sold than the total amount of water supplied from the production sites was preferred for two main reasons. Firstly, to adequately collect revenue with minimal (or no) water losses, utilities have to employ more field employees and consequently, incur higher network maintenance costs reflected in their operating expenses. In such case, the amount of water sold reflects better the input requirement. Secondly, to distribute water, utilities with higher water losses reflected also in reduced revenue collections could appear efficient due to their low input use (operating expenses). In such case, the amount of water sold provides a better output indicator that takes into account also, any water losses (non-revenue water). To attain universal quality water services coverage for all urban customers in Uganda, WUs need to strengthen their revenue collection for reinvestment in increased piped water provision.

Taking into account yearly inflation and deflation, GDP price deflators were used to convert utilities operational expenditures (measured in current prices) into constant-dollar GDP measures. Unlike other price indices including the Consumer Price Index, GDP price deflators reflect annual changes in country consumption and investment patterns. The use of utilities operational expenditures allows the study to capture also managerial malfunctions reflected in inefficient resource utilization among other corrupt practices. To explain efficiency differences between the two utility groups, the study takes into account utilities (i) target population over total active water connections share and (ii) managerial ownership structure.

Operational data from 27 urban WUs (10 *public-public* owned, 17 *public-private* owned) in Uganda is used. The sample represents more than 23 percent of the total urban WUs in Uganda (by 2007). While the data is limited (lacks in particular output revenue information), it permits consistent technical efficiency estimation and comparison across both WU-groups between 2005 and 2007. The short analysis period allows the study to assume minimal (or no) technological change across observed utilities.

Data for both groups was first sourced from the sector's annual reports available online. However, to cross-check the validity of gathered information and fill-in missing information gaps, a field visit to Uganda was necessary by the end of 2008. This allowed access of the internal management information systems of the Directorate of Water Development (of the MWE) and NWSC, by the authors. Both information depositories capture and store centrally operational information for the *public-private* owned and the *public-public* owned WUs, respectively.

Table 1 provides some summary statistics of the different input, output and environmental variables used for the study between 2005 and 2007. Over the three years, the *public-public* owned urban WUs expensed about five million Ugandan shillings more than the *public-private* owned utilities. Consequently, the *public-public* owned utilities increased their piped water connections serving more persons on average than the *public-private* owned utilities. The latter utilities covered (with piped water systems) about twenty six thousand less customers. Compared to the *public-private* owned utilities, the *public-public* owned utilities managed to penetrate better their urban water markets (within their licensed jurisdiction) and meet much of the existing demand for quality water services. This is reflected in their lower share of target population per total water connections (see Table 1). Moreover, the *public-public* owned utilities made more collections than the *public-private* owned utilities. The former utilities sold on average eleven thousand more cubic meters of water than the *public-private* owned utilities (see Table 1).

Table 1: Input, output and environmental variables summary statistic

	Group	Obs	Mean	St. Dev.	Minimum	Maximum
Input variable						
Operational	*Public-public*	30	49054899	22114458	24076000	98396000
expenditures*	*Public-private*	51	43514117	26801008	7760589	155864768
	All	81	45566258	25168687	7760589	155864768
Output variables						
Volumetric water sold	*Public-public*	30	53131	27054	16346	119500
(cubic meters)	*Public-private*	51	42004	22509	12251	99224
	All	81	46125	24723	12251	119500
Served population	*Public-public*	30	38789	20704	9727	94669
with piped water	*Public-private*	51	11820	4684	3144	27684
(persons)	All	81	21809	18462	3144	94669
Environmental variables						
Managerial ownership	*Public-public*	30	1	0	1	1
(dummy variable)	*Public-private*	51	0	0	0	0
	All	81	0.37	0.49	0	1
Target population over	*Public-public*	30	20.30	6.43	12.81	37.46
total water connections	*Public-private*	51	57.99	50.30	14.26	316.95
share	All	81	44.03	43.95	12.81	316.95

* GDP price deflated

6 Study results and discussion

6.1 Efficiency and market organisation

In light of the 'service-expanding' objective of the Ugandan urban water sector, like other water sectors across the developing nations in particular; technical inefficiency implies that specific utilities can potentially increase their output without changing their input levels relative to respective group and meta-frontiers. Table 2 provides the bias-corrected technical efficiency estimates relative to (i) specific group's best practice frontier and (ii) the overall urban water distribution technology (metafrontier).

On average, *public-public* owned utilities produced 78 percent of the potentially attainable output (given existing inputs) relative to the water distribution technology across the *public-public* owned utilities. The *public-private* owned utilities on the other hand, produced on average about 64 percent of the potentially attainable output (given existing resources) relative to the *public-private* group's best-practice frontier.

In terms of the technology gap estimated by the metatechnology ratio (equation 5), the *public-public* owned group frontier (0.83) than the *public-private* owned group frontier (0.74), is found much closer to the (convex) metafrontier. This implies that the *public-private* owned utilities operate under unfavourable environments (beyond utility managers control) compared to the *public-public* owned utilities. The latter utilities can at maximum attain about 9 percent more output devoid of the restrictive operational environments (see Table 2). Consequently, the *public-public* owned utilities are found more technical efficient, relative to the overall *urban water sector* best practice frontier in Uganda.

Table 2: Bias-corrected technical efficiency estimates (DEA – VRS)*

	Group frontier			**Metafrontier**			**Metatechnology ratio (**)**		
Group	***Public-public***	***Public-private***	***All***	***Public-public***	***Public-private***	***All***	***Public-public***	***Public-private***	***All***
Observations	30	51	81	30	51	81	30	51	81
Mean	0.781	0.638	0.732	0.648	0.465	0.586	0.829	0.736	0.797
Median	0.718	0.616	0.650	0.586	0.416	0.496	0.790	0.759	0.783
Std. Dev.	0.176	0.211	0.211	0.173	0.196	0.199	0.128	0.239	0.205

* Weighted by the total number of served population per utilities' licensed jurisdiction.
** Technical efficiency relative to metafrontier by technical efficiency relative to the group frontier ratio.

This technology gap can be explained by the differently implemented regulatory framework within the urban water sector in Uganda. While utilities in both groups sign performance contracts with the government (MWE), the *public-public* owned utilities self-regulate to a large extent their operations, through the NWSC (see Muhairwe, 2009). Such internal monitoring potentially helps improve in particular, the *public-public* owned utilities' technical efficiency. This is evidenced by the shorter distance of the *public-public* owned group frontier to the overall best-practice metafrontier. The latter is computed in light of the key urban water sector objectives, that is, to increase piped drinking water coverage and concurrently, enhance collections (revenues).[7] The private management flexibility, among other classical private sector traits, are found insufficiently relevant in advancing *public-private* owned utilities performance compared to utilities under *public-public* partnerships.

Exploring utility efficiency estimates overtime provides further interesting trends. *Public-public* owned utilities produced on average 25, 21 and 20 percent less output relative to their respective group frontiers in 2005, 2006 and 2007 (see Table 3).

Table 3: Annual bias-corrected technical efficiency estimates*

Group	Period		Group Frontier	Meta frontier	Metatechnology ratio**
Public-public	2005	Mean	0.751	0.620	0.826
		Median	0.721	0.567	0.802
	2006	Mean	0.790	0.663	0.835
		Median	0.720	0.617	0.789
	2007	Mean	0.798	0.659	0.826
		Median	0.711	0.607	0.797
Public-private	2005	Mean	0.651	0.426	0.656
		Median	0.616	0.404	0.643
	2006	Mean	0.593	0.466	0.777
		Median	0.602	0.486	0.787
	2007	Mean	0.658	0.509	0.794
		Median	0.650	0.479	0.769

* Weighted by the total number of served population per utilities' licensed jurisdiction.
** As defined earlier, see Table 1

The *public-private* owned utilities produced on average 35, 41 and 34 percent less output (given existing inputs) relative to their respective group's water distribution technology in 2005, 2006 and 2007 (see Table 3). The technology gap declined overtime especially, for the *public-private* owned utilities. Their group's best practice frontier was found closer to the overall urban water sector metafrontier in 2007 than 2005. The *public-public* owned utilities' best practice frontier was found 83, 84 and 83 percent closer to the urban water sector's metafrontier in 2005, 2006 and 2007, respectively. The *public-private* owned utilities' group frontier was on the other hand found 66, 78 and 79 percent closer to the urban water sector's metafrontier respectively in 2005, 2006 and 2007. While the *public-private* (compared to the *public-public*) owned utilities are in general found less technically efficient, their technology gap has indeed declined overtime. This can be explained, among other reasons, by the increased performance-based regulation across these utilities by the MWE, overtime (MWLE, 2006: 2007: 2008).

[7] Taking into account other sector objectives like to increase the number of active water connections provided analogous estimates. This results are available upon request.

In determining WUs' returns to scale nature, that is, relative to each group's best-practice frontier, utilities technical efficiency measures under VRS assumption were compared to those estimated under non increasing returns to scale (hereafter, NIRS). For the latter estimates, the sum of weights (in equation 6) were restricted to less than or equal to one ($\sum \lambda_{it} \leq 1$). Identical VRS and NIRS technical efficiency scores signify decreasing returns to scale operation while nonequivalent VRS and NIRS technical efficiency scores denote operation in an increasing return to scale region (Krasachat, 2003).

The majority *public-public* owned utilities are found to operate under a DRS region while, most *public-private* owned WUs are found to operate under an IRS region (see Table 4). In terms of the managerial ownership organization, 3 and 1 utilities are found to operate, overtime, under a DRS region for the *public-public* owned and the *public-private* owned WUs, respectively. More so, 2 and 5 WUs are found to operate overtime under an IRS region respectively, for the *public-public* owned and the *public-private* owned utilities. For the rest *public-public* owned, 2, 3 and 4 utilities operated under a DRS in 2005, 2006 and 2007, respectively. However, 3 (2005), 2 (2006) and 1 (2007) utilities were found to operate respectively, under an IRS region. On the contrary, 5, 6 and 9 utilities were found to operate under an IRS region for the *public-private* owned WUs in 2005, 2006 and 2007, respectively. More over, 6 (2005), 5 (2006) and 2 (2007) WUs operated under a DRS region for the *public-private* owned WU-group.

Table 4: Utilities return to scale estimates

***Public-public* owned water utilities**				***Public-private* owned water utilities**			
UTILITY	**2005**	**2006**	**2007**	**UTILITY**	**2005**	**2006**	**2007**
Arua	D	D	D	Adjumani	D	I	D
Bushenyi	I	I	I	Bugiri	D	I	I
FPortal	I	D	D	Busia	I	D	I
Kabale	I	D	D	Buwenge	I	I	I
Kasese	I	I	I	Kaliro	I	I	I
Lira	D	I	I	Kalisizo	D	D	D
Masaka	D	D	D	Kamuli	I	I	I
Mbale	I	D	D	Kapchorwa	I	I	I
Soroti	D	I	D	Kayunga	I	D	I
Tororo	D	D	D	Kiboga	I	I	D
				Kitgum	I	D	I
				Kumi	D	D	I
				Luwero	D	I	I
				Moyo	I	I	I
				Nakasongola	D	I	I
				Rukungiri	D	I	I
				Wobulenzi	I	D	I

I = increasing returns to scale, D = decreasing returns to scale

In terms of the water industry market characterization, WUs found to operate under a DRS region have reached and exceeded their optimum water distribution capacity. That is in terms of attaining optimal service provision with existing resources. To accommodate potential growth in demand, these utilities could advance individual than shared piped water connections. Given the positive correlation between household income (as well as better education) and increased willingness and ability to connect to individual water connections (see Larson, *et al.*, 2006), such would more over, reinforce cross-subsidized services to the low income customers.

To universally extent services to the yet unserved population for WUs operating under IRS, increased investment in infrastructure and human development among other things is needed. This will allow effectiveness attainment in terms of water production and distribution mains expansion (to new customers) and maintenance (for existing customers) at affordable connection and user fees. More over, utilities could exploit possible customer density economies and benefit from increased collections for re-investment purposes.

6.2 Efficiency determinants

6.2.1 Managerial ownership

To confirm further *public-public* owned WUs' superiority (see section 6.1), the study explored in a second stage, managerial ownership influence on utilities technical efficiency. Indeed, *public-public* managerial ownership was found significantly and positively linked to increased utilities' technical efficiency (see Table 5). The *public-public* than *public-private* service provision ownership type was associated with a 15 percent increase in utilities' efficiency.

This positive outcome attests the inherent links between efficiency and effectiveness. Indeed, to achieve *a priori* specified performance targets, (strongly) regulated utilities are motivated to improve their technical efficiency. Across the *public-public* (than the *public-private*) owned utilities in Uganda, exemplary performance is quarterly rewarded with bonuses, cash prizes, trophies and staff promotions (Muhairwe, 2009). Poorly performing WU managers (for more than 3 consecutive months) are demoted or laid off.

6.2.2 Market capture

To provide additional insights, WUs market capture trends were examined. Increasing the share of target population over the total active water connections was linked to declined utilities' technical efficiency, though not significant (see Table 5). Increasing piped water connections across specific WUs jurisdiction will likely reduce the unserved population and ultimately, increase utilities efficiency.

Table 5: Efficiency determinants

Dependent variable: Bias-corrected technical efficiency estimates relative to the metafrontier

	Parameter	Standard deviation	P-value
Constant (N=81)	0.431	0.047	0.000$^{(***)}$
Managerial ownership (*public-public* = 1)	0.147	0.047	0.002$^{(***)}$
Share of target population over total water connections	-0.00009	0.001	0.895
Sigma constant	0.190	0.016	0.000$^{(***)}$

$^{(***)}$ statistically significant at all levels (10, 5 and 1 percent, respectively), N = observed sample size

7 Conclusion

Following the late 1990s neoliberalistic urban water sector reforms that advanced in particular increased private sector participation in water service provision, two managerial ownership structures emerged in Uganda; the *public-public* and the *public-private.* Using a two-stage double bootstrap truncated regression metafrontier technique; this paper examined first, technical efficiency differences of and technology gaps between two heterogeneous urban WU-groups in Uganda. Secondly, the paper explored whether WUs' technical efficiency is significantly different across both WU-groups and whether other utility and sector specific environmental factors explain WU-group's technical efficiency differences. Utilities technical efficiency was considered in light of the main service-expanding objective of the urban water sector in Uganda.

Relative to the accessible water distribution technology across both WU-groups, the (i) *public-public* owned utilities produced more (78 percent) potentially attainable output given existing inputs, while (ii) the *public-private* owned utilities produced much fewer outputs (64 percent) relative to the potentially attainable outputs given existing resources available to utilities within the group. This implies that, both WU-groups can potentially increase their output, given existing input resources by 22 (for the *public-public* owned) and 36 (for the *public-private* owned) percent, relative to their respective best-practice frontiers. The *public-public* (compared to the *public-private)* group frontier was found much closer to the overall urban water sector best practice frontier (defined by the metafrontier). This dwindled technology gap can be explained by the additional NWSC's self-monitoring of WUs under its mandate. Such creates (and retains) inter-group competitive pressures that eventually transform into enhanced group performance.

The *public-public* (than *public-private*) managerial ownership arrangement was found significantly and positively linked to increased utilities' technical efficiency. This was positively influenced by increased market penetration (capture) in terms of increased active water connections per utilities' target population. Indeed under a *public-public* (than a *public-private)* arrangement, investments are more directly linked to service provision. Such facilitates water works expansion (and maintenance) to new governmental, residential and industrial buildings. Nonetheless, since procured private operators under the *public-private* arrangement only (often) manage existing assets, maintenance operations (than network expansion) for existing customers are foremost prioritized.

Nonetheless, the technology gap especially across the *public-private* owned utilities was found to decline overtime. Such decline is attributable to the increased performance-based regulation advanced across the *public-private* owned WUs in particular, by the government. Such initiative among others, could eventually help bridge any technology gaps between the groups and especially, for utilities found to operate under an IRS region.

Overall, while managerial ownership matters in explaining WUs technical efficiency overtime, the underlying institutional (such as sector regulation - see for instance Cook, 1999; Bognetti and Obermann, 2008), political and environmental factors conjointly influence utilities productivity. More over, the public sector provides water services to more than 90 percent of the world's population (WHO and UNICEF, 2000; Prasad, 2006). As is the case in most developed economies (Checchi, *et al.*, 2009), the public sector will likely continue to dominate the African urban water industry (as asset owner, service provider or both) in the foreseeable future (Bayliss and McKinley, 2007; Castro, 2008). It is imperative therefore to strengthen public sector capabilities (investment, regulation, provision etc) as a development policy solution for inclusive quality water services access among other basic public utility services in Uganda and Africa in general.

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Annex 1: Earlier studies on the role of ownership on urban water supply utilities efficiency				
Authors	**Data (period, place)**	**Technique**	**Variables**	**Significant (in)efficiency determinants**
***Private rather* than *publicly-owned* urban water utilities are more (significantly) efficient**				
Crain & Zardkoodi, 1978	112: 88 public, 24 private (1970, North America)	CD prod function	3 inputs (C); 1 output (Q)	Capital, labor and OPEX overuse
Crain & Zardkoohi, 1980	78 (1970, North America)	Multiple regression	3 inputs (C); 2 output (Q), 1 Z	Salary incentives and lower operating costs
Raffiee, *et al.*, 1993	112: 238 public, 33 private (1989, North America)	CD cost function	4 inputs (C); 1 output (Q)	Property rights attenuation
Bhattacharyya, *et al.*, 1995	221: 190 public, 31 private (1992, North America)	Translog cost function	4 inputs (C); 2 outputs (Q); 10 Z	Customer diversification & scale of operation
Estache & Kouassi, 2002	21: 18 public, 3 private (1995-97, Africa)	CD prod function	3 inputs (Q); 1 output (Q); 3 Z	Corruption & sector governance
Bitran & Valenzuela, 2003	13: 8 public, 5 private (1998-2001, Chile)	PI	2 inputs (CQ); 3 outputs (Q); 1 Z	Private equity, economies of scale
Moreira, *et al.*, 2005	148: 135 public, 13 private (2002, Brazil)	CD prod function	2 inputs (Q); 1 output (Q)	Capital and labor overuse
Andrés, *et al.*, 2008	49 (15 years, 8 LA countries)	Econometric	3 inputs (Q); 3 outputs (Q); 3 Z	Water losses, services continuity and reliability
Gassner, *et al.*, 2009	977: 836 public, 141 private (1973-2005, LA & Cb)	Regression & DD	1 inputs (Q); 5 outputs (Q); 3 Z	Labor productivity & daily water supply hours
Picazo-Tadeo, *et al.*, 2009	34: 8 public, 26 private (2001, Spain)	DEA	4 inputs (Q); 3 outputs (Q); 5 Z	Labor productivity & density economies
Correia & Marques, 2011	68: 14 public, 23 private, 31 SA (2004-05, Portugal)	Translog cost function	4 inputs (C); 2 outputs (CQ); 5 Z	Scale and scope economies
***Public rather* than *privately-owned* urban water utilities are more (significantly) efficient**				
Lynk, 1993	10 private (1979/80 to 1987/88, United Kingdom)	Multiproduct cost function	3inputs (C); 3 output (Q); 2 Z	Joint service production
Bhattacharyya, *et al.*, 1994	257: 225 public, 32 private (1992, North America)	TGV cost function	3inputs (C); 1 output (Q); 2 Z	Excessive capitalization
Shaoul, 1997	10 private (1985-1999, England and Wales)	Accounting techniques	3 inputs (CQ); 3 outputs (CQ)	Decreased technological change
Saal & Parker, 2000	10 private (1985-1999, England and Wales)	Translog cost function	2 inputs (C); 2 outputs (Q); 2 Z	Price-cap regulation & economies of scope
Saal & Parker, 2001	10 private (1985-1999, England and Wales)	Tornqvist indexes	5 inputs (CQ); 1 output (Q)	Decreased TFP growth but high economic profits
Estache & Trujillo, 2003	4 PR: 1 public, 3 private (1999-2001, Argentina)	Tornqvist indexes	3 inputs (CQ); 2 outputs (C)	Information symmetry
Saal, *et al.*, 2007	10 private (1985-2000, England and Wales)	GPP index	3 inputs (CQ); 4 outputs (Q); 4 Z	Undue operation scale, technical economic losses
Marques, 2008	70 (1994-2001, Portugal)*	PI, TFP and DEA	2 inputs (CQ); 2 outputs (Q); 4 Z	Investment costs and outsourcing
Souza, *et al.*, 2008	342: 324 public, 18 private (2002-2004, Brazil)	CD cost function	1 input (C); 2 outputs (C); 4 Z	Population density & water treatment
No significant efficiency difference between *public* and *privately-owned* urban water utilities				
Feigenbaum & Teeples, 1983	319: 262 public, 57 private (1970, North America)	Hedonic cost function	3 inputs (C); 6 output (Q)	High labor, energy and purchased water costs
Hausman, et al., 1986	64: 32 public, 32 private (1899, North America)	Ordinary Least Squares	7 inputs (CQ); 3 output (CQ)	Rates of return
Byrnes, *et al.*, 1986	127: 68 public, 59 private (1976, North America)	Linear programming	7 inputs (Q); 1 output (Q)	Scale of operation
Teeples & Gyler, 1987	119: 67 public, 52 private (1980, North America)	Dual cost function	8 inputs (C); 1 output (Q); 8 Z	Model mis-specifications
Lambert, *et al.*, 1993	270: 238 public, 32 private (North America)	DEA	4 inputs (Q); 1 output (Q)	Capital, labor, energy and material overuse
Estache & Rossi, 2002	50: 30 public, 20 private (1995, Asia and Pacific)	CD cost function	1 input (C); 3 outputs (CQ); 4 Z	High labor costs and low coverage and service
Saal & Parker, 2004	10 private (1985-1999, England and Wales)	PIN, Translog cost function	5 inputs (CQ); 1 output (Q)	High labor productivity growth
Kirkpatrick, *et al.*, 2006	14, out of 110 (2000, Africa)	DEA, CD cost function	3 inputs (C); 2 outputs (Q); 7 Z	Regulation, but not significant
Souza, *et al.*, 2007	164: 149 public, 15 private (2002, Brazil)	Translog cost function	2 inputs (C); 1 output (C); 5 Z	Cost (in) efficiency

* based on the DEA models; C = cost vectors; Q = quantity vectors; CQ = both cost and quantity vectors; Z's = environmental variables, CD = Cobb-Douglas; prod = production; LA = Latin America; Cb = Caribbean; RE = random effects, FE = fixed effects; DD = difference-in-difference based on the propensity score nearest-neighbour matching; SA = semi autonomous; TGV= Translog generalized variable; PR = provincial regulated water operators; OPEX = operating costs; PI = performance indicators; TFP = total factor productivity; GPP = generalized parametric productivity; PIN = Price index numbers

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