# Effects of Incentive Applications on Technical Efficiencies: Empirical Evidence from Ugandan Water Utilities

*Forthcoming in Utilities Policy*

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October, 2006

**Abstract**

*This study outlines practical cases of incentive applications in water utilities operating under public-public management settings in Uganda, Kenya, Tanzania and Zambia. The paper dispels a common belief that incentive applications are only possible under public-private management settings. Specifically, the study utilizes empirical historical data (period 2000-2006) in fifteen National Water and Sewerage Corporation (NWSC) water sub-utilities in Uganda. Applying stochastic frontier analysis (SFA) econometric methods using a log-linear input distance specification, we find that financial incentive[2] applications have positive impacts on reduction of firm technical inefficiencies. The empirical evidence contributes to literature, debate and water utility management in a number of ways. In particular, it shows that, apart from having positive effects under public-private partnership settings, financial incentive applications can have similar effects under public-public management settings.*

**Key words:** Incentive Applications, Technical Efficiency, Input Distance Stochastic Frontier Analysis.

## 1. Introduction

The principal objective of this study is to conduct an analysis of the effects of financial incentive applications on technical efficiencies of urban water supply industry in Uganda. This involves the use of empirical techniques that can accommodate multi-output and multi-input nature of the industry, which are subsequently used to provide estimates of production elasticities and technical efficiencies. Specifically, the current study utilizes an input distance stochastic frontier production function, incorporating a measure of financial incentives applied in National Water and Sewerage Corporation (NWSC)[3] of Uganda, over

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*The author is very grateful to three anonymous reviewers and Prof. Sanford V. Berg (University of Florida, USA), whose comments greatly improved the quality of this paper.

[2] Financial Incentive in this study is measured as annual maximum earnable financial incentives in a particular NWSC-water sub-utility as a proportion of annual employee basic pay (%). These can also be understood as maximum promised incentive for each sub-utility. The max. earnable incentive varies across firms depending the negotiated share of cash operating margin (collections less operating expenses) and varies with time through annual business plan modifications.

[3] NWSC is a publicly owned autonomous water Corporation, established in 1972. The Corporation started with operations in 3 largest urban towns of Uganda but has since expanded its operations to 22 largest urban towns (including Kampala – the Capital City) as at 2006. The Corporation was almost run to near bankruptcy

a period of 6 years (2000-2006) to predict efficiency effects. The main motivation of the paper is to contribute to the existing body of knowledge by analysing a rare operating context for application of incentive regimes: the public-public setting. The discussion has hitherto concentrated on incentive applications in a public-private settings but I argue in this study that there is no reason, in principle, that such incentive compatible regimes cannot be used in the public sector.

Specifically, **the main study proposition** is:

> "In public-public[4] water sector management settings, incentive intensity (promised), measured by the proportion (%) of maximum earnable incentives divided by employee basic pay, has positive effects on reduction of utility technical inefficiencies".

The institutional set up of National Water and Sewerage Corporation is structured in such a way that there is a Head Office[5] on one side entering into multiple contracting[6] with its subsidiary operating sub-utilities in the different towns gazetted under its jurisdiction, as shown in the table below:

Table 1: NWSC Operating Framework since 2000.

| | |
|---|---|
| **Principal:** NWSC-Head Office | **Agent:** *(Operating sub-Utilities: currently 22 towns, as at Oct-2006)* |
| **Main Operating Framework:** | *2000-2003:* Area Performance Contracts (APCs)<br>*2004-2006:* Internally Delegated Area Management Contracts (IDAMCs) |

Under the above operating framework, NWSC managers and staff have negotiated and eventually earned incentives, based on structured incentive plans, incorporated in operating contracts with Head Office. The incentive plans were designed using sets of performance criteria, selected based on changing priority performance objectives. Consequently, the contractualization processes were deliberately made flexible to allow for continuous innovation and creativity. No contracting arrangement can entirely predict future operating conditions and therefore, NWSC managers have adopted a flexible and partnering approach[7].

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in 1998 but with the change of leadership, there has been significant performance turn-around through use of financial incentives for staff and managers, among other performance drivers. For more details of NWSC performance improvement initiatives and achievements, readers are referred to Mugisha et al (2004a), Mugisha et al (2005).

[4] 'Public-public' refers to contractual relations where both parties are publicly owned

[5] The Head Office is directly under the Managing Director (CEO) who is currently (Oct-2006) Dr. William Muhairwe, having taken the leadership of the organisation in 1998 when it was at the verge of near bankruptcy. Dr. Muhairwe has since spearheaded the implementation of a series of turn-around initiatives, which have drastically improved performance of NWSC over the last 7-years.

[6] For Kampala – the Capital City, the water distribution and related commercial operations were under the private management operator up to early 2004.

[7] NWSC managers at Head Office distinguish between partnering and legalistic contracts. Partnering contracts involve strong orientation towards continuous Principal-Agent (P-A) interaction; incorporate persuasive and strong shared problem solving approach and recognises that each party (P-A) needs to learn from one another for continuous performance improvements. In contrast, legalistic contracts involve strong orientation towards

The main characteristics of incentive plans applied at NWSC are multi-facetted. The design ensures that there is a fair share of operating risks, refers to a multi-dimensioned performance criteria aimed at driving priority performance enhancement objectives through a suitable weighting system. In addition, the design discerns unique performance problems for a particular sub-utility that need to be addressed. Deliberate efforts are made to make the incentive computational formulae simple to understand by a wide spectrum of operating staff for effective stakeholder mapping, ensuring that use of performance indicators that exhibit minimum variability/volatility is paramount. Table 2 shows a summary of incentive computational formulae that have been adopted by different water utilities in East and Central Africa, with the assistance of NWSC External Services Unit, following the same design principles used at NWSC.

Table 2: Incentive Application in Selected Water Utilities in East and Central Africa

| Sno | Utility/Country | Incentive Computational Formula[8] |
|---|---|---|
| 1 | Nkana Water and Sewerage Company (NWSC-Z), Zambia | MIE = 10% of M.P[1 + $(C_a\text{-}C_{sm})/(C_{st}\text{-}C_{sm})$] |
| 2 | Dar Es Salaam Water and Sewerage Corporation (DAWASCO), Tanzania | MIE = 20 + 30 * $(C_a\text{-}C_{sm})/(C_{st}\text{-}C_{sm})$ |
| 3 | Nzoia Water and Sewerage Company (NZOWASCO), Kenya | MIE = X percent * $(C_a\text{-}C_{sm})$ |
| Under these incentive regimes, performance has consistently improved, with the advent of financial incentives regimes[9]. | | |

In particular, sub-utilities (operating agents) under NWSC-Uganda are currently operating under Internally Delegated Area Management Contract (IDAMC) framework. Under this structure (also detailed in Mugisha et al., 2004a), the management fee is calculated as follows:

Management Fee under IDAMC = Base (Fixed) Fee + Performance Fee + Incentive Fee; where:

- Base Fee = All uncontrollable costs + 75% (key partners' pay + controllable costs).
- Performance Fee = 25% (key partners' pay + controllable costs) times (number of achieved weighted targets divided by total number of weighted targets)

arms-length P-A operations, involve strong deterrent and strict zero-tolerance to non-compliance and each party sticks to its obligations and roles – heavy output orientation.

[8] MIE denotes: monthly incentive earned by the group; M.P: monthly pay for staff; Ca: achieved revenue collection; Csm: target revenue collection for the month (based on realistic and achievable principle); Cst: 'stretched' collection target which is set above Csm and reward improvement; X is a negotiated share of efficiency gains earned by staff.

[9] Analysis by NWSC-Uganda's External Services Unit, which has been working in partnership with the utilities in question shows that since incentive were introduced as a performance driver: for DAWASCO revenue collection has improved by 65% over a period of 12 months; NZOWASCO - 15% over a period of 6 months while NWSC-Z has improved its collections by over 52% over a period of 9 months.

- Incentive Fee = X% times $COM_a$ (m $UFW_a$+ n $WR_a$+ p $DRR_a$+ q $CE_a$), where X% is the agreed share of improvement in COM to be retained by the operator as bonus, m, n, p, q are weighting factors, and subscript "a" denotes incremental achievement. The increments are all bounded at (0, 1). The X-value varies from utility to utility, depending on the negotiated value.

More simply, the management fee is made up of three components: (1) a fixed fee that covers 100 percent of uncontrollable and 75 percent of controllable monthly costs, (2) a performance fee, which covers 25 percent of controllable costs if all weighted minimum performance standards are met, and (3) an incentive fee (extra payments for exceeding minimum performance standards).[10]

The management fee structure (Mugisha et al., 2004b) currently being applied under the IDAMC framework exhibits a better incentive arrangement than in the previous programmes. Under this fee structure, the best performing operating utilities receive a maximum performance fee compensation of 5 percent of total operating costs, on average. The performance fee guards against performance declines and is, therefore, based on weighted minimum performance standards according to average performance in the last six months prior to signing the IDAMC. In addition to the performance fee compensation, the best performing utilities get an incentive fee compensation of about 25 percent of total operating costs (including the incentive fee itself). This means the total compensation (performance and incentive fees) is 30 percent of operating costs. The remaining operating costs (base fee) are passed through, and incentives to optimise such costs are implicitly embedded in the sharing of cash operating margin (cash collection minus operating costs). The incentive fee encourages the utilities to reduce operating costs, maximize revenue collection, reduce unaccounted-for water, reduce accounts receivables, reduce the number of disconnected accounts and maximize billed income. The incentive fee compensation is a share of the cash operating margin realised, which ranges from 30 percent for large sub-utilities to 50 percent for small sub-utilities. The remuneration structure is an improvement from the previous arrangement under Area Performance Contracts – APCs (in effect 2000-03), which started with an incentive compensation of 5 percent of operating costs. This was later increased to 10 percent of operating costs.

Thus, the performance fee gives appropriate weight to each target, depending on the importance attached to the corresponding performance area—in a pass/fail framework. The incentive fee does reward movements toward key targets. Apart from incentives, the APCs had a disincentive mechanism applicable to any Area showing persistent failure in achieving agreed performance levels (three consecutive months). The penalty system under IDAMCs involves withholding payment for key partners and part of the controllable costs if some key targets are not met as shown in the management fee formula above.

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[10] Uncontrollable costs are operating costs that the operator is unable to manipulate to achieve savings in the short to medium term, with the incentives provided, without causing flaws in the operational and maintenance systems. These include power and chemical costs, routine infrastructure maintenance costs, vehicle maintenance costs, salary for lower-level staff, etc. In contrast, controllable costs (e.g., telephone, travel, staff allowances, vehicle fuel, etc.) can be a source of savings without threat to the operational and maintenance systems. The categorisation is agreed *ex ante*.

## 2. NWSC Performance Achievements and Challenges

The reform initiatives from 2000 – 2006, that have incorporated significant use of incentives, have had positive impacts. Notably, service coverage has increased from 52% to 70%. Water network coverage increased by 49% (1,117 Km of water mains extensions, primarily from internally generated funds). In addition, new connections increased from 4,317 to 28,312 per year. As a result, total connections are up from 60,826 to 148,312 (or 70% of target population served, from a population base of 1.7 million people as at 2006). Unaccounted for water has fallen from 49% to 29% (Kampala is at 34%, while other areas are now at 15%). Metering efficiency (proportion of metered accounts to total accounts) has increased from 70% to 99.6%, while connection efficiency (proportion of active connections to total connections) has improved from 71% to 93.9%. On the financial side, annual turnover has improved from about US$15million to US$34million. Because of this performance, operating profit after depreciation has improved from losses of US$0.1million to a surplus of US$3.0million. Positive cash flows have financed network expansion and enabled maintenance programs to be scheduled and implemented.

Despite the accomplishments, NWSC still faces challenges in the area of sewerage where the coverage is about 10%. The sewerage investment costs are inherently very high, and the corporation is currently finding it hard to devote resources to such investments, given the payoffs to other uses of those funds. Therefore, achieving the Millennium Development Goals remains a distant goal. NWSC faces the challenge of serving the poor communities where cost recovery is questionable. The infrastructure in such communities is very poorly planned and extending services to such areas involves significant difficulties. Nevertheless, the organization continues to explore cost-effective ways to carry out this task.

However, these achievements are based on partial performance indicators and fall short of showing progress based on more meaningful advanced statistical techniques that incorporate multiple input and multiple output production technology. This study aims at taking the analysis beyond partial efficiency measures to more representative and all-encompassing technical efficiency measures.

## 3. Past Studies

Many water utility managers are increasingly acknowledging that incorporation of managerial incentives in their performance improvement plans enhances delivery of superlative outputs and efficiency. Most structural reforms in the water sector during 1990s and early 2000s, especially in African water utilities have been premised on the fact that it is easier to apply optimal incentives in private rather than public companies. This was probably based on two reasons: first, public companies were contemporaneous with long histories of market failures and secondly, public company employees had significant iniquitous tendencies and poor attitude to work compared to private companies where business ownership played a positive balancing effect. Consequently, during that period, emphasis was put on increased private sector participation in water supply business management. However, the recent performance trends have shown that efficiency improvements are possible whether you have a publicly or privately-based operation. One of the common underlying success factors is the structuring of managerial incentive sharing

plans. The following literature survey improves our understanding of the role of managerial incentives as a performance driver. In addition, the literature also reviews some studies that have conducted econometric analyses of urban water supply operations using empirical modelling techniques such as regression analysis, data envelopment analysis (DEA) and stochastic frontier analysis (SFA).

A study of 80 Chinese rural enterprises by Chun et al. (2003) found that introduction of managerial incentives through incentive contracts had positive but not statistically significant effects on the enterprises' performance. Additional research has underscored the role of managerial incentives to improve the performance of state-owned enterprises (Groves et al., 1994, and Li, 1997). More evidence of the positive role of managerial incentives is reported by Kosnik and Bettenhausen (1992), who concluded that managerial compensation through fixed salaries only promote managerial opportunism, whereas financial incentives (equity share) promote managerial compliance with the principal's interests.

It can also be argued that incentive contracts, whether in public or private settings, can be designed to incorporate the same managerial compensation structures, which carry with them the same performance drivers, so that the main distinguishing factor is the ownership or stake in the operating business. Demski and Sappington (1991) modelled the effects of offering incentives to agents through buy-out options and found that such incentives can have significant effects on the re-alignment of the agent's behaviour to the principal's interests. Explicitly put, they suggest that workers whose wages are not linked to the firm's performance may have limited incentive to work diligently, particularly when employee illicit activities cannot be documented conclusively to any third party and so are not verifiable. One of the authors' propositions, which is later proved right through a mathematical modelling procedure, was that employee behaviour can be positively re-aligned when they become residual claimants of the firm's stream of profits. This idea is also emphasised by Groves et al. (1994) in a study of state-owned enterprises in China. They found that when firms were allowed to retain more of their profits, managers strengthened workers' incentives, and productivity increased with increases in bonus payments.

Lambert and Dichev (1993) conducted a comparative analysis of private versus publicly owned water utilities. They used data from 1980 survey conducted by the American Water Works Association (AWWA) and measured technical, allocative and scale efficiency using DEA. The single output variable used was total water delivered, while the four input variables were annual labour, energy used, materials input and value of capital. The study found that technical inefficiency is the main source of inefficiency and that there were no significant differences in performance between private and public firms. Thanassoulis (2000a and 2000b) carried out a DEA of water distribution in the UK using OFWAT data. The model inputs included operating expenditure while the output measures included number of connections, network length, volume of water delivered and pipe bursts. However, the choice of network length and pipe bursts as output could arguably be misleading. A water company should institute means to minimise bursts rather than maximise them and the use of network length, which is normally modelled as input, as output may mean that more input is better.

Byrnes, Grosskopf and Hayes (1986) also carry out a comparative analysis of private/public settings, using DEA techniques. They assess estimates of levels of firm technical efficiencies in each sample. They specify a production function with one output variable, volume of water delivered and seven input variables namely: ground water, surface water, purchased water, part-time labour, full-time labour, and pipeline length and storage capacity. They found out no significant differences in the technical efficiency scores of private versus public firms. Berg and Lin (2006) analyse the consistency in performance rankings for the Peruvian water sector. They use DEA and SFA input distance function model specifications and compare the estimated efficiency rankings with those used by the Peruvian Regulator (SUNASS). The model inputs include operating costs, number of staff and number of connections while the output measures include volume of water billed, number of customers, service coverage and continuity of service. They find out that while efficiency ranking obtained by DEA and SFA approaches are significantly correlated, they are less correlated with those used by SUNASS. On the other hand, Lin (2005) observes that service quality is an important performance indicator of the water and sanitation industry. Using empirical data from Peruvian Water sector and using different specification of frontier cost models, Lin finds that the introduction of quality variables affects performance comparisons across utilities.

The existing literature shows limited coverage of productivity analysis linking incentive applications and technical efficiency in water utility settings. The coverage becomes even sparser in water utilities in developing countries. This study, therefore, helps to increase our understanding in respect to use of direct financial incentives to managers and staff as a performance driver.

## 4.0 Efficiency Measurement Methods

The traditional approach to performance evaluation and benchmarking in the water industry has been single-measure gap analysis. This involves use of separate efficiency indicators such as unaccounted for water, number of staff per 1000 connections and expenditure as a percentage of revenues generated. These measures, normally referred to as 'partial productivity measures', are not substitutes for efficiency frontiers, which recognise the complex nature of interactions between inputs and outputs. There has, therefore, been a shift to the use of either data envelope analysis (DEA) or stochastic frontier analysis (SFA) methods for estimating efficiency of production. A firm is regarded as technically efficient if it is operating on the best practice production frontier in the industry. The degree of technical efficiency is given by the ratio of the minimal input required to the actual input use, given the input mix by the firm.

DEA involves the use of linear programming, whereas SFA involves the use of econometric methods. According to Coelli et al. (1998), some advantages of SFA models over DEA models include their capacity to account for noise and the potential for conventional tests of hypotheses (e.g., appropriateness of the model and the absence of technical inefficiency effects). However, SFA models have the following disadvantages, which DEA methods do not have: there is need to specify a distributional form for the inefficiency term and to specify a functional form for the production function (or cost function, etc.), and it is more difficult to accommodate multiple outputs. Modern analytical methods allow SFA to incorporate multiple outputs and inputs simultaneously through

distance functions under some specific assumption[11]. This case study uses an input distance SFA function[12] to estimate firm efficiencies in view of inherent data inaccuracies associated with inadequate data management traditions in low-income countries. Under SFA modelling, it is possible to consider different forms of functions: the production, cost or profit function. The cost and profit functions under SFA require the behavioural assumptions of cost minimisation and profit maximisation. The production function does not require any of these behavioural assumptions[13].

## 5. Efficiency Measurement Using Input Distance Function

Following Coelli et al. (2003), Estache et al. (2004) and Berg and Lin (2006) the translog input distance function for M outputs and K inputs, is adopted and written as:

$$\ln D_{it} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m-1}^{M}\sum_{n=1}^{M} \alpha_{mn} \ln y_{mit} \ln y_{nit} + \sum_{k=1}^{K} \beta_k \ln x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{kit} \ln x_{lit}$$

$$+ \frac{1}{2}\sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{km} \ln x_{kit} \ln y_{mit} + \sum_{m=1}^{M} \pi_m \ln x_{mit} t + \sum_{k=1}^{K} \kappa_k \ln x_{kit} t + \phi_1 t + \phi_2 t^2 \qquad (1)$$

Where t represents time (t = 1, 2 …T), the Greek-coefficients are unknown technological parameters to be estimated and (i = 1, 2…N = number of firms), $y_s$ and $x_s$ are outputs and inputs respectively. Here $D_{it}$ represents an input distance: D = max *[ρ :( x/ρ) ЄL(y)]; L(y) = [x* $\in R_{+}^{K}$ *: x can produce y)*. The input distance function must be symmetric and homogeneous (of degree +1) in inputs. The restrictions required for homogeneity are:

$$\sum_{k=1}^{K} \beta_k = 1; \ \sum_{k=1}^{K} \beta_{kl} = 0 \text{ (k = 1, 2…K) and } \sum_{k=1}^{K} \delta_{km} = 0 \text{ (k=1, 2…K)}$$

$$\sum_{k=1}^{K} \pi_k = 0 \qquad (2)$$

Those required for symmetry are:

$$\alpha_{mn} = \alpha_{nm} \text{ (m, n = 1, 2…M) and } \beta_{kl} = \beta_{lk} \text{ (k,l = 1,2,….K)} \qquad (3)$$

[11] Readers are referred to Coelli et al. (2003) for more elaborate discussions on multiple input/output methods of efficiency estimation.
[12] An input distance SFA function is selected instead of output oriented specification because according to Coelli et al. (2003), the input distance function is best suited to the case of endogenous inputs and exogenous outputs, which is a reasonable assumption in most network industries, including water. The firms are generally required to supply services to a fixed geographical area, and hence the output vector is essentially fixed.
[13] In the same connection, according to Estache and Kouassi (2002), there are several other reasons why a production function is preferred over a least-cost function in utility performance research in Africa: (1) in most African countries, the production cost structure is either not known or the degree of uncertainty surrounding the cost structures is relatively high; (2) in most classical papers, capital and length of the network are two key variables but they are highly correlated (multi-collinearity issue), which means that only one of these variables must be used, not the two of them; (3) in the specific context of Africa, the number of connections is a very important variable since the average family size is 7-9 (a free rider issue); (4) a production function like a cost function, has a variable t (time) which captures technological impact in the African water industry.

Following Carrington et al. (2002) and Estache et al. (2004), these restrictions can be imposed on equation (1) by normalising the function by one of the inputs. Because of the homogeneity, if we arbitrarily choose one of the inputs, such as the K[th] input, we obtain:

$$D\,(x/x_K, y) = \mathrm{D}\,(x, y)/\,x_K \tag{4}$$

Consequently, the final form is derived as:

$$\begin{aligned}
-\ln(x_{Kit}) &= \alpha_0 + \sum_{m=1}^{M}\alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m-1}^{M}\sum_{n=1}^{M}\alpha_{mn}\ln y_{mit}\ln y_{nit} + \sum_{k=1}^{K-1}\beta_k \ln x^*_{kit} \\
&+ \frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\beta_{kl}\ln x^*_{kit}\ln x^*_{lit} + \frac{1}{2}\sum_{k=1}^{K-1}\sum_{m=1}^{M}\delta_{km}\ln x^*_{kit}\ln y_{mit} + \sum_{m=1}^{M}\pi_m \ln x_{mit}t + \sum_{k=1}^{K}\kappa_k \ln x_{kit}t + \phi_1 t + \phi_2 t^2 \\
&- \ln(D_{it})
\end{aligned} \tag{5}$$

(i = 1,2,………..N; t=1,2,…….T) and $x^*_k = x_k / x_K$

According to Coelli et al. (2003), the error term explains the difference between the observed data points and those points predicted by the transformation function. The distance term –ln ($D_{it}$) can, therefore, be replaced by a composed error term, $v_{it} - u_{it}$, and estimate this function as would be done for a standard stochastic frontier production function. In that case, error term, $v_{it} - u_{it}$ is such that $v_{it}$s are assumed to be independent and identically distributed (i.i.d.) random errors which have normal distribution with mean zero and unknown variance, $\sigma_v$ and $u_{it}$s are non-negative random variables which are associated with technical inefficiency[14] in production of firms in the industry involved.

### 6. Modelling Inefficiency Effects in Input Distance Function

According to Battese and Coelli (1995)[15], for the i[th] firm in the t[th] period, technical inefficiency effect, $u_{it}$, is obtained by truncation of the N($\mu_{it}$, $\sigma^2$) distribution i.e. $u_{it}$ is such that truncation of N($\mu_{it}$, $\sigma^2$) implies:

$$\mu_{it} = z_{it}\psi, \tag{6}$$

where $z_{it}$ is a (1xM) vector of observable explanatory variables whose values are fixed constants, and $\psi$ is an (Mx1) vector of unknown scalar parameters to be estimated. With the specification in Equation (4), it is assumed that an appropriate parametric representation of technical change, e.g., non-neutral technical change in a translog frontier, is specified in the array of x-input variables for the frontier. The ML estimation of this model specification is programmed within the FRONTIER version 4.1 program (Coelli, 1996) and is called "Model 2" or the "technical efficiency (TE) effects model." Since this study investigates the effects of financial incentives on firm-specific inefficiencies, the technical efficiency effects model of Frontier 4.1 is used.

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[14] The technical efficiency measure, $TE_{it} = \dfrac{y_{it}}{\exp(x_{it}\beta)} = \dfrac{\exp(x_{it}\beta - u_{it})}{\exp(x_{it}\beta)}$ is equal to the conditional expectation of exp($-u_{it}$), given the value of ($v_{it}$-$u_{it}$). It is the inverse of the input distance measure, and hence varies between 0 and 1.

[15] Readers are referred to Coelli et al. (1998: Page 207) for a detailed explanation why it is recommended that efficiency effects are modelled in single-stage maximum likelihood (ML) procedure.

## 7. Data and Empirical Results

In this study, in line with past studies in the water industry (see literature review above), three inputs are used: labour, network length (as a proxy for capital) and operating expenses[16] for the period 2000-2006. On the other hand, the outputs include: connections and water billed as a percentage of water delivered[17]. Corresponding data on all the sub-utilities (numbers shown in table 3) of NWSC including Kampala is considered.

Table 3: Utilities under NWSC – Period 2000-2006

| **Period** | **Number of Sub-Utilities** |
|---|---|
| 2000-2001 | *12* |
| *2002-2006* | *15* |

Apart from basing the input-output selection on commonly used parameters in econometrics analysis literature, the choice is based on the way incentive plans have been designed in NWSC-Uganda. The main performance objective for staff and managers for the period 2000-2006 has been to improve financial sustainability. Unaccounted for water has been a common problem in NWSC sub-utilities and hence improvement of water billed to water delivered ratio[18] has been at the heart of performance initiatives. On the other hand, service coverage has been low – therefore increasing connections as a surrogate for increased access has been another target output of performance programmes in NWSC. In addition, the production inputs of labour, network length and operating expenses have been key areas of consideration by managers to achieve optimal results given that the related performance indicators as at 2000 had significant gaps. Table 4 and Table 5 list the input distance SFA model specification and summary statistics respectively.

Table 4: Input Distance Function Specification

| **Variable** | **Indicator** |
|---|---|
| Inputs | Pipe Network Length |
| | Operating expenses (including depreciation) |
| | Staff (labour) |
| Outputs | Water billed/Water Delivered (%) |
| | Connections |
| Efficiency Parameter | Max. earnable utility specific incentive /Employee Basic Pay (%) |

[16] Operating expenses are computed by adding employee related costs, administrative costs, static plant operation and maintenance costs, premises maintenance costs, supplies and services costs and provision for uncollectible debts.

[17] Percentage of water billed to water delivered was used because log. water billed is highly correlated with log. connections (correl. coeff. of 0.98), which would result into statistical bias due to multi-collinearity problem in the regressors for the input distance function, if water billed is used as output, like in many empirical studies.

[18] Water billed to Water delivered (%) is the inverse of unaccounted for water.

Table 5: NWSC Summary Statistics 2000-2006

| **Variable** | **Mean** | **Standard Dev.** | **Minimum** | **Maximum** |
|---|---|---|---|---|
| Inputs | | | | |
| Network Length | 164 | 245 | 31 | 1,149 |
| Staff (No.) | 72 | 128 | 15 | 548 |
| Opex. (Ushs/year) | 2,301,289 | 5,285,632 | 198,315 | 24,351,848 |
| Outputs | | | | |
| Water Billed/Water del. (%) | 77 | 11 | 49 | 95 |
| Connections | 7,165 | 16,012 | 597 | 93,929 |
| Eff. Parameter | | | | |
| Max. earnable incentive /Employee basic pay (%) | 31.49 | 30.99 | 1.20 | 111.02 |

Given the above model specification, it means for the translog input distance model specification in equation (5), K = 3, M = 2, N = 84 and T = 6. In line with Estache et al. (2004) and Coelli et al. (2003), this study sets all period numbers to 1 and set the firm numbers to vary from 1 to 84 (even though from table 3 above the data is derived from un-panelled data of 12-15 firms over a period of six years). Accordingly, this is done to ensure that the Frontier program treats each observation individually. According to Coelli et al. (2003), if this is not done, we would be imposing a restriction on the model that the technical efficiency of the i-th firm must be constant across all the six years (which is imposed by Frontier program when panel data are used). This way, also in line with Berg and Lin (2006), we are utilising pooled data.

Coelli et al. (2003) also point out that in order to interpret the estimated first order parameters in the SFA function as production elasticities, evaluated at the sample means, we can express all data in deviations from the sample means. Consequently, in this analysis, all data have been computed[19] as deviations from the column sample means. The time trend variable is also in deviation from the mean, that is, as the mean of the time trend variable is 3.64 (un-panelled data) in this instance, the mean corrected trend variable is converted from (1, 2, 3, 4, 5, 6) to (-2.64, -1.64, -0.64, 0.36, 1.36, 2.36).

**Model Estimation**

We are now in position to estimate the parameters in the translog specification in equation (5). Since this study is analysing the effects of incentive applications on firm technical efficiencies, we include the efficiency parameter (percentage incentive paid/employee basic pay) and model it in the secondary equation (6). Since $TE_{\mathbf{it}} = \exp(-u_{\mathbf{it}})$, a negative value of $\psi$ in equation $\mu_{it} = z_{it}\psi$, as obtained from efficiency effects model specification of Frontier program, will signify a positive impact on firm technical efficiency. As already pointed out, in the SFA input distance function model, the distance term can be replaced with a composite error term, $v_{it}$-$u_{it}$ and estimate the function as a standard stochastic frontier production function. On the other hand, Coelli and Perelman (2000) employ a traditional estimation method of distance functions (without two-component errors) and rely on corrected ordinary least squares (COLS). The main

[19] Detailed excel-computational data sheets are available from the author on request.

difference between COLS and SFA is that COLS attributes all deviations to inefficiency while SFA models attribute part of the deviations to inefficiency and part of the deviations to random noises. Since data in NWSC utilities cannot be considered free of noise (due to evolving and infancy nature of performance data capture systems) this study employs SFA techniques. Frontier 4.1 (developed by Tim Coelli) is used for estimation. Since the study investigates efficiency explanatory factors, the technical efficiency effects model specification of Frontier program is used.

Although the translog function is a flexible functional form, it often violates assumptions required in input distance function, such as monotonicity[20] and freedom from multi-collinearity between regressors[21]. Multicollinearity influences the statistical significance of the model (Berg and Lin, 2006). In particular, given the sample size of the data set in this study, the translog functional form consumes too many degrees of freedom (21 regressors in a translog model). Therefore, this study employs a log-linear input distance function model, which minimises the above problems. In this case, the distance function in equation (5) is simplified as follows:

$$-\ln(x_{Kit}) = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + \sum_{k=1}^{K-1} \beta_k \ln x^*_{kit} + \phi_1 t + \phi_2 t^2 - u_{it} + v_{it} \qquad (7)$$

(5)

(i = 1, 2…N; t=1, 2 ….T) and $x^*_k = x_k / x_K$

The model dependent and regressor data are computed as shown in table 6.

Table 6: Model dependent variable and regressors

| **Variable** | | **Computation**[22] | ***Symbol*** |
|---|---|---|---|
| Dependent variable | | -log(net. length) | *-x3* |
| Regressors (ind. variables) | Output | log(water billed/water del.*100) | *y1* |
| | | log(connections) | *y2* |
| | Normalised input | log(staff)-log(net. length) | *x1-x3* |
| | | log(opex)-log(net. length) | *x2-x3* |
| | t-trend | Time | *t* |
| | | time-squared | *t^2* |
| *Efficiency explanatory variable* | | *Max. earnable Incentive/basic pay*100* | *z1* |

[20] According to Sauer et at. (2006) monotonicity requirement is fulfilled if there are positive marginal products with respect to all inputs. This requires that $\delta y_i / \delta x_i \succ 0$. Since the data is already expressed as deviations from sample means, the analysis checks if the first order parameters of the translog function have the right signs to satisfy the above requirement. Frontier program results, using a translog input distance specification, show that all the first-order output parameters have negative signs and all the first-order input parameters have positive signs. This would be okay but only half of them are statistically significant, with standard errors less that the actual values. The others are insignificant and the values of the standard error terms are greater than the corresponding parameters. It is, therefore, not possible to guarantee positive marginal products with respect to inputs all the time.

[21] When multiple correlations analysis of the regressors for the translog function is carried out, a number of correlations between regressors exceed 0.85 and some above 0.95. According to Berg and Lin (2006) such problems may prevent us from making meaningful conclusions.

[22] The computations are carried out based on deviations from sample means e.g. y1 = ln(y1) – ln($y1_m$), $y1_m$ is the sample mean of y1s; x1-x3 = (ln(x1)-ln($x1_m$))-(ln(x3)-ln($x3_m$)) where the notation m again refers to the sample mean.

The results of Frontier 4.1 program for the translog specification in equation (7) are shown in table 7. The empirical results indicate that the input distance SFA model is well behaved. All the terms have correct signs: the output coefficients are negative while the input coefficients are positive. Notice that the dependent variable is negative input. The results also show that the elasticities for staff and expenses add up to less than one. Since the network length variable is used to normalize the other inputs, the latter shows that the production elasticity for network length is also positive. All this means that after controlling for inputs, an increase in output should require an increase in input. Similarly given the outputs, an increase in other inputs will result into a decrease in the specific input. Therefore the coefficients of outputs are positive. The impacts of proportion of water billed/water delivered[23]; connections, staff, network length and expenses are all statistically significant. This is not surprising, given that NWSC-utilities have implemented deliberate performance improvement programmes targeting these performance areas, since 2000 (Mugisha et al. 2004a). The time trends show positive and significant coefficients. The positive technological progress (about 4.9%) is not surprising, given that NWSC sub-utilities have, since 2000, implemented a series of innovative programmes[24] (ever-changing ways of doing things). The maximum likelihood estimated parameter 'gamma' is 0.785 ($\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$) and significant, indicating that inefficiency is the main source of deviation.

Table 7: Log-linear Input Distance SFA Model Results

| **Parameter** | **Coefficient** | **Standard-error** | **t-ratio** |
|---|---|---|---|
| beta 0 | -0.097 | 0.039 | -2.460 |
| log(water bill/water de*100) | -0.136 | 0.144 | -0.940 |
| logconnection | -0.876 | 0.030 | -29.197 |
| logstaff/net.legth | 0.351 | 0.097 | 3.633 |
| logopex/net.length | 0.261 | 0.098 | 2.659 |
| t | 0.049 | 0.018 | 2.757 |
| t-squared | 0.055 | 0.013 | 4.069 |
| $\psi_0$ | -0.571 | 0.636 | -0.898 |
| Max. earnable incentive/basic pay*100 | -1.574 | 1.448 | -1.087 |
| $\sigma_u^2$ | 0.065 | 0.033 | 1.948 |
| $\gamma$ | 0.785 | 0.145 | 5.403 |

[23] The ratio "water billed/water delivered" is the inverse of un-accounted for water and is technically referred to as "billing efficiency". All NWSC performance improvement initiatives have considered optimisation of billing efficiency as one of parent performance indicators.

[24] For example the rationalisation of medical scheme in 2000, introduction of the new transport policy in 2001, restructuring of audit activities in 2004 etc improved operating cost containment technologies. On the other hand, the tariff simplification in 2001 and new connection policy in 2004 improved the number of new connection hook-ups and hence technological progress.

Log likelihood function = 44.26

LR test of the one-sided error = 0.24199529E+01; with number of restrictions = 3

## Testing the study proposition

As already pointed out, $TE_{it}$ = exp (-$u_{it}$) where $u_{it}$: truncation of N ($\mu_{it}$, $\sigma^2$) such that $\mu_{it} = z_{it}\psi$. Consequently a negative value of $\psi$ signifies positive impact of $z_{it}$ on reduction of technical inefficiencies. The $\psi$-coefficient (max. earnable iincentive/basic pay*100) in table 7 is negative implying a positive but insignificant impact on exp (-$u_{it}$) or technical efficiency. When Frontier 4.1 is run without the intercept coefficient ($\psi_0$), the $\psi$-coefficient reduces to -0.383 (standard error of 0.315) and statistical significance increases to a t-value of -1.216. In both cases, the impact on technical inefficiency reduction is positive but with varying levels of statistical significance (at Upper_ Tail areas between 10 and 25 percent).

## 7. Conclusions

This paper outlines practical cases of incentive applications in water utilities operating under public-public settings. The paper dispels a common belief that incentive applications are only possible under a privately managed management settings. The study also utilizes empirical data, obtained through documentary review of historical data (period 2000-2006) in fifteen NWSC water sub-utilities in Uganda. Applying stochastic frontier analysis (SFA) econometric methods using a log-linear input distance specification, positive effects are found between maximum (‘promised’) earnable financial incentives and firm technical efficiencies.

The small significance of the incentive impact could imply that NWSC sub-utility and partners can make better of incentives through a number of ways (1) the NWSC practice of incentive ‘ceilings’ beyond which managers and staff are not entitled to additional incentives may be a perverse incentive itself (2) the limited knowledge of the structure of incentive by most staff on the ground, except the managers and a few key staff, may also be detrimental to the effectiveness of the incentive (3) the incentive scheme of NWSC does not seem to take full account of environmental factors like disparities in customer willingness and ability to pay, customer market differentiation advantages etc – this might also discourage managers and staff in disadvantaged sub-utilities.

The empirical evidence contributes to literature, debate and water utility management in a number of ways. In particular, it shows that, apart from having positive effects under public-private partnership settings, financial incentive applications can have similar effects under public-public management settings.

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