Managerial Incentive Plans for Water Utility Management: Practical Applications in Sub-Saharan African Water Companies

By: Dr. Silver Mugisha
February, 2006

Abstract

A number of studies exist in relation to monitoring/regulation of complex forms of water operations management contracts, particularly leases and concessions. The latter are implemented, more rationally, in operating environments where perceived market entry risks have been adequately mitigated prior to actual implementation of reforms. In these cases, it is possible to implement incentive activities, characterised by mutually and objectively negotiated tariff/rate regimes. Incentive plans involving tariffs/rate regimes, are however, not easily applicable in simple forms of incentive contracts like management, service or performance contracts. We know that in developing countries where perceived market entry risks are high, the latter forms of contracts form the bulk of the initial preparatory activity. And yet incentive applications in these contracts/performance improvement programmes have not received sufficient research and debate. This paper outlines practical application of incentives in public-public settings and presents empirical evidence in respect to a case of National Water and Sewerage Corporation (NWSC), Uganda where managerial incentive intensities positively impact on technical efficiency and total factor productivity.

1. Introduction

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 skirting 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 in both public and private management settings.

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. In contrast to this study of farming businesses in a country with a long history of communism, Bardhan and Roemer (1992) claim that contracting arrangements can provide sufficient incentives for

socialistic firms to become as efficient as their capitalistic counterparts. 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. According to Fama and Jensen (1983), the agency theory posits that managers will be less likely to engage in behaviour that is in conflict with the principal's interests when managerial compensation is linked to firm performance and equity share. However, as Kosnik and Bettenhausen (1992) point out, this debate is inconclusive and ongoing. This research study seeks to contribute to this debate by studying the effects of intensity of managerial incentives on efficiency and productivity improvement in utilities. Although there has been considerable research on the effects of managerial incentives, it has been in respect to other dependent variables; little has been done in respect to the effects on efficiency and total factor productivity, which this case study is addressing.

One side of the debate has posited that it is difficult to provide proper monitoring and apply managerial incentives to utility managers in a public-public partnership setting. Renzetti and Dupont (2004) report on a number of studies in the United States, United Kingdom and France that found no compelling evidence that private utilities have outperformed public utilities or that privatising water utilities leads to unambiguous improvements. Similarly, a research study on relative technical efficiency between public and private companies by Bahattacharyya et al. (1994), found public companies to be more efficient! These findings correlate well with a growing body of empirical evidence that refutes the theoretical argument that public ownership of water utilities reduces incentives that promote economic performance. Contrary evidence is provided by the empirical work of Lynk (1993) on the UK water industry. This study concludes that the publicly owned water sector immediately prior to privatisation operated at significantly lower levels of inefficiency than the privately owned sector. Clearly, there are no unequivocal choices as to what works best. The inconclusive debate gives this study sufficient ground to investigate the effects of managerial incentives in a public-public setting. In fact, since incentive contracts in public-public settings, particularly in the water sector, are a relatively new phenomenon, this study is a useful demonstration of the potential efficacy of such contracts as the first step to full commercialisation in low-income countries.

It is also possible to argue credibly 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. The associated moral hazard problems can easily be leveraged through various forms of buyout possibilities agreed with the principal (Demski and Sappington, 1991). These can be put explicitly to the agent right at the onset, as a stakeholder-building activity during the contract implementation process. Demski and Sappington (1991) have modelled this scenario and found that it 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 skirting cannot be documented conclusively to any third party and so is not verifiable. One of the authors' propositions, which they later prove 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 their 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.

In the sections that follow, I discuss the practical examples of incentive plans that are being applied in selected utilities in sub-Saharan Africa. These include National Water and Sewerage Corporation (NWSC) of Uganda; Nzoia Water and Sewerage Company (NZOWASCO) of Kenya; Dar Es Salaam Water and Sewerage Corporation (DAWASCO) of Tanzania and Nkana Water and Sewerage Company (NWSC) of Zambia. In addition I outline empirical evidence of the effects of managerial incentive intensity on technical efficiency and total factor productivity with reference to NWSC-Uganda. The paper then ends with concluding remarks.

2. Examples of Incentive Applications in Sub-Saharan African Water Utilities

There have been deliberate efforts to incorporate both financial and non-financial incentive arrangements in performance improvement programmes of water utilities in some utilities in Sub-Saharan Africa. National Water and Sewerage Corporation (NWSC) of Uganda where change management programmes have been evolving since 1998 has been the pivotal launch pad. In NWSC, these incentive applications have been at the centre of significant performance improvements. For example, non-revenue water in all other towns (except Kampala) has reduced from about 45 percent in 1998 to about 16 percent in 2005. In fact, four of the utilities have non-revenue water of less than 10 percent. The company has drastically improved its financial performance from a loss situation (before depreciation) in 1998 to a positive surplus after depreciation and financing costs in 2005. This performance makes NWSC one of the very few water utilities in Africa that is able to break-even at a reasonable tariff (averaging about 0.65 US$ per cubic metre). Because of this experience, NWSC-Uganda, through its External Services arm, has been involved in advising other regional water utilities in implementing tailor-made incentive plans aimed at enhancing their performances.

In particular, utilities 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)

- 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).

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).[1]

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 utilities to 50 percent for small 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.

[1] 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*.

In Dar Es Salaam Water and Sewerage Corporation (DAWASCO), Tanzania, under the Operational Rescue Plan[2] (July-September, 2005):

$$\text{Monthly Incentive Earnable, MIE} = 20 + 30 * \frac{\text{Achieved\_Coll.} - \text{SM\_Coll}}{\text{St\_Coll.} - \text{SM\_Coll}}.$$

Provided:	Achieved_Coll $\geq$ SM_Coll;
Otherwise:	No incentive award
Where:	"Achieved_Coll" stands for achieved revenue collection during the month.
	SM_Coll stands for SMART (Specific, Measurable, Achievable, Realistic and Timely) revenue collection target.
	St_Coll stands for Stretch (set above SMART) revenue collection target
	MIE is in million Tanzanian Shillings (M'Tshs).

The MIE was shared among all staff of the qualifying Area, on pro-rata basis. However, the DAWASCO management could discretionary decide to partition the earned incentive to give special awards to excelling individual staff.

For NZOWASCO in Kenya, in order to drive performance, the 3-months Programme (February – April, 2006) incorporates a simple incentive mechanism, which is purely based on revenue collections. This is because in the current financial situation of NZOWASCO any incentive payment for achievements of performance indicators that do not directly translate into physical cash would be fatal to the Company. Liquid cash is critical for the company at this stage. And because money makes money, any incentive payments based on actual cash collections are quite justifiable and certainly enhance the cash flow position of NZOWASCO. Due to the volatile nature of targets such as response time to leaks and complaints, unaccounted for water etc; it was not possible to take into consideration these targets because such targets need time to establish authentic and transparent data capture procedures. Incorporating such targets in the incentive plans can easily lead into contentions and thus negative impacts on performance objectives.

The incentive mechanism considers a simple approach based on "SMART" collection target. It is based on a sharing plan for surplus realized above the target collection. Its computation is as follows:

<u>The Monthly Incentive Earnable, MIE = X percent * (C_A-C_T)</u>

Where:

- C_A stands for the actual monthly collection achieved during the month under review
- X percent is a factor that NZOWASCO management sets, from time to time, in such way that its cash-flows are not affected negatively and staff motivation is also enhanced.

[2] The Operational Rescue Plan was designed and implemented after the take-over of DAWASCO management from the Private Lease Operator in May, 2005.

- C_T is the monthly collection target for the month under review
- Upon determining X-factor, Management pays earnable incentives when the Area concerned has submitted an "Incentive Sharing Plan (ISP)" that has been agreed by the Area Management Team. Such ISP takes cognizance of the different extents of staff contribution during the month.
- If C_A is less than C_T no incentive is earned. If C_A/C_T is less than 0.85, management deserves the right, at their discretion, to slap penalties (including possible demotions) on the Area Team.

NZOWASCO management may, discretionary, decide to award special awards to excelling Areas in order to drive financial viability of the Company.

The incentive plan for **Nkana Water and Sewerage Company, Zambia** is almost similar to that of DAWASCO because it incorporates two levels of targets; SMART and Stretch. The mechanism does not consider operating expenditure because Nkana Water is still in the process of decentralizing financial management responsibilities to its operating Divisions[3]. In this case, putting full cost-containment responsibility on Divisions may not reflect fairness and reciprocity. This will be considered during the next phase of performance improvement programme.

The financial incentive mechanism is based on (1) reward of SMART target achievement and (2) additional reward to improvements from the SMART level towards Stretch level. This criterion is based on the successful experience with a similar programme in NWSC-Uganda. It puts emphasis on group incentives, as the company strengthens its managerial systems to a level where it can graduate into individual incentive plans. Consequently, the following incentive plan has been designed to apply during the 100-Days Stretch-Out Programme:

(i) If the operating Division achieves SMART collection target, pay each Division staff a bonus of 10% of monthly salary

(ii) If the Division exceeds the SMART collection target pay each Division staff a bonus computed as follows:

$$Bonus\ Pay = 10\%\ \text{of}\ \text{M.P}\left[1 + \frac{\text{Achieved Coll} - \text{SMART Coll}}{\text{STRETCH Coll} - \text{SMART Coll}}\right]$$

Where: M.P = Staff Monthly Pay (ZmKs)

Coll = Collection (ZmKs)

Bonus Pay is capped at 20% of Staff Monthly Pay.

In all cases, the performance improvement plans incorporate a significant inter-Area/operating entity competition to enhance performance and keep the teamwork spirit

[3] A Division in the context of Nkana Water and Sewerage Company is an operating entity, headed by a General Manager. Ideally, it is supposed to operate with full managerial autonomy in the areas of financial management, procurement, human resource and technical operations. However, Nkana Water is yet to realise this objective fully.

high, among staff. The operating Areas/entities compete for trophies and cash awards in key performance areas. DAWASCO, for example considered the areas of Revenue Collection, Leakage Control, Customer Care and other Water and Sanitation Services (WATSAN) Services. NWSC-Uganda considers quantitative IDAMC performance (non-revenue water, working ratio, day's receivable ratio and connection efficiency); ambiance and processes; customer care and cost optimisation. There are trophies and cash awards for the Overall Winner, Runner-Up and individual performance areas. The competition takes place monthly or quarterly and trophies are not won for keeps. They rotate with no restrictions on the number of times an Area can win a given trophy. An Area can win as many trophies as possible. The amount of the cash award that accompanies the trophies for the respective operational Areas is determined by respective oversight managements. The trophies are awarded in public functions where all the Areas/entities are involved to promote the comparative competition spirit and ensure that the winners feel fully recognized. The laggards are also distressed through the naming and shamming activity.

In the following sections, I present empirical evidence of the role of incentives in enhancing technical efficiency and productivity.

3. Empirical Application: A Case of National Water and Sewerage Corporation (NWSC) – Uganda

3.1 Analytic Framework

(a) Efficiency Measurement

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 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. The measure of technical efficiency was introduced by Farrell (1957), deriving from the 1951 work of Debreu and Koopmans (both cited in Farrell, 1957) to avoid problems associated with traditional average productivity measures (ratios). Farrell proposed that efficiency could be determined relative to a best performance frontier derived from a representative peer group. 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. This case study uses an SFA model 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.

However, according to Coelli et al (1998), in order to avoid obtaining statistically biased results, the right hand side of the regression in the production function should be free of endogeneity problems. In other words, the right hand side (RHS) variables (regressors) should be exogenous i.e. their values are determined outside the system. Zellner et al (1966) points out that the direct estimation of a production function will not suffer from simultaneous equations bias if it is appropriate to assume that the producer is attempting to maximise *expected* rather than *actual* profit.

This study utilises the production function because (1) NWSC utilities under this study, due to their public-ownership nature, try to achieve targeted/expected operating profits other than actual profits since they are not required to pay dividends to shareholders (2) it is not justifiable to assume profit maximisation or cost minimisation objectives with regard to public water utilities, which have a significant statutory social mission objective (3) it is logical to assume that the regressors (input variables) used in this study are exogenous to the system since it is hard for utilities to select combinations of such input variables (for example water produced, connections, staff, network length, market size) to maximise output (4) the input prices, in NWSC utilities cannot be assumed to be competitive or regulated, as required by cost/profit functions, since most of these utilities incorporate a significant subsidy system in their operational activities. Moreover, (5) the cost and profit function data requirements relate significantly to input and output prices, which are either competitive or regulated and such requisite information is extremely difficult to get with reference to specific NWSC utilities. However, the input and output quantity data necessary for production functions is readily available due to NWSC data capture history.

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]); (4) a production function like a cost function, has a variable t (time) which captures technological impact in the African water industry.

If the estimation of the cost and profit functions did not have major constraints as outlined above, the unavoidable residual endogeneity problems of the production function regressors would be alleviated through estimations of cost/profit functions and

[4] A bigger proportion of people consuming free water but paid for by a single family head

subsequently deriving the production function there from. According to Coelli et al (1998), a production function can be derived from a profit function as follows: (1) derive the maximum profit function using econometrics methods (2) from the profit function, derive the input demand and output supply equations using Hotelling's Lemma, in terms of input and output prices (3) solve the input demand and output supply equations to eliminate price variables, leaving the production function. Likewise, a production function can be derived from a least-cost function using the same procedure but replacing Hotelling's with Shephard's Lemma in stage (2). However, according to Coelli et al (ibid.), not all functional forms used in econometric analyses of profit and cost allow one to derive an explicit expression for the underlying production function. This does not mean that the production function does not exist – only that the mathematical derivation of its form is intractable. An example of such a functional form is the translog.

Stochastic Frontier Production Models

The general stochastic frontier production function, for a set of panel data, has the form of:

$$\ln y_{it} = f(x_{it}, t; \beta) + \xi_{it}, \qquad (1)$$

where y_{it} denotes output, x_{it} is a matrix of inputs, t represents time (t = 1,2,……T), βs are unknown technological parameters to be estimated and f is some appropriate functional form. The error term is $\xi_{it} = v_{it} - u_{it}$, where 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, σ_v and u_{it}s are non-negative random variables which are associated with technical inefficiency in production of firms in the industry involved.

The ratio of the observed output for the ith firm, relative to the potential output, defined by the frontier function, given the input vector, x_{it} is used to define the technical efficiency of the ith firm:

$$TE_{it} = \frac{y_{it}}{\exp(x_{it}\beta)} = \frac{\exp(x_{it}\beta - u_{it})}{\exp(x_{it}\beta)} = \exp(-u_{it}). \qquad (2)$$

According to Coelli et al. (1998), the stochastic frontier model in (1) above is not without problems. The main criticism is that there is generally no *a priori* justification for the selection of any particular distributional form of the u_{it}s. The specifications of more general distributional forms, such as the truncated-normal and the two parameter gamma, have partially alleviated this problem, but the resulting efficiency measures may still be sensitive to distributional assumptions. Huang and Ho-Chuan (2004) point out that the gamma-model exhibits richer and more flexible parameterisation of the inefficiency distribution but its application is limited because of its complexity in evaluating the log likelihood function. Consequently, Coelli (1996) has incorporated the generalised truncated-normal distribution in the computer-based FRONTIER version 4.1 programme, which this study uses.

Stochastic frontier production functions can assume either a translog stochastic frontier production function or a Cobb-Douglas functional form. A translog stochastic frontier model incorporates estimation of coefficients (βs) for second order input quantities. This function offers a more flexible form, although inclusion of the second

order and cross-terms leaves the model with very few degrees of freedom. A simple Cobb-Douglas functional form is the mostly commonly applied specification in water benchmarking studies (e.g., Estache and Rossi, 2002) but it is better to start with a more comprehensive translog specification and carry out suitable tests to check whether the Cobb-Douglas provides a better representation of a given set of data. The parameters of the stochastic frontier production function, defined by Equation 1, can be estimated by using either the maximum likelihood (ML) method or the corrected ordinary least squares (COLS) method (Richmond, 1974, cited in Coelli, et al., 1998). The COLS approach is not as computationally demanding as the ML method, but empirical studies (Coeli, 1995) have found that the ML estimator is significantly better than the COLS estimator when the contribution of the technical inefficiency effects in the total variance term is large. The contribution of technical inefficiency to the total variance term is significantly apparent in NWSC water utilities, given their history of managerial inefficiencies (Mugisha et al., 2004a). The ML estimator is therefore a better estimator of the unknown parameters of Equation 1, given the NWSC panel data used in this study.

Investigating Effects on Firm Technical Inefficiencies

A number of researchers (e.g., Pitt and Lee, 1981, cited in Coelli et al., 1998) have investigated factors affecting technical inefficiencies among firms in an industry by carrying out regression analysis of predicted inefficiency effects, obtained from frontier modelling, on a set of firm-specific factors such as firm size, type of management option, etc., in a second-stage analysis. This approach faces one potential pitfall. In the first stage it is assumed that the inefficiency effects (in Equation 1) are independent and identically distributed (i.i.d.) in order to use the frontier analysis methods. In the second stage (regression analysis), this i.i.d. assumption is violated unless all the coefficients of the factors are simultaneously equal to zero. Consequently, researchers such as Kumbhakar et al. (1991) and Battese and Coelli (1995) noted this inconsistency and specified enhanced stochastic frontier models in which inefficiency effects were incorporated as explicit functions of some firm-specific factors, and all unknown scalar parameters were estimated in a single-stage ML procedure. According to Battese and Coelli (1995), 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.:

$$u_{it}\text{: truncation of } N(\mu_{it}, \sigma^2) \qquad (3)$$

$$\mu_{it} = z_{it}\,\delta, \qquad (4)$$

where z_{it} is a (1xM) vector of observable explanatory variables whose values are fixed constants, and δ 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 intensity of incentives on firm-specific inefficiencies, Model 2 is used.

(b) Productivity Measurement through Malmquist Total Factor (TFP) Index

This study utilises frontier methods to obtain TFP growth estimates since other approaches, e.g., Tornqvist/Fisher index methods, involve the need to assume that all firms are cost minimisers and revenue maximisers. Because we are analysing public sector firms that are inherently not-for-profit, the application of index methods is not without problems. In NWSC, all the utility operations incorporate a significant social equity activity that restricts the use of Tornqvist/Fisher index methods. In addition, Tornqvist/Fisher methods require cost/price data. This is a potential problem in this study because NWSC only started to operate a firm-specific accounting system in 1998. It is at this point that one can get some firm-specific cost data. The index methods, can therefore, be used from 1998 onwards where as this study stretches back to 1995. Frontier-based TFP estimation methods also have the potential to decompose the Malmquist TFP into two components: one attributable to technical change and the other attributable to efficiency change, which is the main consideration in this study.

The Malmquist index is defined by using distance functions. Distance functions are classified into input and output distance functions. An input distance function characterises the production technology by looking at minimal proportional contraction of the input vector, given an output vector. An output distance function considers a maximal proportional expansion of an output vector, given an input vector. Most empirical studies (e.g., Lovell, 2003) utilise the output distance specification to compute the TFP. If we define the production technology by using the output set, P(x), as follows:

$$P(x) = \{y: x \text{ can produce } y\} \tag{5}$$

then the output distance function is defined on the output set, P(x), as:

$$Do(x,y) = \min\{\delta:(y/\delta)\text{Є}P(x)\} \tag{6}$$

According to Lovell (2003), the Malmquist TFP index is best defined on the basis of a benchmark technology that satisfies constant returns to scale (CRS), which is distinguished from a best practice technology that allows for variable returns to scale (VRS). This characteristic allows it to incorporate the influence of scale economies. This study therefore estimates the TFP index according to CRS technology. Based on the specification by Fare et al. (1994), the Malmquist (output-oriented) TFP change index between period t (the base period) and period (t+1) is given by:

$$M_o\left(y_t, x_t, y_{t+1}, x_{t+1}\right) = \left[\frac{D_0^t\left(y_{t+1}, x_{t+1}\right)}{D_0^t\left(y_t, x_t\right)} x \frac{D_0^{t+1}\left(y_{t+1}, x_{t+1}\right)}{D_0^{t+1}\left(y_t, x_t\right)}\right]^{1/2} \tag{7}$$

where $D_o^t(x_t,y_t)$ represents the distance from the period t+1 observation to the period t technology. A value of M_o greater than 1 will indicate positive TFP growth from period t to period (t+1), while a value less than 1 indicates a TFP decline.

Equation (7) can also be written as:

$$M_o\left(y_t, x_t, y_{t+1}, x_{t+1}\right) = \frac{D_0^{t+1}\left(y_{t+1}, x_{t+1}\right)}{D_0^t\left(y_t, x_t\right)}\left[\frac{D_0^t\left(y_{t+1}, x_{t+1}\right)}{D_0^{t+1}\left(y_{t+1}, x_{t+1}\right)} \times \frac{D_0^t\left(y_t, x_t\right)}{D_0^{t+1}\left(y_t, x_t\right)}\right]^{1/2} \tag{8}$$

where the two terms in Equation (8) are defined as:

Efficiency change, between periods t and (t+1) = $\dfrac{D_0^{t+1}\left(y_{t+1},x_{t+1}\right)}{D_0^{t}\left(y_{t},x_{t}\right)}$ (9)

whereas

Technical change, from period t to (t+1) = $\left[\dfrac{D_0^{t}\left(y_{t+1},x_{t+1}\right)}{D_0^{t+1}\left(y_{t+1},x_{t+1}\right)}\times\dfrac{D_0^{t}\left(y_{t},x_{t}\right)}{D_0^{t+1}\left(y_{t},x_{t}\right)}\right]^{1/2}$ (10)

Since this study uses stochastic frontier productivity estimation methods, for reasons given before, I consider TFP estimation using the same methods. From Equation 9, by observing that $D_0^{t+1}\left(y_{t+1},x_{t+1}\right)$=$TE_{i(t+1)}$ and that $D_0^{t}\left(y_{t},x_{t}\right)$ = TE_{it}, where i denotes the firm:

Efficiency change = $TE_{i(t+1)}/TE_{it}$ (11)

According to Coelli et al. (1998), the technical change index, based on Equation 10, is simply an evaluation of the partial derivative of the production function, with respect to time, at a particular data point. If the technical change is non-neutral, this change index may vary for different input vectors. Thus,

Technical change = $\left[\left\{1+\dfrac{\delta f\left(x_{it},t,\beta\right)}{\delta t}\right\}\times\left\{1+\dfrac{\delta f\left(x_{i(t+1)},(t+1),\beta\right)}{\delta(t+1)}\right\}\right]^{1/2}$ (12)

The indices of technical efficiency change in Equation 11 and technical change in Eqation 12 can then be multiplied together to obtain a Malmquist TFP index.

3.2 Empirical Applications

(a) Technical Efficiency Analysis

The study utilises panel data for NWSC utilities (except Kampala) for the period 1996-2004. Because of the different periods under which some utilities have been progressively added on to NWSC operational jurisdiction, the data is unbalanced. Accordingly, the panel ranges from eight utilities in 1996 to fourteen in 2004, as shown in Table 1.

Table 1: Utilities under NWSC for the Period 1996-2004

Period	Number Of Utilities (Excl. Kampala)
1995-96	8
1996-2002	10
2002-2004	14

Kampala water utility is left out because it has significantly different operational properties from the other utilities. Its operations account for about 70 percent of NWSC operations (scale advantages), and it has been under private sector management arrangements since 1997, which makes it unsuitable for this study of utilities which have instead been under public-public incentive contracts. The sample data include annually assessed measures of water billed (WB) in cubic metres /day as the output; the inputs are water delivered (P) in cubic metres/day, number of connections (C), water network length (N) in kilometres and number of staff (S). This input-output production technology was chosen because NWSC has all along been emphasising financial sustainability as the

main objective. Because the government does not give NWSC subsidies to support its day-to-day operations, improving revenues has been the main pre-occupation of NWSC improvement programmes in the period considered. The structure of the input-output variables chosen also relates well with what has commonly been used in most empirical applications in similar settings e.g. Estache and Kouassi (2002).

Water delivered is a very important input in NWSC because of its significant influence on management of unaccounted-for water (UFW). UFW is a key performance indicator in NWSC programmes and relates to enhancement of operating efficiency of utilities. Number of connections and water network length are equally emphasised in NWSC because of their direct relationship with improved service coverage, currently the main water sector objective of the government of Uganda. The summary statistics are presented in Table 2. The sample consists of unbalanced panelled data of 14 cross-sections, 9 time periods and 100 observations.

Table 2: NWSC Summary Statistics 1996-2004

Variable	**Sample Mean**	**Sample Standard Deviation**	**Minimum**	**Maximum**	**Type of Variable**
Water Billed (m^3/day)	2,141	1,818	150	9,341	Output
Water Delivered (m^3/day)	3,418	2,870	250	11,163	Input
Staff (No.)	64	37	17	147	
Connections (No.)	2,410	1,591	350	8,545	
Network Length (km)	80	42	22	236	
Market Size (Target Population)	63,707	27,946	22,353	144,178	Environmental

For the stochastic frontier approach, a translog stochastic frontier production function, based on Equation 1, is initially specified as follows:

$$\ln(WB_{it}) = \beta_0 + \beta_P \ln(P_{it}) + \beta_S \ln(S_{it}) + \beta_C \ln(C_{it}) + \beta_N \ln(N_{it}) + \beta_{PP}(\ln(P_{it}))^2 + \beta cc(\ln(C_{it}))^2 + \beta_{NN}(\ln(N_{it}))^2 + \beta_{SS}(\ln(S_{it}))^2 + 2\{ \beta_{PS}\ln(P_{it})\ln(S_{it}) + \beta_{PC}\ln(P_{it})\ln(C_{it}) + \beta_{PN}\ln(P_{it})\ln(N_{it}) + \beta_{SC}\ln(S_{it})\ln(C_{it}) + \beta_{SN}\ln(S_{it})\ln(N_{it}) + \beta_{CN}\ln(C_{it})\ln(N_{it})\} + \beta_t t + \beta_{tt} t^2 + v_{it} - u_{it};$$

$$i = 1,2,......,N \text{ (number of utilities)}; \; t = 1,2,\ldots\ldots\ldots,9, \qquad (13)$$

where WB_{it} = water billed (in m^3/day) by the i^{th} utility in the t^{th} year; P_{it} = water delivered (in m^3/day); C_{it} = connections (in numbers); N_{it} = water network length (in Km); t = time trend; "ln" refers to natural logarithm and β_{is} are unknown parameters to be estimated; v_{it}s are random errors as defined in Equation 1. The u_{it}s are non-negative random variables associated with firm technical inefficiencies and are assumed to be i.i.d. such that the distribution of u_{it} is obtained by truncation at zero of the normal distribution with mean m_{it} and variance σ_u^2, where: $m_{it} = \delta_0 + \delta_{FII}(Z_{FIIit}) + \delta_{EII}(Z_{EIIit}) + \delta_M(Z_{Mit})$ (14)

and where Zs are explanatory variables - in this case, the environmental variables, namely, market size and managerial incentive intensity (MII). The δs are unknown scalar quantities (δ_{FII}, δ_{EII} and δ_M) to be estimated. The managerial incentive intensity is decomposed into two sub-variables: (1) financial incentive intensity[5] (FII) and (2)

[5] Financial incentive intensity corresponds to pecuniary incentives that directly affect individual (take home) pay.

emotional incentive intensity[6] (EII). The decomposition is important in providing a more intuitive picture of the comparative effects of these types of incentives. A negative value of δj would mean that the corresponding environmental variable has a positive impact on the reduction of firm technical inefficiencies (see Equation 2). The inclusion of market size (target population), M, in the production function is important, particularly in the context of African water utilities where service coverage is still low (50-80 percent in NWSC utilities). It is an excellent proxy for service area. This is because every urban dweller in Ugandan urban centres depends on piped water to some degree, through public standpipe facilities, although this ad hoc service is normally not well captured in service coverage calculations. Consequently, the amount of water billed, to a large extent, depends on the entire urban population. According to Coelli et al. (1999, cited in Estache et al., 2002), measuring net efficiency relative to environmental factors is an important issue, as it allows one to predict how companies would be ranked if they were operating in equivalent environments.

The data relating to two managerial incentive intensity sub-variables FIIs and EIIs is derived as follows:

(i) FIIs are calculated as the percentages of performance related pay for each individual staff relative to the total monthly basic pay of the staff, on annual basis, for the period 1996-2004. The FIIs have ranged from 5 to 50 percent since 1996, with the highest intensities recorded in the period 1999-2004 when the incentive programmes were introduced in NWSC. The FIIs can therefore be represented by an interval/ratio scale, like the rest of the variables in Table 2.

(ii) The EIIs are taken as temporal dummy scores; i.e., 1 if there was comparative competition activity among utilities, benchmarking and structured recognition of good performing utilities, and zero otherwise.

Table 3: NWSC's Computed Financial Incentive Intensity and Emotional Incentive Intensity Values

Year	FII	EII	Remarks
1995/96 to 1997/98	5	0	No incentive programmes; only a normal performance related pay of 5% of staff monthly basic pay.
1998/99	5	1	Incentive programmes started and incorporated significant competition, recognition and benchmarking activities but no increase in performance related pay.
1999/00 to 2000/01	25	1	As a primer to incentive programmes, performance related pay was increased to 25% of staff monthly basic pay.
2001/02	5	0	The second phase of Incentive Contracts (Area Performance Contracts) had an irrationally rigid incentive structure that made it impossible for staff to earn above 5 % as incentive. It required all performance standards to be met 100%. There was no room for proportionate performance reward. This resulted into the degeneration of the motivation system to the one prior to 1998. In addition there was managerial laxity and performance recognition, competition and benchmarking were absent.
2002/03	50	1	"Stretch-out" programme (see Mugisha et al, 2004b) introduced to rejuvenate the rigid incentive system[7] and hence turn-around the declining performance.

[6] Emotional incentives are non-monetary and include facets like praise, recognition, reprimand, competition, etc.

[7] The incentive system was restructured to allow for pro-ration and negotiation of more specific, measurable, achievable, realistic and timely (SMART) targets. The achievement of SMART

2003/04	50	1	"Stretch-out" programme (see Mugisha et al, 2004b) introduced to rejuvenate the rigid incentive system and hence turn-around the declining performance, as in 2002/03, but with Internally Delegated Area Management Contracts (IDAMCs) towards the end of 2004.

Source: Analysis of NWSC APC (2000-2003) and IDAMC-2004 documents

With the reasons given before (choice between COLS or ML estimations), the maximum-likelihood (ML) estimates of the translog function in Equation 13 above are obtained by using the computer program FRONTIER version 4.1 developed by Coelli (1996). Because the production function (Equation 13) involves estimation of technical inefficiency effects, the technical efficiency (TE) model - "Model 2" - is selected. I take advantage of the great flexibility of the translog stochastic frontier model to test the following null hypotheses: (1) that the utilities are fully efficient, i.e. there are no technical inefficiency effects (H_0: $\gamma = 0$); (2) that the Cobb-Douglas production specification is an adequate representation of the data, given the specifications of the translog function (H_0: $\beta_{PP} = \beta_{SS} = \beta_{CC} = \beta_{NN} = \beta_{PS} = \beta_{PC} = \beta_{PN} = \beta_{SC} = \beta_{SN} = \beta_{CN} = 0$); (3) that the environmental variables are not significant ($\delta_{FII} = \delta_{EII} = \delta_M = 0$).

The alternative models, estimated as a result of imposing the above restrictions, are tested using Likelihood Ratio (LR) tests. This test is based on the log likelihood function as follows:

$$LR = -2(L_R - L_U), \qquad (15)$$

where L_R is the log likelihood of the restricted model and L_U is the log likelihood of the unrestricted model. Asymptotically, the LR statistic has a chi-square distribution with degrees of freedom equal to the number of restrictions involved. According to Lee (1993), where the null hypothesis includes the restriction $\gamma = 0$ (a point on the boundary of the parameter space), the likelihood ratio statistics will have asymptotic distribution equal to a mixture of chi-square distribution $\frac{1}{2}\chi_0^2 + \frac{1}{2}\chi_1^2$. The hypothesis test results are shown in Table 4.

Table 4: Null Hypothesis Tests

Null Hypothesis	**Log Likelihood**	$\chi^2_{0.99}$ **Value**	**Test Statistic (LR)**
Given Model (from equation 13)	73.50		
H_0: $\beta_{PP} = \beta_{SS} = \beta_{CC} = \beta_{NN} = \beta_{PS} = \beta_{PC} = \beta_{PN} = \beta_{SC} = \beta_{SN} = \beta_{CN} = 0$	57.50	23.21	**32.00**
H_0: $\gamma = 0$	53.12	14.33*	**40.74**
H_0: $\delta_{FII} = \delta_{EII} = \delta_M = 0$	57.58	11.34	31.84

* Critical value of a mixture of chi-square $\frac{1}{2}\chi_0^2 + \frac{1}{2}\chi_1^2$ distribution obtained from Table I of Kodde and Palm (1986).

From the results of Table 4, we reject all three null hypotheses and conclude that (1) there are technical inefficiency effects, (2) the environmental variables are significant and (3) the Cobb-Douglas production function is not an adequate representation of the data set, given the specifications of the translog function in

targets lead to award of 25 percent of basic pay as incentive while provisions were made to earn an extra 25 percent if staff achieved "Stretched" targets which were set above the SMART targets.

Equation 13. We therefore outline the FRONTIER 4.1 maximum likelihood estimates based on the translog stochastic production function in Equations 13 and 14, as shown Table 5:

Table 5: Maximum Likelihood Estimates

Type	Coefficient	Standard Error	t-ratio
beta 0	5.931	0.849	6.983
beta 1 *(water del., P)*	1.148	0.667	1.721
beta 2 *(staff, S)*	2.848	0.542	5.254
beta 3 *(connections, C)*	-2.798	0.648	-4.317
beta 4 *(network length, N)*	-0.712	0.637	-1.117
beta 5 (P^2)[8]	-0.336	0.133	-2.524
beta 6 (S^2)	0.275	0.030	9.091
beta 7 (C^2)	-0.083	0.207	-0.400
beta 8 (N^2)	-0.455	0.314	-1.448
beta 9 *(P*S)*	0.422	0.101	4.161
beta10 *(P*C)*	0.539	0.267	2.014
beta11 *(P*N)*	-0.160	0.191	-0.840
beta12 *(S*C)*	-0.988	0.206	-4.796
beta13 *(S*N)*	-0.198	0.099	-1.979
beta14 *(C*N)*	0.859	0.409	2.098
beta15 *(t)*	0.146	0.029	4.984
beta16 (t^2)	-0.011	0.003	-3.268
delta 0	5.955	0.817	7.287
delta 1 *(FII)*	-0.030	0.029	-1.067
delta 2 *(EII)*	-0.163	0.109	-1.496
delta 3 *(Market size)*	-0.521	0.071	-7.297
sigma-squared	0.044	0.004	10.286
Gamma	0.999997	0.003	3011.837

Log likelihood function = 73.50; LR test of the one-sided error = 40.74, with number of restrictions = 5

[Note that this statistic has a mixed chi-square distribution]; mean efficiency = 81.46 percent.

Table 5 shows that the production elasticities (measured by betas) are positive with respect to water delivered elasticity (beta 1) and staff (beta 2). The water delivered elasticity is not surprising given that the billing efficiency (water billed: water produced), as outlined in chapter one, has been improving from about 60 percent in 1998 to about 80 percent in 2004. The positive staff elasticity means that utilities can gain by having more staff specialise in a particular task. The elasticities with respect to connections and network length are negative. The negative connection elasticity is most probably attributable to a relatively large proportion of disconnected accounts (about 15-20 percent) that do not directly contribute to water billed. It shows that the utilities can gain by reducing the number of disconnected accounts and "social" connections. The

[8] We note that beta 1 (on P) has a positive coefficient but beta 5 (on P-squared) has a negative one, implying that the "net" elasticity depends on the amount of water delivered. Taking partial derivatives of equation 13 with respect to P using the coefficients in table 5.5, we obtain $\delta\ln(WB)/\delta\ln(P) = 1.148 - 0.336\ln(P)$. The latter clearly shows that if $\ln(P) > 3.42$, we get a negative effect. There is however need for care in making conclusions about this result because there are other additional terms in equation (13) involving P.

disconnected accounts are, as established through experience, “unofficial consumers” of water delivered under the “illegal connections” category. The negative network length elasticity is probably attributable to the organisation’s social mission objective, which means that water mains extensions are not necessary driven by considerations of financial viability. It is also common for some water network extensions to be constructed according to certain engineering feasibility (economic) considerations but the reality turns out differently, rendering this sunken investment initially redundant. It means the utilities can gain by minimising the “social mission” water extensions.

Note however that the effects of water mains extensions may not be immediate. To account for this possibility, the FRONTIER modelling procedure was ran in which the network length variable is lagged by one year. This is in line with the practice in other empirical studies (e.g., Chun et al., 2003; Groves et al., 1994). Consequently, a significant positive elasticity (beta 4 in Table 5 becomes 1.38) is obtained between network length and water billed, which confirms the prediction of initial investment redundancy. The results for environmental variables are the same, although there is a slightly weaker statistical significance for FII but a stronger one for EII and market size.

It should be noted that the production function has a mixture of first and second coefficients, which, as shown in Table 5, have both positive and negative signs. This means that the effects of any of the variables on water billed can take on either sign, depending on the quantities being considered. The beta value for the technical change factor (t) suggests that there has been continuous positive annual technological progress (frontier shift) over the period of study. In NWSC utilities, this is expected, given that there has been continuous improvement of the management information systems, e.g., increased computerisation. This has made it possible to continuously develop the capacity to produce maximum output given the same vector of input quantities.

(b) Malmquist Total Factor Productivity (TFP) Analysis

As noted, a Malmquist TFP productivity index is best measured relative to a CRS technology. According to Coelli et al. (1998) the CRS can be imposed on Equation 13 by normalising the output and inputs (dividing them all by any one of the inputs). In this study we arbitrarily select the staff (labour). Normalising with staff offers a more intuitive perspective to the resultant performance indicators, given that overstaffing is a common problem in most low-income utilities. According to Burns and Weyman-Jones (1994, cited in Estache et al., 2002), once a model involves environmental variables, which relate to scale, the elasticity is given by the proportionate effect on production of changes in input variables and the environmental variable. On the environmental variables, we therefore normalise only “market size” variables since they relate to scale. The summary statistics of normalised data are presented in Table 6. As before, the sample consists of unbalanced panelled data of 14 cross-sections, 9 time periods and 100 observations.

Table 6: NWSC Summary Statistics (Normalised Data) 1996-2004

Variable	**Sample Mean**	**Sample Standard Deviation**	**Minimum**	**Maximum**	**Type of Variable**
Water Billed (l/day/staff)	38,084	25,957	7,270	119,756	Output
Water Delivered (l/day/staff)	56,726	34,157	11,607	160,851	Input

Staff (No.)	64	37	17	147	
Connections (No./staff)	45	26	14	110	
Network Length (m/staff)	1,627	1,022	427	4,500	
Market Size (p'ple/staff)	1,350	901	348	4,513	Environmental

We use the same model in Equation 13 and compute the ML estimates with FRONTIER 4.1 and the normalised data. By testing the null hypotheses as in the previous section, we obtain results shown in Table 7.

Table 7: Null Hypothesis Tests (Normalised Data)

Null Hypothesis	**Log Likelihood**	$\chi^2_{0.99}$ **Value**	**Test Statistic (LR)**
Given Model (from equation 13)	66.00		
H_0: $\beta_{PP} = \beta_{SS} = \beta_{CC} = \beta_{NN} = \beta_{PS} = \beta_{PC} = \beta_{PN} = \beta_{SC} = \beta_{SN} = \beta_{CN} = 0$	57.96	23.21	16.08
H_0: $\beta_S = \beta_{t^2} = \delta_M = 0$	56.82	27.69	18.36
H_0: $\gamma = 0$	53.14	14.33	25.72

As before, the null hypothesis that there are no technical inefficiency effects is rejected. However the null hypotheses that the Cobb-Douglas production function is an adequate representation of the data set and that the staff, t^2, and "market size/staff" variables are insignificant are accepted, given the specifications of the translog function in Equation 13. I, therefore, use this specification with the tested restrictions in our analysis. The FRONTIER 4.1 maximum likelihood estimates based on the restricted Cobb-Douglas specification and normalised data are summarised in Table 8.

Table 8: Maximum Likelihood Estimates (Normalised Data)

Description	**Coefficient**	**Standard-Error**	**t-ratio**
beta 0	0.726	0.216	3.356
beta 1 *(Water Delivered/staff)*	0.836	0.030	27.574
beta 2 *(Connections/Staff)*	0.167	0.051	3.238
beta 3 *(Network Length/staff)*	0.023	0.039	0.591
beta 4 *(t)*	0.018	0.008	2.169
delta 0	0.357	0.116	3.076
delta 1 *(Financial Incentives)*	-0.025	0.055	-0.461
delta 2 *(Emotional Incentives)*	-0.226	0.106	-2.130
sigma-squared	0.043	0.012	3.673
Gamma	0.999	0.000	4692.447
log likelihood function	56.82		
LR test of the one-sided error (no of restrictions/degrees of freedom = 4)	32.15		
Mean technical efficiency	78.86		

As in the previous case, the water delivered elasticity is positive. The connection/staff elasticity is now positive. This is probably because of the normalising effect of staff, whose elasticity was positive in the previous case (un-normalised data). It means that the negative effects from disconnected accounts are cancelled by the positive effects of staff rationalisation.

We calculate indices for technical efficiency change and technical change for each utility in each pair of adjacent years using Equations 11 and 12, respectively. To maintain consistency, we present the results of the computations from ten utilities across the entire period of study; four other utilities were added to the NWSC operational frame

in 2002. We then aggregate the indices using geometric means and subsequently covert them into cumulative (chained) indices, which are presented in Table 9.

Table 9: Cumulative Indices of Technical efficiency Change, Technical Change, TFP Change and Incentive Intensity Score

Parameter/Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
Efficiency Change Index	1.000	0.930	0.900	1.018	1.118	1.148	1.004	1.139	1.249
Technical Change Index	1.000	1.018	1.037	1.055	1.074	1.094	1.114	1.134	1.154
Malmquist TFP Index	1.000	0.947	0.933	1.075	1.201	1.256	1.118	1.291	1.441

Notice in Figure 5.9 that the trend of aggregated (corporate) TFP growth is significantly related to the trend of the technical efficiency change index. This means that the corporate total productivity in the ten NWSC towns served since 1996 has been positively associated with the efficiency change index, which is positively correlated with managerial incentive intensity. To obtain an intuitive interpretation of the relationship between managerial incentive intensity and corporate Malmquist total factor productivity (TFP), I carry out the production function estimation excluding managerial incentive intensity sub-variables as model inputs. Later, the resultant TFPs are correlated with the incentive intensity scores to obtain the relationship between the two.

Consequently, by excluding FII and EII sub-variables as inputs and using the data whose summary is shown in Table 6 in a FRONTIER 4.1 modelling procedure, I obtain a certain set of translogarithmic stochastic production function maximum likelihood estimates. I, then, carry out suitability null hypothesis tests as before. Table 10 shows a number of null hypothesis tests, which are carried out as before.

Table 10: Null Hypothesis Tests (Normalised Data)

Null Hypothesis	Log Likelihood	$\chi^2_{0.99}$ Value	Test Statistic (LR)
Given Model (from equation 13), but equation (14) is modified to: $m_{it} = \delta_0 + \delta_M (Z_{Mit})$	62.94		
H_0: $\beta_{PP} = \beta_{SS} = \beta_{CC} = \beta_{NN} = \beta_{PS} = \beta_{PC} = \beta_{PN} = \beta_{SC} = \beta_{SN} = \beta_{CN} = 0$	49.98	23.21	25.92
H_0: $\beta_S = \beta_t^2 = 0$	47.56	26.22	30.76
H_0: $\gamma = 0$	53.14	10.50	19.60

From Table 10 it can be seen that all the null hypotheses are rejected. Therefore, the Cobb-Douglas production is not an adequate data representation. The staff and t^2 variables cannot be eliminated from the modelling procedure and the utilities are not fully efficient given the model specifications. I, therefore, present the translogarithmic stochastic production function FRONTIER estimates as shown in Table 11.

Table 11: Model Estimates, without FII and EII Scores as Model Inputs

Type	Coefficient	Standard Error	t-ratio
beta 0	2.413	0.975	2.475
beta 1 *(water del., P)*	3.414	0.613	5.569
beta 2 *(staff, S)*	-0.661	0.390	-1.696
beta 3 *(connections, C)*	0.862	0.719	1.199
beta 4 *(network length, N)*	-4.243	0.781	-5.433
beta 5 *(P^2)*	0.100	0.010	9.512
beta 6 *(S^2)*	0.079	0.093	0.844
beta 7 *(C^2)*	0.514	0.248	2.072

beta 8 *(N^2)*	0.404	0.136	2.963
beta 9 *(P*S)*	-0.354	0.129	-2.749
beta10 *(P*C)*	-0.397	0.272	-1.458
beta11 *(P*N)*	-0.248	0.038	-6.520
beta12 *(S*C)*	0.242	0.191	1.262
beta13 *(S*N)*	0.397	0.127	3.123
beta14 *(C*N)*	-0.168	0.196	-0.858
beta15 *(t)*	0.055	0.030	1.876
beta16 *(t^2)*	-0.0003	0.003	-0.104
delta 0	-0.538	0.453	-1.188
delta 1 *(Market size/staff)*	0.079	0.076	1.039
sigma-squared	0.061	0.011	5.579
gamma	0.999	0.002	660.833

Log likelihood function = 62.94; LR test of the one-sided error = 19.60: with number of restrictions = 3

As before, I calculate indices for efficiency change and technical change for each utility in each pair of adjacent years using Equations 11 and 12, respectively. Again, the results of the computations from ten utilities over the entire period of study to maintain consistency are presented. The indices are then aggregated using geometric means and subsequently converted into cumulative (chained) indices that are presented in Table 12.

Table 12: Cumulative Indices of Technical efficiency Change, Technical Change, TFP Change and Incentive Intensity Score (With no Incentive Intensity Inputs)

Parameter/Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Efficiency Change Index	1.000	0.904	0.861	0.950	0.997	1.004	0.866	0.962	1.009
Technical Change Index	1.000	1.051	1.101	1.151	1.199	1.246	1.290	1.333	1.373
Malmquist TFP Index	1.000	0.950	0.948	1.093	1.195	1.251	1.117	1.282	1.384
Financial Incentive Intensity (FII)	5.0	5.0	5.0	5.0	25.0	25.0	5.0	50.0	50.0
Emotional Incentive Intensity (EII)	0	0	0	1	1	1	-	1	1

A Pearson correlation analysis between TFP change indices and the incentive intensity scores of Table 12 gives a significant relationship coefficient of 0.895 and 0.811, corresponding to the sub-variables FII and EII, respectively ($c_{ritical}$ = 0.765, ρ = 0.01). As before, I consider the possibility of "after effects" of water mains extensions, by lagging the normalised network length variable. A fresh FRONTIER analysis is then carried out obtaining values of cumulative Malmquist TFP indices. Consequently, a Pearson correlation analysis between these fresh TFP indices and the incentive intensity indices gives values of 0.92 and 0.77, corresponding to FII and EII sub-variables, respectively. These values are again significant at a 1 percent level, which gives more robustness to the result obtained earlier.

4. Concluding Remarks

This paper outlines practical cases of how incentive plans can be applied in water utilities operating under public-public settings. The paper dispels a common brainwave that incentive applications are only possible under a privately managed operational dispensation. I also use empirical data, obtained through documentary review of historical data (period 1996-2004) in fourteen NWSC water utilities in Uganda. The utilities have implemented simple forms of incentive contracts during the period 2000-2004 and none in the period 1996-1999. Applying stochastic frontier analysis (SFA)

econometric methods on the data, positive effects are found between managerial incentive intensity (in both cases of financial and non-financial incentive intensity indices) and utility efficiency. Similarly, positive effects are also found between managerial incentive intensity and corporate total factor productivity. 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, managerial incentives have the same effects under public-public partnership settings.

REFERENCES

Bardhan, Pranab and Roemer, John (1992), "Market Socialism: A Case of Rejuvenation," *Journal of Economic Perspectives* 6(3):101-116.

Battese, G.E. and Coelli, Tim (1995), "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data," *Empirical Econometrics*, 20, 325-332.

Bhattacharyya, A., E. Parker and K. Raffiee (1994), "An Examination of the Effect of Ownership on the Relative Efficiency of Public and Private Water Utilities," *Land Economics* 70(2): 197-209.

Chun Chang, Brian P. McCall, and Yijiang Wang, (2003), "Incentive Contracting versus Ownership Reforms: Evidence from China's Township and Village Enterprises," *Journal of Comparative Economics* 31(3): 414-28.

Coelli, T.J. (1996), "A Guide to FRONTIER Version 4.1: A Computer Program for Frontier Production Function Estimation", CEPA Working Paper 96/08, Department of Econometrics, University of New England, Armidale.

Coelli, Tim (1995), "Estimators and Hypothesis Tests for a Stochastic Frontier Function: A Monte Carlo Analysis," *Journal of Productivity Analysis* 6: 247-68.

Coelli, Tim, Prasada, D.S., Rao and Battese, E., George (1998), "An Introduction to Efficiency and Productivity Analysis," Kluwer Academic Publishers

Demski, Joel S. and David, E. M., Sappington (1991), "Resolving Double Moral Hazard Problems with Buyout Agreements," *RAND Journal of Economics* 22(2): 232-40.

Estache, Antonio and Eugene, Kouassi (2002), "Sector Organisation, Governance and the Inefficiency of African Water Utilities," Research Paper, World Bank Institute, Washington, D.C.

Estache, Antonio, Martin, A., Rossi and Christian A. Ruzzier (2002), "The Case for International Coordination: Evidence from the Measurement of Efficiency in South America," World Bank Policy Research Working Paper 2907, Washington, D.C.

Estache, Antonio, Martin, A., Rossi and Christian, A., Ruzzier (2004), "The Case for International Coordination: Evidence from the Measurement of Efficiency in South America," *Journal of Regulatory Economics* 25(3): 271-95

Fare, R., S. Grosskopf, M. Norris and Zhang, Z. (1994), "Productivity Growth, Technical Progress, and Efficiency Changes in Industrialised Countries," *American Economic Review* 84: 66-83

Farrell, M.J. (1957), "The Measurement of Production Efficiency," *Journal of Royal Statistical Society*, Series A, 120: 253-81

Groves, Theodore, Yongmiao Hong, John McMillan and Barry Naughton (1994), "Autonomy and Incentives in Chinese State Enterprises," *Quarterly Journal of Economics* 109(1): 183-209.

Huang (River) and Ho-Chuan (2004), "Estimation of Technical Inefficiencies with Heterogeneous Technology," *Journal of Productivity Analysis* 21: 277-96

Kodde, David A. and Franz, C., Palm (1986), "Wald Criteria for Jointly Testing Equality and Inequality Restrictions," *Econometrica* 54 (5), 1243-48

Kosnik, Rita D., and Kenneth L. Bettenhausen (1992), "Agency Theory and the Motivational Effect of Managerial Compensation: An Experiment Contingency Study," *Group Organisational Management* 17(3): 309-330.

Kumbhakar, S.C., Ghosh, S. and McGuckin, J.T. (1991), "A Generalised Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms," *Journal of Business and Economic Statistics* 9: 279-86.

Lee, L. (1993), "Asymptotic Distribution of the Maximum Likelihood Estimator for Stochastic Frontier Function Model with a Singular Information Matrix," *Economic Theory 9*: 413-30

Lovell, C. A., Knox (2003), "The Decomposition of Malmquist Productivity Indexes," *Journal of Productivity Analysis* 20: 437-48

Lynk, E. (1993), "Privatisation, Joint Production and the Comparative Efficiencies of Private and Public Ownership: The U.K Water Industry," *Fiscal Studies* 14(2): 98-116.

Mugisha, Silver, Sanford V. Berg, and Gaddi Ngirane Katashaya (2004a), "Short-Term Initiatives to Improve Water Utility Performance in Uganda: The Case of the National Water and Sewerage Corporation," *Water 21*, June.

Mugisha, Silver, Sanford V. Berg, and Heather Skilling (2004b), "Practical Lessons for Performance Monitoring in Low-Income Countries: The Case of National Water and Sewerage Corporation, Uganda," *Water 21*, October: 54-56.

Renzette, Steven and Dupont, Diane (2004), "Ownership and Performance of Water Utilities," Greenleaf Publishing

Zellner, A., Kmenta, J. and Dreze, J. (1966), "Specification and Estimation of Cobb-Douglas Production Function Models", *Econometrica*, 34, 784-795.