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MAXIMIZING THE BENEFITS FROM WATER AND ENVIRONMENTAL SANITATION

The influence of commercial and customer orientation[1] on utility efficiency[2]: Empirical evidence from NWSC, Uganda

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Many water utilities in low income countries, in an effort to revamp their performances often begin with heavy infrastructural investment projects. Experience has shown that focussing on this engineering approach alone does not deliver the required efficiency gains. In this paper, we make use of data drawn from the operations of 14 NWSC utilities and our study covers the period 1995-2004. Due the non-availability of input price data and the need to account for 'noise' the study uses stochastic frontier analysis(SFA) to show that after a long spell of engineering orientation, a shift in emphasis to commercial/commercial orientation has a positive impact on reduction of utility technical inefficiencies.

Introduction

The National Water and Sewerage Corporation (NWSC) was set up as a government owned parastatal under decree No. 34 of 1972, and its legislative framework was strengthened by the NWSC Act, 2000. The NWSC operations have grown from 3 towns in 1972 to 15 towns at present. These towns include Kampala, Jinja, Entebbe, Tororo/Malaba, Mbale, Lira, Gulu, Masaka, Mbarara, Kabale, Kasese and Fort Portal, Bushenyi/Ishaka, Soroti and Arua. Three more towns of Mukono, Lugazi and Iganga are in advanced stages of being added unto NWSC operational frame. The latter operations represent an urban population of about 2.2 million people (~80% of urban population) and water service coverage of about 65%.

The NWSC has moved from efficiency with funds for investment available in the early 70's, to dilapidation of the water and sewerage systems in the later part of the 1970's and early 80's. The mid 1980's and early 1990's were characterised by rehabilitation of the water and sewerage systems. These activities were carried out carried through a number of reforms supported by the World Bank and other strategic partners. This was, however, deemed unsatisfactory even after two to three successive projects, until the late 90s when there was a change in emphasis towards institutional reforms. The need to refocus the performance improvement activity is clearly suggested in a World Bank Report of 1998, which alluded to the fact that over the previous 10 years, the Government of Uganda (GOU), in partnership with the World Bank and other donors had made significant investments (over US $ 100 million) in the urban water and sewerage sector. The report pointed out that these investments had contributed immensely in rehabilitating the existing infrastructure under the NWSC management. Accordingly, however, these investments had not been matched with the necessary efficient commercial and financial managerial capacity that could ensure the delivery of sustainable services in the medium to long-term.

Mugisha et al (2004a) outlines a number of performance enhancement programmes that have been initiated and implemented in NWSC since 1998. Consequently, significant financial and operational performance achievements have been registered in the last 7 years. Among others, the staff productivity has improved from about 36 staff per 1000 connections to 10 staff per 1000 connections and unaccounted for water (UFW) reduced from 55 percent to 34 percent (other utilities exempting Kampala have UFW of less than 20 percent). In addition, the Corporation's financial situation has improved from an operating profit[3] before interest and tax (PBIT) of negative US$ 3 million to positive US$ 2 million. Furthermore, the connections have increased from about 50,000 to 110,000 connections.

The overarching performance drivers in NWSC relate to increased managerial autonomy through decentralization of decision making to business units operating in its towns. There has also been a deliberate effort to separate the functions of day-to-day operations from performance monitoring/regulation to enhance accountability, creativity and initiative taking at operational level. Another important consideration has been increased commercial and customer orientation through activities aimed at increased customer satisfaction in a cost-effective manner. In short, the approach to performance improvement in NWSC has been the incorporation of "private" sector-like management principles in public-public setting. There have been continuous attempts to change organizational behaviour from one characterized by laziness, sluggishness and "I don't care" attitude to that of speed, commitment, hard work and performance orientation. Details of the performance improvement programmes that have been implemented in NWSC since 1998 can be found on www.nwsc.co.ug.

This paper presents empirical evidence of the positive influence of commercial and customer care orientation on utility efficiency. We use stochastic production function analysis methods to analyze the effects of commercial/customer care orientation on utility efficiency over a period of 9 years (1995-2004). Common performance parameters typical of an evolving water utility in a low income country are used. We investigate the main proposition, which states that **"after a long spell of heavy engineering orientation[4] in a water utility, a shift into significant commercial/customer orientation is positively associated with reduction in technical inefficiencies"**.

Analytical framework: Efficiency estimation methods

Efficiency measurement

According to Chen (2004), 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. Chen posits that 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. According to Estache and Kouassi (2002), 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.

This 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, we can 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. This study utilises the production function because the cost and profit data for each utility cannot be accurately assessed due to long history of a centralised and combined accounting system in NWSC (up to 1999).

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 has a variable t (time) which captures technological impact in the African water industry.

Stochastic frontier production models

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

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

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 i^{th} 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 i^{th} firm:

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

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 uits. 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. In a personal communication with Coelli (in November 1995) Knox Lovell[5], had not encountered any empirical evidence in which distributional assumptions have a significant influence on predicted technical efficiencies. While this observation does not provide a substitute for distributional selection problems, it at least opens a window for meaningful application of the model to estimate firm efficiencies. Huang and Ho-Chuan (2004) point out that the gamma-model exhibits richer and more flexible parameterization of the inefficiency distribution but its application is limited because of its complexity in evaluating the log likelihood function.

Stochastic frontier production functions can assume either a trans-logarithmic stochastic frontier production function or a Cobb-Douglas functional form. A trans-logarithmic 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 most 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.

Panel data models and their attributes

If a number of firms are observed over a number of time periods, then the data obtained are known as panelled data, which may be balanced or unbalanced depending on whether the number of firms in each time period is equal or different, respectively. If data is available for only one time period, it is called cross-sectional data. Panel data has several advantages over cross-sectional data: (1) it amplifies the sample size and alleviates the data shortage problem and (2) it allows for simultaneous estimation of both technical change and technical efficiency change over time. In African water utilities, which have recently been under constant pressure (mostly from development partners) to improve efficiency, the assumption that technical inefficiency effects are time-invariant is more difficult to justify as T in Equation 1 becomes larger. This study, therefore, employs a time-varying inefficiency modelling approach.

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. According to Coelli et al 1998, 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.:

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

$$\mu_{it} = z_{it}\,\delta, \tag{4}$$

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 4.2 program (Coelli, 1996) and is called "Model 2" or the "technical efficiency (TE) effects model". This study investigates the effects of commercial/customer orientation on firm-specific inefficiencies, and hence Model 2 of FRONTIER 4.1 computer program is used.

Empirical application

Model data and specification

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 since 1995/96

PERIOD	*NUMBER OF UTILITIES (EXCL. KAMPALA)*
1995-96	8
1996-2002	10
2002-2004	14

Kampala water utility is left out because it is significantly different from the other utilities. Its operations account for about 65 percent of NWSC operations (scale advantages), and it has been under private sector management since 1997, which makes it unsuitable for a study of utilities that have long 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). Consequently, 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.

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

$$\begin{aligned} \ln(WB_{it}) &= \beta_0 + \beta_P\ln(P_{it}) + \beta_S\ln(S_{it}) + \beta_C\ln(C_{it}) + \\ &\beta_N\ln(N_{it}) + \beta_{PP}(\ln(P_{it}))^2 + \beta cc(\ln(C_{it}))^2 + \\ &\beta_{NN}(\ln(N_{it}))^2 + \beta_{SS}(\ln(S_{it}))^2 + 2\{\beta_{PS}\ln(P_{it})\ln(S_{it}) + \\ &\beta_{PC}\ln(P_{it})\ln(C_{it}) + \beta_{PN}\ln(P_{it})\ln(N_{it}) + \\ &\beta_{SC}\ln(S_{it})\ln(C_{it}) + \beta_{SN}\ln(S_{it})\ln(N_{it}) + \beta_{CN}\ln(C_{it})\ln(N_{it})\} + \\ &\beta_t t + \beta_{tt}t^2 + v_{it} - u_{it}; \\ &i = 1,2,\ldots\ldots,N \text{ (number of utilities)};\ t = 1,2,\ldots\ldots\ldots,9, \end{aligned} \tag{5}$$

where WB_{it} = water billed (in cubic.m/day) by the i[th] utility in the tth year; P_{it} = water delivered (in cubic.m/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 μ_{it} and variance σ_u^2, where:

$$\mu_{it} = \delta_0 + \delta_{CCO}(Z_{CCOit}) + \delta_M(Z_{Mit}) \tag{6}$$

and where Zs are "efficiency" explanatory variables - in this case, the environmental variables, namely, market size and commercial/customer orientation (CCO). The δs are unknown scalar quantities (δ_{CCO} and δ_M) to be estimated. 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. 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. Z_{CCO}, in this study is taken as a dummy variable; taking on a value of "1" for the years 1999-2004; when there was a significant shift from engineering to strong commercial/customer orientation. Z_{CCO} takes on a value of "0" for the years 1996-1998 when the orientation in NWSC was heavily engineering.

Table 2. Summary statistics

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

Model analysis results

The maximum-likelihood (ML) estimates of the translog function in Equation 5 above are obtained by using the computer program FRONTIER version 4.1 developed by Coelli (1996). Because the production function (Equation 5) involves estimation of technical inefficiency effects, the technical efficiency (TE) model - "Model 2" - is selected. We 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 (H_0: $\delta_{CCO} = \delta_M = 0$). 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:

$$LR = -2(L_R - L_U), \quad (7)$$

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 3.

From the results of Table 3, 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 Equation 5. Consequently, the FRONTIER 4.1 program maximum likelihood estimates based on the translog stochastic production function in Equations 5 and 6, are shown Table 4.

Table 4 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) has been improving from about 60 percent in 1998 to about 80 percent in 2004. The staff elasticity is also not surprising given that the staff productivity (number of staff/1,000 connections) has significantly improved since 1998 through deliberate staff rationalisation activities. The elasticities with respect to connections and network length are surprisingly negative. The negative connection elasticity is likely attributable to a relatively large proportion of disconnected accounts (about 15-20%) that do not directly contribute to water billed (output production). This tends to create an excess input situation. 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 efficiency considerations, in reality rendering this sunken investment initially redundant.

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. The two environmental variables market size (M) and commercial/customer orientation (CCO) have negative coefficients. According to equation (2) and (4) this result suggests that the two variables are positively associated with reduction in technical inefficiencies. We note from table 4, however, that the M-coefficient is significant while the CCO-coefficient is insignificant.

Conclusion

The empirical evidence confirms our study proposition that after a long spell of heavy engineering orientation in a water utility, a shift from significant commercial/customer to engineering orientation is positively associated with reduction in technical inefficiencies. The result contributes to the body of knowledge in respect to public utility management policy

Table 3. Null hypothesis tests

NULL HYPOTHESIS	*LOG LIKELIHOOD*	$\chi^2_{0.99}$ *VALUE*	*TEST STATISTIC (LR)*
Given Model (from equation 13)	66.15		
H_0: $\beta_{PP} = \beta_{SS} = \beta_{CC} = \beta_{NN} = \beta_{PS} = \beta_{PC} = \beta_{PN} = \beta_{SC} = \beta_{SN} = \beta_{CN} = 0$	47.62	23.21	37.06
H_0: $\gamma = 0$	53.14	14.33*	26.02
H_0: $\delta_{CCO} = \delta_M = 0$	57.59	11.34	17.12

*Critical value of a mixture of chi-square $^1/_2\chi_0^2 + {}^1/_2\chi_1^2$ distribution obtained from Table I of Kodde and Palm (1986).

Table 4. Maximum likelihood estimates

	coefficient	*standard-error*	*t-ratio*
beta 0	3.903	0.994	3.928
beta 1 *(water del., P)*	1.503	0.305	4.924
beta 2 *(staff, S)*	2.643	0.757	3.491
beta 3 *(connections, C)*	-2.609	0.825	-3.162
beta 4 *(network length, N)*	-0.578	0.289	-1.200
beta 5 $(P^2)^1$	-0.148	0.227	-0.650
beta 6 (S^2)	0.194	0.187	1.037
beta 7 (C^2)	0.116	0.419	0.276
beta 8 (N^2)	-0.217	0.608	-0.357
beta 9 *(P*S)*	0.347	0.137	2.529
beta10 *(P*C)*	0.200	0.358	0.559
beta11 *(P*N)*	-0.254	0.255	-0.996
beta12 *(S*C)*	-0.860	0.223	-3.851
beta13 *(S*N)*	-0.097	0.088	-1.095
beta14 *(C*N)*	0.617	0.528	1.168
beta15 *(t)*	0.102	0.028	3.369
beta16 (t^2)	-0.007	0.003	-2.408
delta 0	4.603	1.223	3.763
delta 1 *(M)*	-0.412	0.109	-3.780
delta 2 *(CCO)*	-0.123	0.128	-0.957
sigma-squared	0.063	0.015	4.118
gamma	1.000	0.000	969494

Log likelihood function = 66.15; LR test of the one-sided error = 26.02, with number of restrictions = 4
[Note that this statistic has a mixed chi-square distribution]; mean efficiency = 81.27%.

in low income countries. It is a good primer for managers seeking to carry out performance-led reforms aimed at enhancing financial and commercial sustainability.

Notes

[1]Commercial orientation in this study assumes the meaning similar to Cullivan et al (1988) definition of commercialisation that relates to the degree to which actions in an institution are driven by cost effectiveness and operating efficiency. The authors point out that institutional performance should be guided by the urge to become self-sufficient financially at an appropriate stage in growth and that the institution should strive to establish a reputation as a financially well run business in the eyes of the financial and outside community. On the other hand, our understanding of customer orientation is similar to Kordupleski et al (1993) disposition that satisfying customers is essential to success: thus an effective organisation must listen to its customers and serve them effectively. Their conclusion is that ‘if management can improve the internal measures, and if a statistical link exists between the internal process measures and quality as perceived by the customer, then a predictable improvement should also take place in customer perceived (true) quality’.

[2]This is the ratio of actual (observed) output relative to maximum output, given a set of production inputs.

[3]Profit after depreciation of about US$ 6 million

[4]This orientation involves predominant emphasis on engineering operations in an organisation at the expense of commercial/customer care operations.

[5]Prof. Knox Lovell is the editor-in-chief of the *Journal of Productivity Analysis.*

[6]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 5 with respect to P using the coefficients in table 4, we obtain $\delta\ln(WB_{it})/\delta\ln(P_{it}) = 1.503 - 0.296\ln(P_{it}) + 0.694\ln(S_{it}) + 0.400\ln(C_{it}) - 0.508\ln(N_{it})$. The latter clearly shows that if ln (Pit) > $[1.503 + 0.694\ln(S_{it}) + 0.400\ln(C_{it}) - 0.508\ln(N_{it})]/0.296$, we get a negative effect. On the other hand, $\delta\ln(WB_{it})/\delta\ln(C_{it}) = -2.609 + 0.232\ln(C_{it}) + 0.400\ln(P_{it}) - 1.720\ln(S_{it}) + 1.234\ln(N_{it})$ implying that if $\ln(C_{it}) > [2.609 - 0.400\ln(P_{it}) + 1.720\ln(S_{it}) - 1.234\ln(N_{it})]/0.232$, we get positive effects.

References

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

Chen Lin (2004), “Quality-Incorporate Benchmarking in Public Utilities: An Application to the Peru Water Sector,” Working Paper, University of Florida, USA.

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

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.

Cullivan D, Tippett B, Edwards B Daniel, Rosensweg F & McCaffery J (1988), "Guidelines for institutional assessment of water and waste water institutions", WASH Activity No 146, Washington, DC.

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.

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

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

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

Kordupleski Raymond E., Roland T. Rust & Anthony J. Zahorik (1993), "Why Improving Quality does not Improve Quality (Or Whatever Happened to Marketing?)", pp82-95, California Management Review, Volume 35, Number 3, University of California.

Kumbhakar, S.C., S. Ghosh and J.T. McGuckin (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.

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.

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