International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Productive Efficiency of Water Utilities in Kenya in the Millennium Development Goals Era: Implications on Operations and Service Delivery

Victor Mose*

Kenya Institute for Public Policy Research and Analysis, P.O. Box, 56445 – 00200, Nairobi, Kenya
Email: vmose@kippra.or.ke

Abstract

The policy framework in Kenya requires water utilities to operate efficiently. This study investigates productive efficiency of the utilities using cross-sectional data from Water service Regulatory board between 2011 and 2015. Productive efficiency focuses on optimal utilization of resources and capacity. The study establishes an overall productive efficiency of 66 percent, which is a product of technical efficiency (75 percent) and scale efficiency (89 percent). The standard deviation on technical efficiency, scale efficiency and overall efficiency were 20 percent, 14 percent and 21 percent respectively. The wide standard deviations indicate significant disparity in efficiency across the utilities which may be indicative of inadequate information sharing, limited peer-learning and skewed capacity building mechanism. Higher efficiency is associated with large size, rural environment, higher O+M coverage, higher production per capita, higher staff productivity, higher revenue efficiency, higher metering ratio and higher connections density. Data Envelopment Analysis was used to estimate efficiency scores while probability and correlations analysis were used to investigate factors association with efficiency differentials. Other recommendations are; scaling up of the water utilities to reap economies of scale, review of optimum staffing requirement, building capacity among rural water utilities on productive efficiency, focusing on both functionality of meters and metering ratio.

Keywords: Technical; Scale; Productive; Efficiency; Productivity; Water; Utilities.

----

* Corresponding author.

1. Introduction

This paper seeks link utilization of resources by water utilities in Kenya as they transform them to water services and firm operational deliverables.

1.1. Background Information

In the theory of a firm, productive efficiency is a crucial incentive towards maximization of profit. This is achieved through input minimization and optimal mix as output is maximized [1]. Productive efficiency, to a large extent should be taken as a necessary pre-condition towards enhancing access to water services and generation of water revenue. Such efficiency requires that firm inputs are minimized as output is maximized thus translating to reduced water costs, lower tariffs, expanded water services and more water revenues. It also espouses performance of a firm at full capacity. Productive efficiency is a survival condition of firms in a competitive market and that variation in productive efficiency may be a significant source of variation in financial performance [1].

Kenya's water policy environment encourages efficiency as one of the strategies in improving service delivery and institutional sustainability. The water utilities commonly known as water service providers[a] are regulated by the Water Service Regulatory Board (WASREB) which is mandated to licence and supervise all activities and issues related to water service delivery including efficiency. WASREB monitors the performance of water utilities mainly on nine performance indicators which include; water coverage, sanitation coverage, non-revenue water, drinking water quality, hours of supply, metering ratio, revenue collection efficiency, coverage of operation and maintenance costs, and staff productivity. The utilities are ranked on the basis of their performance in these indicators. The indicators are among various performance indicators recommended by the International Benchmarking Network, IBNET as noted in [2].

The regulatory board (WASREB) is mandated by the Water Act "to develop guidelines for and provide advice on the cost-effective and efficient management and operation of water services" [3, 4]. In the procedure for obtaining license to offer water services the Act requires that utilities should demonstrate plans for the provision of efficient, affordable and sustainable water services. Further, the Water Service Regulations in [5] sets the obligations related to productivity and efficiency which require observance of standards and guidelines in supply of potable water and sewerage services, efficient asset management, commercial orientation with cost recovery principles (technical, commercial, financial and administrative functions), competence of employees as well as training programme.

Water tariffs are regulated by WASREB which sets water tariff guidelines whose objectives are to; promote efficiency in the delivery of water services, ensure financial sustainability of the water utilities, foster access to safe water as a human right, encourage conservation and ensure simplicity in the pricing structure of water [6]. Tariff changes are supposed to be subjected to public participation and approved by the licensing Authority.

[a] In the Water Act (2002), a water service provider is defined as "...company, non-governmental organization or other person or body providing water services under and in accordance with an agreement with the licensee within whose limits of supply the services are provided"

Approval of changes in tariffs is based on recovery of operations and maintenance costs, debt repayment, investment and depreciation, water production and performance of the utility.

1.2. Research Problem

The water utilities are expected to ensure universal access to water and recover all costs incurred in maintenance and operations from the water revenue. Their water coverage reached 53 percent by 2015 demonstrating a potential annual increment of 1 percent only, according to [7]. This low coverage implies high informal access to water which is more prone to unaccountable quality and high health costs. According to UNICEF in [8], "...80 percent of hospital attendance in Kenya is due to preventable diseases and about 50 percent of these illnesses are water, sanitation and hygiene related." UN-Water World Water Assessment Programme [9] indicates that 60 percent of the diseases in Kenya are waterborne, water related or sanitation related" In addition the World Health Organization [10], indicates that between 3,697 and 10,475 people die in Kenya annually due to unsafe water.

Over the period 2011-2015 over 50 percent of water utilities do not recover the costs incurred on operations and maintenance, meaning they operate below 100 percent of O+M costs [7]. Benchmarked against full cost recovery which is rated at 150 percent of O&M costs, over 90 percent of the utilities do not meet this requirement. This is a longstanding problem since Ministry of Water and Irrigation in [11] similarly asserted in the national water service strategy that most of the utilities in Kenya did not recover their O+M costs from the revenue they raised and that this threatened their sustainability. In addition, low recovery of cost and low performance of the Water utilities were associated with unpredictable water supply, high water losses, low water quality and deterioration of assets [11]. Though this may be largely attributed to water losses in terms of nonrevenue water averaging at about 50 percent, inefficiency in resource and capacity utilization cannot be ruled out. Low cost coverage demonstrates low rate of revenue generation. This limits the capacity of the utilities to grow, maintain infrastructure, pay debts and sustain water service delivery besides, increasing dependence on grants.

The average tariffs have been increasing [7], moving from 42 to 63 Ksh/M3 between 2009 and 2015 with a peak of 68 in 2012. Increase in water tariffs can be attributed to operational inefficiencies, in addition to uneconomical usage of resources and inflationary pressures. Increasing tariffs make services expensive and excludable thus limiting access.

This situation of low water coverage, non-recovery of costs and increasing tariffs underscores the need to investigate the efficiency of water utilities in Kenya. This should target productive efficiency by looking at how optimally resources are utilized. Optimal utilization would require that inputs are as minimal as possible at maximum possible output and that full scale of capacity is mobilized.

1.3. Research Questions

The overall question the study seeks to answer is whether productive inefficiency inhibits water service delivery in Kenya. Towards this end, answers to these questions shall inform policy decisions.

- How do water utilities in Kenya optimize on resources and capacity?
- Which characteristics of water sector are associated with productive efficiency?

1.4. Research Objectives

The overall objective of this study is to examine productive efficiency of the water utilities in Kenya. In this regard the study aims study seeks to;

- Estimate productive efficiency of water utilities
- Assess degree of association between efficiency and water sector performance indicators

1.5. Justification of the Study

The study seeks to establish the extent to which efficiencies in resource and capacity utilization contribute to the performance of water utilities. Kenya's status on water stress[b] is expected to worsen during the period 2013-2017. Demand for water for domestic, industrial and agricultural use will increase due to increasing population, rural-urban migration, manufacturing, urban areas growth activities and irrigation. For instance as contained in the second medium term plan of Vision 2030 of Kenya [12], it is projected that by the year 2017 the total population of people will hit 46.7 million up from 41.4 million in 2012 and urban population will reach 17.6 up from 4.2 million in 2012 with urban population growth largely attributed to increased rural-urban migration. This is likely to put more pressure on water resources in the urban areas.

The study considers maximization of resource and capacity potential is supportive in increasing water coverage, revenue collection and recovery of operations and maintenance costs in Kenya. This will improve commercial viability and sustainability of service by the utilities. Therefore, efficiency in resource and capacity use should be an integral component in strategies geared towards sustainable development. Improved efficiency promotes service delivery and financial stability. Water coverage by the utilities by 2015 was is low at 53 percent with annual increment capacity of 1 percent. This was below Kenya's Millennium Development Goals on water coverage targeting 76 percent by the year 2015, an average of 80 percent for urban and 72 percent for rural. Kenya's Vision 2030 targets 100 percent coverage by the year 2030, which will require not only more resources but also effective and efficient use for maximum outputs and outcomes.

2. Materials and methods

2.1. Theoretical Literature

There are two main competing theories with respect to potentials of firms, systems or processes. These are productivity and efficiency. To open up the debate on the difference between the two one may start with Fried, Lovell and Schimdt [1] who stipulate that productivity is a ratio of output to inputs while efficiency is a frontier concept which compares observed inputs with minimum potential inputs as well as observed outputs with maximum potential output.

[b] Water stress occurs when the demand for water is more than supply of water. It can be viewed as water scarcity.

2.1.1. Productivity theory

Productivity theory compares output and inputs (factors of production), where higher output per unit of input or a set of inputs is considered to be more productive. Therefore, productivity is assessed as ratio of a volume of output to a volume of input and can be determined at single factor or multiple factor levels [13]. For instance, labour productivity (output per unit labour) and capital productivity (output per unit capital) are single factor productivities while total factor productivity (output over weighted set of inputs) is a multiple factor productivity as explained by [13,14]. Total factor productivity is comprehensive productivity and involves the contribution by all inputs [14]. Changes in productivity are productivity improvement [14], and this can occur over time in an economy/firm or across economies/firms.

Total factor productivity may be considered as a profitability ratio which compares total revenue to total cost [13]. Relative performance on profitability ratio is important is assessing productivity differences over time or across players in an industry, where higher TFP showing higher performance. This level of productivity can be assessed over time to differentiate the level of catching up or spread across firms. Improvements in productivity are signals of improving efficiency.

2.1.2. Efficiency theory

Efficiency is a measure of productivity relative to maximum possible productivity that is physically achievable with current technology and given a fixed amount of inputs [14]. Therefore, efficiency is a level of production relative to some feasible maximum or optimal production frontier. Shifts in production frontier are often attributed to technological change and not change in efficiency [14].

The theory on productive efficiency is largely attributed to the works of Koopmans [15], Debreu [16], Farrell [17] and Leibenstein [18, 19]. Productive inefficiency is excessive resource use or failure to produce maximum service from the available resources, [1]. This shows that productive efficiency is a two-prong strategy on which both output maximization and input minimization should run concurrently. According to Koopmans [15], “an efficient manager chooses that combination of productive activities which maximizes the amount produced for a given available quantities of factors which have given qualitative characteristics.” The author also says in Porcelli [20] "a producer is technically efficient if an increase in an output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output". Efficiency of an economic system by developing a coefficient of resource utilization [16]. The coefficient is the ratio of the utilized physical resources in production to the utilizable physical resources that are required to produce a certain amount of output that can satisfy some given optimal consumption. Accordingly, to the author, the coefficient takes into account employment of resources, technical efficiency of the production units and efficiency in economic organization of the system. Optimal utilization will show the coefficient being equal to one and non-optimal will have the coefficient being less than one. Farrell [17] proposes three measures of efficiency namely; price efficiency, technical efficiency and overall efficiency or economic efficiency.

A firm's technical efficiency is the "…success in producing as large as possible output from a given set of inputs" [17]. The author adds that, a firm obtains price efficiency or allocative efficiency if it produces the maximum possible output using a combination of inputs with minimum possible costs based on the relative prices of the inputs and further notes that the product of technical and price efficiency maps the overall efficiency or economic efficiency. X-efficiency is the effectiveness with which available resources and opportunities are utilized in production thus would manifest in "labour utilization, capital utilization, time sequence, extent of employee cooperation, information flow, bargaining effectiveness, credit availability, and heuristic procedures" [18,19].

It can therefore be observed that efficiency is premised on the optimization of inputs and outputs. Consequently, producers should use minimum quantities of inputs to produce maximum possible quantities of output(s), this culminates in technical efficiency. Further, optimization theory in production assumes that producers are rational and aim at maximizing profits, an objective which is achievable by maximizing revenue and by minimizing costs. The producer should therefore broker minimum possible prices of inputs to maintain operations at minimum costs and charge maximum possible prices of outputs, these leads to cost efficiency. Productive performances of firms in the same industry vary even if they use the identical set of inputs and production technology Salim [21].

2.2. Empirical Literature

Efforts toward assessing performance of the water utilities in Kenya with respect to efficiency and productivity are attributable to regulatory board in Kenya [7]. The analysis is based on partial ratios in the key performance indicators, which is one of the methodologies recommended by International Benchmarking Network (IBNET. 2005). However, a number of them are not measures of productivity or productive efficiency per se, they are rather outcome based; for example, between 2012 and 2016, water coverage which improved from 52 percent to 53 percent, quality of water with respect to level of chlorination quality and bacteriological quality dropped from 93 percent to 91 percent, sewerage coverage of urban population dropped from 21 percent to 16 percent, revenue collection efficiency moved from 87 percent to 93, metering ratio which improved from 74 percent to 89 percent, and non-revenue water improved from 51 percent to 42 percent. The measures supervised by the regulatory board [7] that are related to analysis of productivity and efficiency are operations and maintenance (O+M) cost coverage which compares revenue to costs, staff productivity which measures number of staff per unit 1000 connections. In the period 2012-2016, sector wide O+M cost coverage declined from 107 percent to 100 percent while staff productivity remained at 7, however there were differences across utilities.

An investigation by [23] gave insight into differences in efficiency between private and public ownership of 53 water utilities in Italy. The study used DEA on 2009 data with aqueduct length, sewerage length, production cost as input and revenue from service as output. The industry technical efficiency (VRS_TE) was 68 percent with scale efficiency (SE) of 90 percent. Public utilities had average overall efficiency (CRS_TE) of 64 percent and technical efficiency of 71 percent. The average overall and technical efficiencies of private utilities were 71 percent and 80 percent respectively. Further the study established that private sector participation enhances efficiency and that large scale is not necessarily a source of efficiency. Geographical location and connections per municipalities showed significant positive effect on efficiency. Population, number of municipalities, number of connections, and connections per network length, did not have significant influence on efficiency.

Iranian water utilities were found to have operated at 88 percent technical and scale efficiency in a study by Nourali and his colleagues [24]. The study used DEA with connections, operation cost, number of employees as input and water billed and number of customers as output. This study involved 34 water utilities and run over the period 2008-2011. The authors concluded that DEA is a "powerful tool for water industry regulators who seek to defend the public interest against the potential abuse of monopoly power and to encourage water providers to improve efficiency"

Another study estimated that in 2006 the average efficiency of the water utilities in Iran was 76 percent (overall) and 82 percent (technical) thus with a scale efficiency of 93 percent. This was done by Mahmoudi and his colleagues [25] whose study investigated efficiency of 17 water utilities using DEA which also found that 53 percent and 47 percent of the utilities operating below the average overall and technical respectively. In the study output variables included volume of water consumed, number of customers (connections) and income while the inputs were total cost and capital. Total cost included wages, water loss costs, O+M costs, energy cost and raw materials cost while capital included total value of plants, transmission and distribution networks, other equipments, storages and buildings. Besides the finding that scale of operation only contributed 7 percent to the inefficiency, capital and water losses were major sources of the inefficiency. Overall the authors stated that about 70 percent of the companies had significant technical inefficiencies.

Cunningham [26] investigated efficiency of 54 water utilities in Australia using cross sectional data approach on 2005-2010 data and applied SFA with translog production function. The quantity and quality of water, number of customers, quantity of sewage collected and level of treatment were used as outputs while capital and labour as inputs with capital being length of mains network. The writer found that the utilities operated at an average TE of 62 percent falling gradually at an average rate of 0.5 percent per year between 2005 and 2010. The decline was suspected to have been caused by low productivity investments, increased resources devoted to non-business activities such as environmental initiatives, and poor control over input use. Ground water as source of water, proportion of customers connected to sewerage and proportion of wastewater had small negative effect on productivity. Though scale of operation had positive effect on productivity this effect was small, estimated at 0.3 percent per year and was said to be offset by negative effect of combined changes in technological progress and technical efficiency which resulted in a decline of productivity by 0.7 percent annually.

A study by [27] used 2006 data to investigate efficiency of 340 water utilities in Germany. The study applied both SFA and DEA. Input/explanatory variables were private consumption, industrial/other consumption, water meters against an output of revenue, proxy for total costs. TE by SFA was 84 and 86 percent for Cobb-Douglas and translog functions respectively which were higher than the DEA TE of 73 percent. In the second stage, variations in the input slacks from DEA were found to respond significantly and positively to variations in output density, water losses, groundwater ratio, elevation differences, location in East Germany, governance mode, joint provision of water and sewage services and per-capita debt of a municipality. However, when per-capita debt, private governance mode, and scope effects with sewage services were regressed against efficiency score from SFA they were found to be insignificant.

Another study by [28] on 364 water utilities in German used 2006 data, DEA production function and established that the utilities' average TE was about 60 percent (without considering structural factors) and 87 percent (when structural factors are included). The output variables used were final water deliveries (to both residential and non-residential), bulk water supplies (to other water utilities), number of connections, with an addition of structural factors like share of water produced (to control for utilities which buy over 20% of processed water), output density (to control for different area densities and obtained by dividing water delivered to final connections/customers by network length), share of water losses (to control for network quality as output), groundwater usage (to control for water quality). The input variables included length of network for capital, number of employees for labour inputs as well as dummy for rural and urban environment orientation. Output density and share of water losses were found to have positive impact on efficiency while share of groundwater usage had negative impact.

Cruz and his colleagues [29] used DEA on 2007 data to compare efficiency levels between 55 water utilities from Portugal and 33 water utilities from Italy. Two models were used with model one using revenue water and population served as output and staff cost, capital expenditure and operational expenditure as inputs; model 2 used revenue water and population served as output against number of employees, main length, and operational expenditure as inputs. The authors found for model 1 the VRS efficiency was 77 percent and 74 percent, CRS efficiency was 68 percent and 65 percent, and scale efficiency was 88 percent and 79 with Portuguese utilities having higher percent than Italian utilities in all categories. For model 2, VRS efficiency was 77 percent and 76 percent, CRS efficiency was 72 percent and 70 percent, and scale efficiency was 93 percent and 92 percent with Portuguese utilities having higher percent than Italian utilities in all categories. The study also found public utilities to be more efficient than mixed utilities and both public and mixed utilities being better than private utilities.

A total of 28 water utilities from English and Wales were investigated by Bottasso and Conti [30] and found to have average cost inefficiency of about 12 percent over the period 1995-2001 improving from 15 percent in 1995 to 10 percent in 2001. These results were from estimation of a SFA cost function with operating expenditure as the explained variable against explanatory variables which included water delivered, length of mains, firm's size (distribution input), unit cost of labour, share of water delivered to non-households customers on total water delivered, stock of capital average pumping head and proportion of river sources on total sources. When average pumping head was dropped the average cost inefficiency over the period 1995-2001 drop to 9 percent. Further when both average pumping head and share of river sources are dropped average inefficiency for the same period hit 11 percent ranging from 16 percent. In the estimation the parameters/elasticity output, wage, average pumping head to cost, proportion of river sources on total sources, joint water and sewerage dummy were found to be positive and significant to cost. Size and population density had negative significant elasticity to inefficiency. According to the author there existed over-capitalization due to insignificant but positive capital elasticity.

Worthington [31] used Malmquist indices to estimate efficiency levels for 55 water utilities in Australia with panel data of 2006-2009. Linear regression was also used to determine the variables explaining the efficiency differences. The input variables used included operating expenditure (operations and maintenance but not capital expenditure) while the output variables were chemical and microbiological compliance, and the inverses of real losses per connection, the number of water main breaks per 100 km of water main, and water quality and service complaints per 1,000 properties. Annual productivity growth (TFP) averaged 1.04 percent ranging from 0.09 percent to 2.98 percent across all utilities. This 1.04 percent TFP generated from efficiency gain of 4.7 percent and Technological change of 0.22 percent. Further Efficiency change was powered by pure technical efficiency of 2.11 percent and gains from scale of 2.23 percent. Efficiency varied inversely with number of properties served per km of the water main length. Technological change is affected by source of water than the size of the utility. High connection/length density indicates problem of congestion, though by small percentage the size of utilities has inverse relationship with efficiency change and source of water has affects technological change. Technological improvements were small (0.17–0.29 per cent) indicating slow pace of best practice improvement.

An average TE of 54 percent with standard deviation of 0.19 of the water utilities was established by [32] for 21 water utilities from Africa over the period 1995-1997. The study estimated SFA and DEA cost function. The individual scores ranged from 85 percent and 83 percent to 35 percent and 30 percent for SFA and DEA respectively. In the data Benin, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Mauritius, Togo, Tunisia, Uganda, Namibia, Niger, Senegal, and Zambia were each represented by one utility while Morocco and South Africa by 2 utilities and Nigeria by 4 utilities. In the first stage involving estimation of DEA/SFA the explained variable used was water production while the explanatory variables were labour, capital and material quantities, hours of work, energy costs in constant prices, number of connections, capacity utilization. The second stage involved running regression of efficiency scores on institutional factors (corruption, governance and ownership). Corruption and bad governance were found to hamper efficiency. Privatization was significant and positively linked to efficiency thus promoting efficiency. The study concludes that TE is low with 0nly 12 percent utilities performing at acceptable efficiency levels ad suggests that policies should be put in place to combat corruption and bad governance as well as encouraging continued financing through both the public and private sector.

In Uganda, Mugisha [33] used SFA and Translog Production function with time trend on panel data, 2002-2010, to investigate efficiency of 19 water utilities. The mean efficiency established was 87 percent. The author fitted revenue water as output in the first stage with water production per connection, operating expenditure per connection and staff per connection as inputs. The estimated coefficients of water production and operating expenditure variables, 0.911 and 0.216 respectively were significant. The author associated insignificantly small coefficient of staff, 0.026, with inappropriate staff mix skewed towards non-technical staff and this was supported by the interactive term of staff and produced water which was positive and significant indicating that the performance of revenue water uniquely depends on produced water per connection than the staff per connection. The sum of input parameters in the frontier model was more than one implying that large number of connections was preferred. In the second stage inefficiency score was the explained variable with service coverage, level of financial incentives, revenue water target difficulty, and year of observation as explanatory variable. The study found coefficients of service coverage and financial incentives negative and significant to inefficiency, with only target-difficulty being insignificant but with negative sign. The study concludes that increasing monetary incentives and service coverage as well as reducing non-revenue water would improve efficiency. Target-difficulty setting was said to be leading to low efficiency and suspected to be too difficult to achieve thus demoralizing the staff thus need to be improved.

In Australia, Coelli & Walding [34] found 18 water utilities to have operated at TE of 0.904 and SE 0.903 on average. The authors estimated DEA production function using 2003 cross-sectional data. The authors interpreted the mean TE score of 0.904, as indicating the average firm could have reduced input usage by 9.6 percent and still produce the same output level. On the other hand, the mean SE score of 0.903 indicated that same output could be produced by an average firm with 9.7 percent reduction in input per unit of output. In the model the authors used operating expenditure and capital as inputs and the number of properties connected and volume of water delivered as outputs. According to the authors capital could have been best described as written down current cost of fixed assets but total expenditure minus operational expenditure was used as well as length of the Mains. Same results were witnessed for using length of the mains and the difference between total expenditure and operating expenditure.

On average, the Italian water industry operated at 28 percent inefficiency according to [35] who used SFA with translog cost function to estimate the efficiency levels of water utilities in Italy using data of 25 years. The inefficiency levels were 21 percent in the first year, hitting highest 32 percent in the 10th year and decreasing to 22 percent in the 25th year. Delivered water and total cost were used as outputs and the inputs were chosen in two dimensions, production and cost; from production, labour, electricity costs, materials and capital while from cost point of view; amount of delivered water, price of labour, the purchase price of electricity and the price of materials, services and capital, network length, level of losses and time trend. The authors observed that cost elasticity to output, network length and factor prices was positive and significant but had weak variability response to the time variable indicating that technical progress does not necessarily reduce variable costs. The writers also observed that inefficiency and population density had positive relationship indicative of possible congestion problems in the mains length at the same time indicate that the benchmarking methods should be reviewed to compensate for the density variable. For smaller firms the economies of output density were very high thus utilities could obtain cost reduction through further mergers. Increasing inefficiency rates followed by decreasing rates of tariffs over time indicated that tariff-cap system which had been enforced over time was not working. The authors argued that efficiency of network services is influenced by environmental and morphological conditions.

The work of [36] used SFA and DEA to estimate efficiency of water providers in France for the year 2009 and found TE of for 0.83 and 0.72 for public and private firms and national TE of 0.75 with minimum of 0.37. The mean TE score indicated that on average a company could reduce costs by almost 25 percent and still produce the same level of outputs. The study used revenues as a proxy for costs as output with an interpretation that this revenue accommodates operations costs, capital costs and mark-up. Billed water, number of customers (properties connected), pipes' length and service quality (ratio of billed water to produced water) were used as inputs. The study is cautious to note that the quality of service variable could assume various proxies like water quality, customer satisfaction, and service coverage, among others. In addition, the study models input slacks with environmental factors as dummies including population density, touristic area, ground water as main source of water or otherwise, interconnected due to some utilities being managed jointly by various municipalities, mixed treatment due to multiple sources of water, and complex treatment due to use of simple of advanced chemical and physical treatment of water. Finally, the study investigates the efficiency differences between the privately owned to public owned utilities and established an average efficiency difference of 6 percent in favour of public utilities.

Correia [37], used SFA, Translog cost function to investigate efficiency of 68 water utilities in Portugal over the period 2004-2005. The dependent variable was cost of production while independent variables were volume of revenue water and volume produced wastewater together with price if labour, price of capital, and price of other inputs. The study argued that price of labour can be represented by ratio of the staff costs to staff number and price of capital by capital expenditure divided by mains length. The study established average efficiency of 89.3 percent, meaning utilities would reduce costs by 10.7 percent and still produce same outputs of water and wastewater. The maximum efficiency score was 0.907 and minimum 0.697. Private owned utilities were more efficient than public. Utilities specializing in offering water only were also more efficient than the composite (offering both water and sewage or waste water treatment) but the difference was small.

Water Utilities in Malaysia were found to have significant room of 34 percent to improve on technical efficiency as well as closing the differences in efficiency across States. These were findings by Hon and Lee [38] who used DEA to estimate the efficiency of 17 utilities in Malaysia over the period 1999-2005. Operating expenditure is the only input variable used versus total consumption, number of connections and length of mains as output variables. The study established mean TE 66 percent, ranging between 56.9 percent and 72.2 percent over the period.

Parker and his colleagues [39] use DEA, SFA and partial ratios to estimate efficiency and labour productivity for 13 countries in Africa which had private utilities offering water services. These countries included “Cape Verde, Cameroon, Cote d’Ivoire, Gabon, Ghana, Kenya, Nigeria, Morocco, Republic of Guinea, Senegal, South Africa, Tunisia and Zambia” Parker and his colleagues 2006. On efficiency the authors used cost, water delivered and hrs of access as outputs and manpower cost per employee (proxy for average skill level of staff), material cost per unit of water distributed and the number of water treatment works as inputs. Further the study investigated efficiency differences against freedom index, fiscal balance index, property index (protection rights), population density (population/connection), annual water resources per capita, ownership (private/public), and wealth (GDP). The study established the relationship of operating costs with water delivered, service quality, labour price, and material cost to be significant and positive. Water resources availability and property protection rights had negative and significant coefficient on cost. Income per capita, the freedom index and fiscal management measure had negative but insignificant coefficient indicating weakly that wealth and good governance induces cost efficiency. Network density and ownership were statistically insignificant. The authors concluded that privatization may not have significant impact in efficiency. However, though weak, governance and institutional factors have influence on efficiency and productivity. The study used labour costs to total costs, number of staff to number of water connections and staff to volume of water distributed to measure labour productivity. It was established that private water utilities have higher labour productivity then public.

2.3. Overview of Literature

Productivity of an economy/firm is resultant effect of the level of efficiency at a given state of technology. Changes in total factor productivity can be decomposed into changes in efficiency and changes in technology. 'Efficiency change' is a measure of movements toward best practice, being shifts toward the production frontier. In contrast technology change refers to changes in best practice, being shifts of the production frontier [14].

Theoretical literature demonstrates that productive efficiency is important and can be measured through the effectiveness with which inputs are utilized to produce output. This encompasses minimization of resources and maximization of output. The main challenges emanating from the empirical literature is multiplicity of methodology especially in terms of estimation technique and common variables that should be used in measuring efficiency of water utilities. However, literature narrows down to two competing modern methodologies, SFA and DEA. Due to the different estimation techniques and underlying assumptions the efficiency scores from SFA and DEA are bound to be different and uncorrelated, however the choice between them depends on their differences. Studies have also advocated for post efficiency diagnosis of factors that may be associated with different performances in efficiency. This is therefore done in two stages with the first stage involving estimation of the efficiency scores and the second stage the variations in efficiency or inefficiency scores are analysed against other factors which are hypothesized to be associated with variations in efficiency.

In the first stage, to estimate cost efficiency various studies have chosen revenue or total cost or operating costs as output against selection of inputs from aqueduct length, sewerage length, delivered water, sewage water, customers or connections, capital and labour as well as their derivatives. On the other hand, to estimate production/operational technical efficiency revenue water, quantity of sewage, connections, customers, aqueduct length, sewerage length and income/revenue are common outputs while capital, labour and operating expenditure appear in most of the studies as inputs.

In the second stage a number of factors have been analyzed against efficiency scores. Some of the factors emerging from the literature that they are likely to influence variations in efficiency across firms are; ownership, specialization, population density (population/connection), service coverage, size, wealth of the region, municipalities served, number of connections, population served, water service provider's geographical location and water service operator topology, connection/number of municipalities and number of connections/network length, population density, ground water as source of water, proportion of customers connected to sewerage and proportion of wastewater, corruption, governance and ownership, level of financial incentives, revenue water target difficulty, and year of observation, touristic area, mixed treatment, complex treatment, freedom index, fiscal balance index, property index (protection rights) and annual water resources per capita.

2.4. Methodology

2.4.1. Theoretical Framework

Optimization behaviour of firms aims at maximum possible output per unit input. This should translate to maximization of revenue against minimization of costs, and this requires that output is maximized while inputs are minimized. In terms of efficiency, the level of production of a firm at a given point can therefore be compared with the maximum possible level given the state of technology, and distance technique can be applied to measure technical, allocative, scale and overall/productive/economic efficiency [1,13]. Two analytical channels emerge in relation to efficiency estimation; these are input oriented and output oriented.

2.4.2. Analytical Framework

The International Benchmarking Network [22], recommends various alternative methods that can be used to benchmark the performance of water utilities, including partial indicators, total factor productivity index, statistical techniques (like ordinary least squares and stochastic frontier approach) and data envelopment analysis. These methods vary in terms of approach and merit and Apgar score [2].

Partial Indicators mainly use proportions, ratios, frequencies or percentages to assess the performance of the utilities. Partial indicators are commonly used because they are easy to compute and interpret. They are good at assessing productivity. However, they do not accommodate the relationship or interaction among the indicators. Besides, they require further analyses based on weighted averages to calculate the overall performance index (OPI) which this brings about the problem of allocating weights. OPI is a simple or weighted average of partial indicators. It is simple if all indicators are treated equal and weighted if the indicators are treated with different importance thus allocated different weights. This introduces the bias of weighting, but it is not a big deal once it is agreed upon across the industry. These are currently used by WASREB where water coverage, sewerage coverage, staff productivity, metering ratio, revenue collection efficiency among others are computed [7].

WASREB has also customized the Apgar score criteria [7] in estimating an overall performance index of a provider where scores are awarded based intervals of performance for each of the nine indicators. Broadly the scaling sums up to a maximum of 200 marks resulting from; 0-30 marks for water coverage, 0-25 marks each for two indicators nonrevenue water and coverage of operations and maintenance costs, and 0-20 marks each for three indicators (hours of supply, revenue collection efficiency and staff productivity), and 0-15 marks for four indicators (metering ratio, sanitation coverage, quality of water based on chlorination and quality of water based on bacteriology). The problem with this approach is that the weights are prone to human bias.

Corrected Ordinary Least Squares (COLS) and Stochastic Frontier Analysis (SFA) are also used which are parametric techniques. IBNET [22] mainly draws difference between the two in that COLS attributes all the deviations from the average frontier line to inefficiency while SFA decomposes the deviation into inefficiency and random error. SFA and COLS are based on average frontier with inefficiency being calculated from the mean line of best fit performance. The limitations of these methods are that they require large sets of data and a functional form (like Cobb-Douglas function or translog function). Misspecification of the model and application of unfitting function leads to erroneous results. Judgment of the correct function and variable specifications require rigorous sensitivity testing which time consuming.

Another method of estimation is Data Envelopment Analysis (DEA). This uses linear programming on a set of inputs producing a set of outputs in computing efficiency. DEA is developed from the understanding that efficiency is measured as the ratio of the weighted sum of output to weighted sum of input. It is a frontier method which is based on the border line as opposed to the average line.

As summarized by Pascoe and his colleagues [40] the main approaches in measuring productivity, capacity utilization and efficiency are stochastic frontier approach (SFA) and data envelopment approach (DEA). The choice of methods for measuring productivity will highly depend on the purpose and the availability of data and the relevance as single input or multiple inputs and relevance at firm or industry levels. However, the author clarifies that in place of single input productivity it should not be construed that the individual factors are independent of each other. In the literature there is increased usage of SFA and DEA in modern assessment of efficiency across sectors.

This paper prefers DEA because of its advantages, mainly so that it is able to measure productive efficiency and scale efficiency and it does not need any data manipulation to fit into priory conditions. DEA is nonparametric unlike SFA thus does not require that the observations mimic a finite probability distribution. This does not tie estimation to conduct diagnostic tests and manipulation of data to fit into the parametric approaches however it lacks allowance to test for significance of outcomes unlike SFA. This approach is simple to follow and execute; it is simply a mathematical programming approach. It does not require a functional form which must be informed by some economic theory like SFA requires. DEA allows for easier multiple outputs modelling unlike SFA. Bottom-line, DEA compares departures of firms' production paths from the best performing optimal firm or path while SFA considers the deviation from the average imaginary line, this makes DEA superior in the sense that firms are compared with best performing firm than SFA which uses the average smoothening imaginary firm. However, SFA decomposes inefficiency term and the error term from the residual term of a regression unlike DEA. Data envelopment analysis has potential to decompose efficiency into technical, allocative and economic efficiencies among these methods only which makes it appropriate for this study

2.4.3. Model Motivation

DEA was introduced by Charnes and his colleagues [41] as a tool for measuring relative efficiency of decision making units (like Water utilities). The authors used linear programming on a set of inputs producing a set of outputs under constant returns to scale (CRS), this version is commonly abbreviated as CCR. Banker and his colleagues [42] modified the CCR by relaxing the CRS condition and allowed for variable returns to scale (VRS), a version abbreviated as BCC. Basically, DEA is developed from the understanding that efficiency is measured as the ratio of the weighted sum of output to weighted sum of input.

For a set of inputs x and outputs y and with u and v being respective weights the relative efficiency for decision making units (DMU) is estimated by equation (1).

$$Efficiency = \frac{Weighted\ sum\ of\ output}{Weighted\ sum\ of\ inputs} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \qquad (1)$$

Where

j *are* $DMUs$, r *are outputs*; $r = 1 \dots s$, i *are inputs*; $i = 1 \dots m$, u_r *is weight of output* r

v_i *is weight of input* i , y_{rj} *is quantity of outputs* r *of* DMU_j, x_{ij} *is quantitity inputs* i *of* DMU_j
s *and* m *are number of outputs and inputs used in production respectively*

The CCR model in [41] advances to equation (4) to equation (5) where the efficiency of the designated decision making unit (DMU0) is estimated by maximizing the path defined by equation (2).

$$Max\ h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

$$s.t.\ \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, u_r, v_i \geq \varepsilon\ \forall\ j = 1 \dots n \text{ and } \varepsilon > 0 \qquad (2)$$

Where

h_0 *is relative efficiency of* DMU_0 $0 \leq h_0 \leq 1$, y_{r0} *is quantity of outputs* r *of* DMU_0 *and*

x_{i0} *is quantitity of inputs* i *of* DMU_0

Note that in equation (2) the condition $\varepsilon > 0$ is a strict requirement that the output and input used by the firms under study are uniform otherwise if $\varepsilon \leq 0$ this allows for differences in outputs or inputs as well as inclusion of variables with spots of missing data. In addition, since h_0 is a ratio and due to different rates of change in the numerator and denominator it has potential to mimic a nonlinear distribution. To ensure linearity of the distribution equation (2) can be transformed to equation (3) by imposing a linearity condition that the numerator is strictly equal to 1.

$$Max\ z_0 = \sum_{r=1}^{s} u_r y_{r0}$$

$$s.t. \sum_{i=1}^{m} v_i x_{i0} = 1,\ \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, -u_r \leq -\varepsilon, -v_i \leq -\varepsilon \qquad (3)$$

Where z_0 *is output of desinated* DMU_0 *and* $\sum_{i=1}^{m} v_i x_{i0} = 1$ *is linearity condition*

Equation 3 defines an output-oriented model of which taking it as a primal equation its dual equation will mark an input-oriented model defined by equation (4). Equation (5) is desirable since it solves the problem of multiplicity of variables in the primal. Given that the optimal solutions for both the primal and dual models are the same then the dual model is preferable for its simplicity in computations.

$$min\ \theta - \varepsilon\left(\sum_{i=1}^{m} s_j^- + \sum_{r=1}^{s} s_i^+\right)$$

s.t.

$\theta x_{i0} - \sum_{j=1}^{n} x_{ij}\lambda_j - s_i^- = 0 \; \forall \, (i = 1..m),\; y_{r0} - \sum_{k=1}^{n} y_{rj}\lambda_j + s_r^+ = 0 \;\; \forall (r = 1..s),$

$\lambda_j, s_i^-, s_r^+ \geq 0,$ *(4)*

Where

θ *is dual variable for constraint* $\sum_{i=1}^{m} v_i x_{i0} = 1$ *in the primal equation* (3)

λ_j *is dual variable for constraint* $\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 1$ *in the primal equation* (3)

s_i^+ *is dual variable for constraint* $-u_r \leq -\varepsilon$ *in the primal equation* (3)

s_j^- *is dual variable for constraint* $-v_i \leq -\varepsilon$ *in the primal equation* (3)

It is important to note that θ is the efficiency score, s_i^+ is a slack variable that represent excess inputs and s_j^- is a slack variable that represent shortage in outputs. In addition, Equations (3) and (4) measure overall efficiency which is a product of technical efficiency and scale efficiency.

The weakness of CCR is that it assumes CRS which in the short run may be violated. To relax this condition BCC model was developed allowing for VRS. A detailed derivation of BCC model is found in Banker and his colleagues (1984) but in this paper a short demonstration is given. Therefore, the BCC model follows equations (5) and (6), the primal and dual respectively which measure pure technical efficiency. In equation (5), the factor u_0 is the returns to scale factor which allows for VRS such that if $u_0 \lesseqgtr 0$, then the firm operates at IRS, CRS or DRS respectively. In equation 6 the convexity variable $\sum_{j=1}^{n} \lambda_j = 1$ allows for VRS.

$Max\; z_0 = \sum_{r=1}^{s} u_r y_{r0} - u_0$

$s.t.$

$\sum_{i=1}^{m} v_i x_{i0} = 1,\; \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \leq 0,\; -u_r \leq -\varepsilon, -v_i \leq -\varepsilon$ *(5)*

The dual problem to equation (5) is stated as shown in equation (6).

$min\;\; \theta - \varepsilon\left(\sum_{i=1}^{m} s_j^- + \sum_{r=1}^{s} s_i^+\right)$

s.t.

$\theta x_{i0} - \sum_{j=1}^{n} x_{ij}\lambda_j - s_i^- = 0 \; \forall \, (i = 1..m)$

$y_{r0} - \sum_{k=1}^{n} y_{rj}\lambda_j + s_r^+ = 0 \;\; \forall (r = 1..s)$

$\lambda_j, s_i^-, s_r^+ \geq 0$

$$\sum_{j=1}^{n} \lambda_j = 1, convexity\ constraint \tag{6}$$

Where

θ *is dual variable for constraint* $\sum_{i=1}^{m} v_i x_{i0} = 1$ *in the primal equation* (5)

λ_j *is dual variable for constraint* $u_0 = \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 1$ *in the primal equation* (5)

s_i^{+} *is dual variable for the constraint* $-u_r \leq -\varepsilon$ *in the primal equation* (5)

s_j^{-} *is dual variable for the constraint* $-v_i \leq -\varepsilon$ *in the primal equation* (5)

2.4.4. Model Specification

The study uses input-orientation analysis of DEA with quantity of water produced (prd) and amount of revenue collected (Rev) as output, and number of connections representing capital (conn), number of staff representing labour (staff size) and costs of operations and maintenance proxing materials (omcost) as inputs. CCR Model estimated the overall efficiency, inclusive of technical and scale efficiency. Following equation (1) we state the efficiency equation as follows in Equation (7).

$$Max\ h_0 = \frac{u_1 prd + u_2 rev}{v_1 conn + v_2 staff + v_3 omcost} \tag{7}$$

Where

u_1 *and* u_2 *are weights of water produced and revenue collected respectively*

To calculate the overall efficiency (θ_{BCC}) the CCR model in equation (3) and equation (4) are applied. In order to obtain pure technical efficiency (θ_{CCR}) the BCC model in equation (5) and (6) are followed. Scale efficiency is then estimated as a proportion of $\theta_{BCC}\ in\ \theta_{CCR}$.

The study investigates a number of factors that are hypothesized to be associated with differences in efficiency across the Water utilities. These factors represent managerial, environmental and technological orientation. To represent managerial factors the study used, water coverage, staff productivity, O+M cost recovery, nonrevenue water, consumption per capita. Environmental factors were represented by region. Technological factors were size, connections per capita, production per capita and sewerage system. Correlation coefficients in equation (10) and equation (11) were used to assess the degree of association between efficiency and the managerial, environmental and technological factors.

The correlation between two variables (x and y) using Pearson's Correlation Coefficient is given in equation 10, where w_i are the weights, if specified, or w_i = 1 if weights are not specified, $\bar{x}$ and $\bar{y}$ are means for the variables (x and y) respectively and (i) are observations.

$$\hat{\rho} = \frac{\sum_{i=1}^{n} w_i(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n} w_i(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n} w_i(y_i-\bar{y})^2}} \tag{10}$$

The significance level of the Pearson correlation coefficient is computed as follows;

$$P = 2 * ttail\left(n-2, \frac{|\hat{\rho}|\sqrt{n-2}}{\sqrt{1-\hat{\rho}^2)}}\right)$$

The Spearman correlation coefficient is simply Pearson correlation coefficient between the ranked variables. In other words, the observations in variables (x and y) are ranked and the spearman rank correlation uses the ranks instead of the actual observations in the estimation of the correlation.

$$\hat{\rho}_r = \frac{\sum_{i=1}^{n} w_i\left(r_{x_i}-\overline{r_x}\right)\left(r_{y_i}-\overline{r_y}\right)}{\sqrt{\sum_{i=1}^{n} w_i\left(r_{x_i}-\overline{r_x}\right)^2}\sqrt{\sum_{i=1}^{n} w_i\left(r_{y_i}-\overline{r_y}\right)^2}} \tag{11}$$

Further, in order to assess the association between efficiency and area, region and specialization, mean and relative frequency analysis is appropriate. Accordingly, the study will use t-test and analysis of variance. The t-test will assess whether there exists any statistical difference in the means of two groups and the candidate variables for this analysis are area and technological orientation which are categorised to either urban or rural and specialized or composite respectively. Specialized utilities offer water services only while composite offer both water and sewer services. On the other hand, ANOVA indicates whether there are significant differences in the means of more than two groups and the variables under this category are region (8 groups) and size (3 groups).

2.4.5. Data Description

The dataset spans the period 2011 to 2015. In assessing productive efficiency, the common outputs from the literature are revenue water, quantity of sewage collected, no of connections, no. of customers, aqueduct length, sewerage length and income/revenue. The common inputs are capital, labour, operating expenditure with aqueduct length, no. of connections and value of fixed assets being used as proxy for capital.

The study uses produced water and revenue as outputs and the number of staff, number of connections (for capital), and expenditure on O+M (for material) as inputs. The rest of the variables were dropped for various reasons. For instance, data on amount of sewage was unavailable. Connections as output are appropriate when assessing cost efficiency but considered as input, in our case it is a perfect proxy for capital recommended where data on fixed assets base or asset value and aqueduct length is not available. Number of customers and connections are highly correlated and can stand for each other unless when the served population under the service area is considered. Though revenue from water may be considered correlated with amount of water, there are distortionary factors like revenue collection efficiency, metering ratio, tariffs and water losses which justify their simultaneous use as outputs. Besides, utilities invest substantially in recovering water losses, increasing metering ratio, increasing revenue collection, thus warrant assessment of how resources are utilized along these functions.

Variations in efficiency scores are investigated against; size (small, medium and large based on connections), region (using eight regions), area (rural and urban), ownership (public and private), water coverage (percentage of population served under service area), O+M coverage (revenue as ratio of O+M costs), specialization status (specialized utility serves water only or composite has water and sewerage), water production and consumption per capita (amount of water per person in the service area), staff productivity (no. of staff per 1000 connections), revenue collection efficiency, metering ratio, connection density (population per connection).

Table 1: Description of data and Hypothesis (Expected Results)

Variable	Description	Type	Hypothesis (relationship with efficiency)
size	small, medium, large	categorical	Larger utilities are more efficient
region	use the eight regions	categorical	Water-rich are more efficiency
area	rural and urban	categorical	Urban is more efficient
O+M coverage	revenue as ratio of O+M costs	continuous	Positively correlated
specialization status	specialized(water), composite (water and sewerage)	categorical	Specialized is more efficient
production per capita	water per person in the service area	continuous	Positively correlated
Staff productivity	number of staff per 1000 connections,	continuous	Positively correlated
connection density	population per connection	continuous	Positively correlated
Revenue efficiency	Percentage of billed water revenue that is collected	continuous	Positively correlated
Metering ratio	percentage of connections with meters	continuous	Positively correlated
Water coverage	percentage of population accessing improved water	continuous	Positively correlated

3. Results

3.1. Efficiency Scores of Water Utilities

Over the period 2011-2015, on average the water utilities had overall productive efficiency of 66 percent, disaggregating to 75 percent technical efficiency and scale efficiency of 89 percent. These averages are derived from table 2 and summarized in figure 1 which show efficiency scores of individual utilities, averages per year and annual standard deviations of efficiencies across the utilities. Over the period, standard deviation on technical efficiency, scale efficiency and overall efficiency were 20 percent, 14 percent and 21 percent respectively. These wide standard deviations indicate significant disparity in efficiency across Water utilities which may be indicative of inadequate information sharing, limited peer-learning, skewed capacity building and geographical advantage. The sector was on an improving trend in terms of productive efficiency during the period 2011-2015. For instance, in figure 1 shows that sector technical efficiency grew from 69 percent in 2011 to 80 percent, scale efficiency (83 percent to 93 percent) culminating in growth of overall productive efficiency from 57 percent to 74 percent over the period (2011-2015). Figure 2 indicates that the sector is closing gaps among the utilities in terms of efficiency since the trends of the standard deviation of the efficiency are on declining path. However, figures (3, 4 and 5) indicate that the number of Water utilities that operated below the sector average during the period 2011-2015 were almost 50 percent broken down as overall productive efficiency (48 percent), technical efficiency (49 percent) and scale efficiency (66) over the five-year period. Though figures (3, 4, and 5) show that the Water utilities performing below the sector average are reducing in absolute numbers, their percentage to the total Water utilities as at 2015 was above 50 percent.

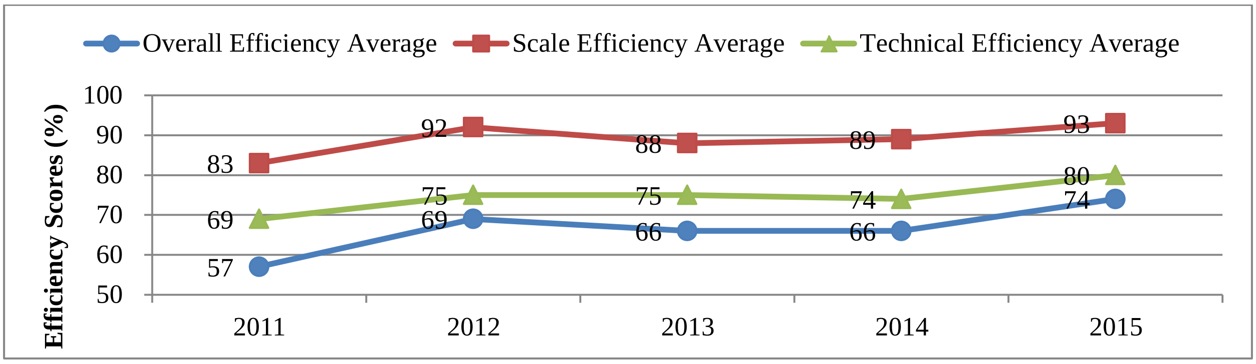

Figure 1: Central Tendency of Efficiency Scores

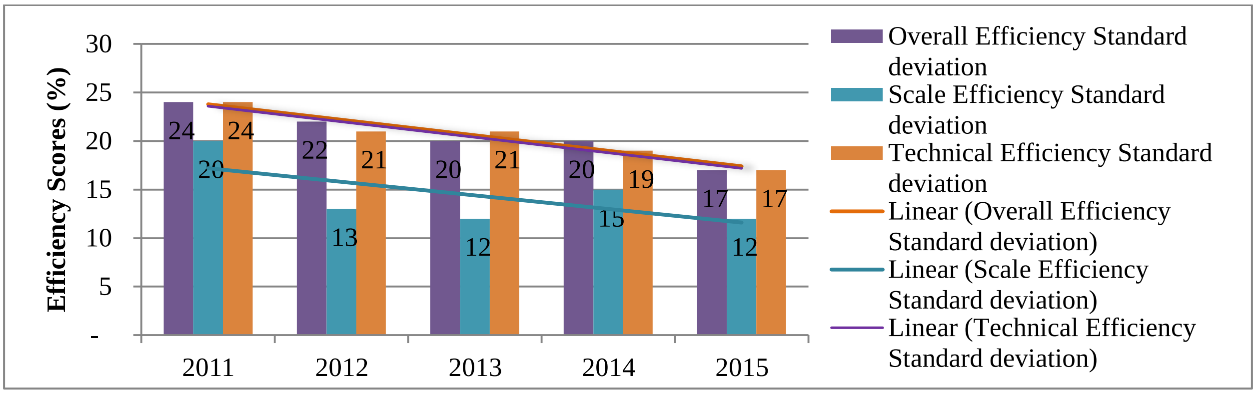

Figure 2: Spread of Efficiency Scores

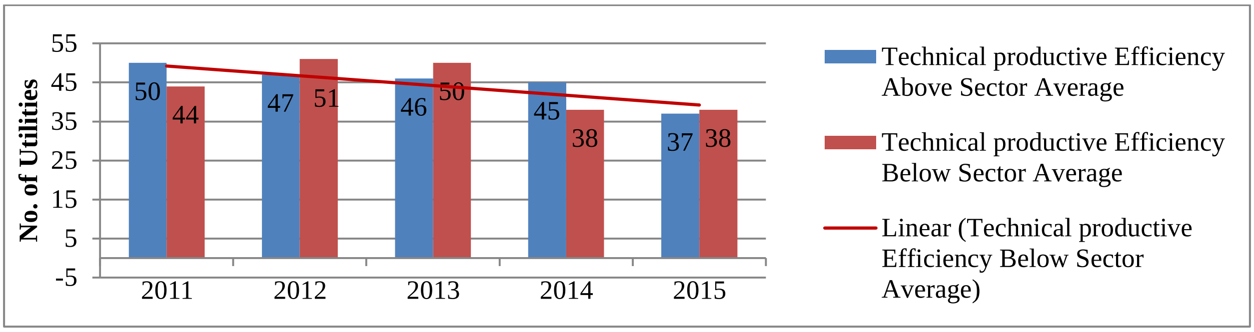

Figure 3: No. of Utilities Above or Below Average – Technical Efficiency

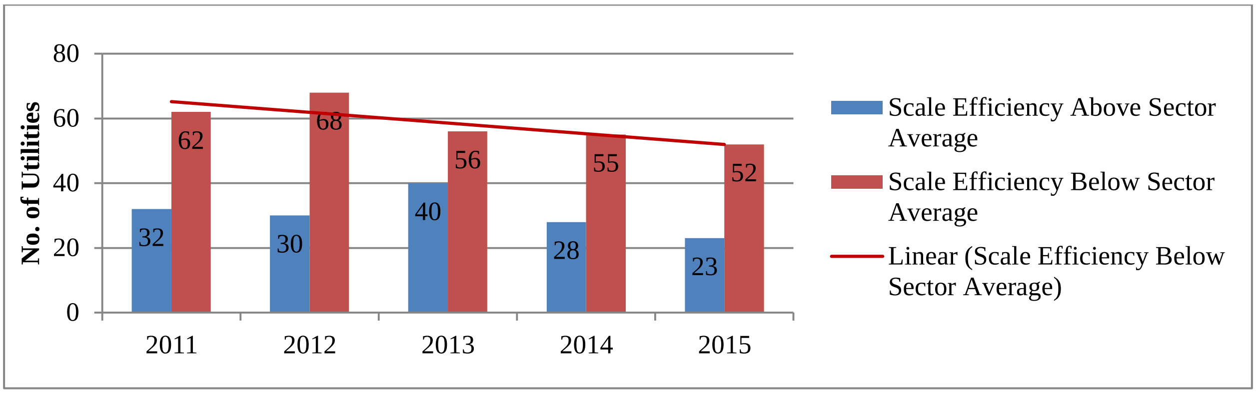

Figure 4: No. of Utilities Above or Below Average – Scale Efficiency

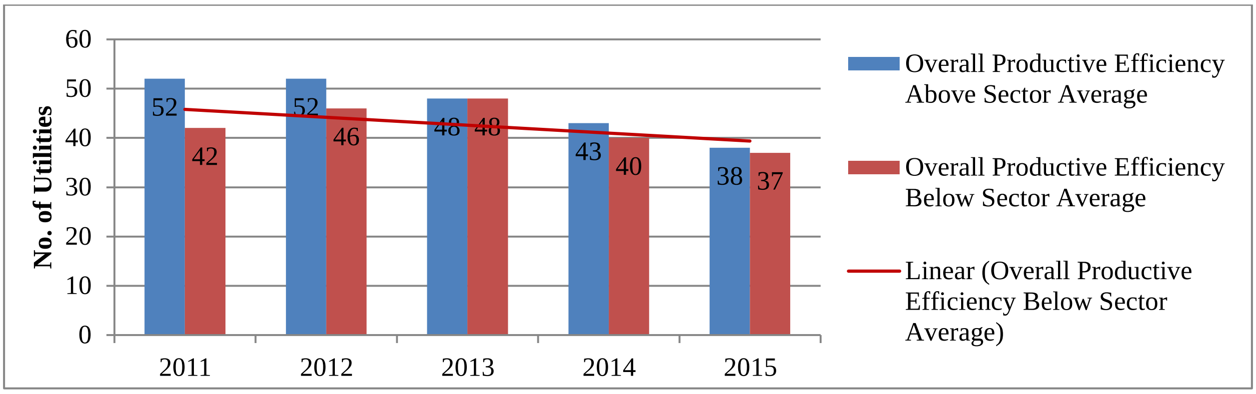

Figure 5: No. of Utilities Above or Below Average – Overall Efficiency

The utilities which operate below their potential scale of operation affect the overall productive score since scale efficiency contradicts the impact of technical efficiency in service delivery. Lower scale efficiency points to the need for management to mobilize resources optimally. The overall productive efficiency is equivalent to the technical efficiency at constant return to scale.

Table 2: Scores of Utilities on Technical, Scale and Overall Productive Efficiency

Year Efficiency (e: 0<e<1)	2011 TE	2011 SE	2011 OE	2012 TE	2012 SE	2012 OE	2013 TE	2013 SE	2013 OE	2014 TE	2014 SE	2014 OE	2015 TE	2015 SE	2015 OE
Amatsi	0.51	0.97	0.50	0.47	0.93	0.44	0.72	0.91	0.65	0.88	0.97	0.85	0.75	0.98	0.74
Bomet													0.65	0.98	0.64
Chemosit	0.44	0.79	0.35												
Eldama_Ravine	0.4	1.0	0.4	0.6	0.9	0.5	0.6	0.9	0.6	0.6	0.8	0.5	0.7	0.7	0.5

Year	2011	2011	2011	2012	2012	2012	2013	2013	2013	2014	2014	2014	2015	2015	2015
Efficiency (e: 0<e<1)	TE	SE	OE	TE	SE	OE	TE	SE	OE	TE	SE	OE	TE	SE	OE
	9	0	8	5	1	9	4	5	1	6	0	3	3	6	6
Eldoret				0.80	0.96	0.77	0.75	0.77	0.58	0.80	0.81	0.64	0.93	0.81	0.75
Embe	0.57	0.95	0.54	0.85	0.98	0.84	0.88	0.94	0.83	0.63	0.89	0.56	0.76	0.96	0.73
Embu	0.74	0.93	0.69	0.90	1.00	0.90	0.86	0.85	0.73	1.00	1.00	1.00	1.00	0.94	0.94
Engineer	1.00	1.00	1.00	0.93	0.79	0.73	0.97	0.75	0.72						
Garissa	0.76	0.87	0.66	0.78	0.99	0.77	0.83	0.91	0.76	0.80	0.97	0.77	0.92	0.85	0.78
Gatamathi	0.47	0.83	0.39	0.77	0.95	0.73	0.65	0.88	0.57	0.84	0.99	0.84	0.68	0.96	0.65
Gatanga	0.68	1.00	0.68	0.73	0.93	0.68	0.67	0.88	0.60	0.90	0.97	0.88			
Gatundu_South	0.72	0.92	0.66	0.73	1.00	0.73	0.88	0.85	0.75	0.75	0.97	0.73	0.89	0.81	0.72
Gichugu				0.99	0.86	0.85									
Gitei				1.00	0.67	0.67	1.00	0.62	0.62						
Githunguri	0.62	0.99	0.62	0.56	1.00	0.56	0.52	0.94	0.49	0.56	0.96	0.53	0.65	1.00	0.65
Gulf	1.00	1.00	1.00	0.46	1.00	0.46	0.34	0.96	0.33						
Gusii	0.43	0.99	0.43	0.58	1.00	0.58	0.52	0.91	0.47	0.44	0.99	0.44	0.47	1.00	0.47
Hola_Tana_River				0.84	1.00	0.84									
Imetha	0.39	0.99	0.39	0.58	1.00	0.58	0.56	0.92	0.52	0.65	0.98	0.64			
Isiolo	0.48	0.98	0.47	0.57	1.00	0.57	0.66	0.89	0.59	0.56	0.98	0.55	0.68	1.00	0.68
Iten_Tambach	0.42	0.67	0.28	0.50	0.84	0.42	0.53	0.99	0.52	0.46	0.62	0.28	0.63	0.97	0.61
Kahuti	0.68	0.87	0.59	0.84	0.99	0.84	0.76	0.88	0.67	0.74	0.98	0.72	0.81	0.94	0.76
Kakamega	0.77	0.69	0.53	0.80	0.91	0.73	1.00	0.92	0.92	0.74	1.00	0.74	0.79	0.99	0.78
Kapenguria	0.49	0.69	0.34	0.42	0.98	0.41	0.44	0.91	0.40	0.50	0.74	0.36	0.52	0.78	0.41
Kapsabet_Nandi	0.57	0.52	0.30	0.59	0.97	0.57	0.60	0.96	0.57	0.64	0.91	0.58	0.58	0.96	0.56
Karimenu	0.55	1.00	0.55	0.72	0.96	0.69	0.78	0.95	0.74	1.00	1.00	1.00	1.00	1.00	1.00
Karuri	0.49	0.88	0.43	0.58	1.00	0.58	0.54	0.92	0.50	0.60	0.96	0.58	0.76	0.99	0.75
Kathiani							0.66	0.56	0.38	1.00	0.76	0.76			
Kathita_Kiirua	0.94	0.90	0.84	1.00	1.00	1.00	1.00	1.00	1.00						
Kericho	0.54	1.00	0.54	0.67	0.99	0.66	0.61	0.86	0.52	0.62	1.00	0.62	0.71	1.00	0.71
Kiambere	0.53	0.90	0.48	0.50	0.88	0.45	0.45	0.98	0.45	0.43	0.95	0.41	0.51	0.96	0.49
Kiambu	0.5	0.9	0.5	0.7	0.9	0.6	0.8	0.9	0.8	0.6	0.9	0.6	0.7	1.0	0.7

Year	2011	2011	2011	2012	2012	2012	2013	2013	2013	2014	2014	2014	2015	2015	2015
Efficiency (e: 0<e<1)	TE	SE	OE	TE	SE	OE	TE	SE	OE	TE	SE	OE	TE	SE	OE
	9	4	5	0	6	7	7	8	6	1	9	1	3	0	3
Kiamumbi	1.00	0.85	0.85	1.00	0.91	0.91	1.00	1.00	1.00	1.00	0.89	0.89	1.00	1.00	1.00
Kibwezi_Makindu	0.51	0.92	0.47	0.62	1.00	0.62	0.60	0.94	0.56	0.53	0.98	0.52	0.69	1.00	0.69
Kikanamku	0.73	0.91	0.66	0.83	0.93	0.77	0.76	0.87	0.66						
Kikuyu	0.54	0.99	0.53	0.63	1.00	0.62	0.55	0.87	0.48	0.57	0.99	0.57	0.59	1.00	0.59
Kilifi_Mariakani	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	1.00	0.82	0.82
Kinja	1.00	0.38	0.38	1.00	0.56	0.56									
Kirinyaga	0.89	0.53	0.47	0.80	0.80	0.63	0.96	0.75	0.71	0.85	0.81	0.69	0.81	0.82	0.67
Kisumu	1.00	0.96	0.96	1.00	1.00	1.00	1.00	0.90	0.90	0.76	0.85	0.65	0.88	0.89	0.78
Kitui	0.53	0.85	0.45	0.72	1.00	0.72	0.65	0.97	0.63	0.57	0.99	0.56	0.62	0.98	0.60
Kwale	0.48	0.99	0.47	0.52	0.96	0.50	0.54	0.94	0.51	0.56	0.98	0.55	0.66	0.97	0.64
Kyeni	0.41	0.66	0.27	0.72	1.00	0.72	0.65	0.99	0.64	1.00	1.00	1.00	0.71	0.97	0.69
Lamu	0.61	0.91	0.56	0.56	0.99	0.55	0.54	0.95	0.51	0.57	0.92	0.53	0.54	0.99	0.53
Limuru	0.49	0.96	0.47	0.82	0.99	0.81	0.73	0.87	0.64	0.67	0.99	0.66	0.85	1.00	0.85
Lodwar	0.65	0.98	0.63	1.00	1.00	1.00	0.83	0.93	0.76	0.53	0.97	0.51	0.72	1.00	0.72
Machakos	0.70	0.98	0.69	0.66	0.97	0.64	0.62	0.87	0.54	0.62	0.99	0.62	0.87	1.00	0.86
Makindu	0.50	0.93	0.47												
Malindi	1.00	1.00	1.00	0.90	1.00	0.90	0.94	0.81	0.76	1.00	0.83	0.83	0.88	1.00	0.88
Mandera	0.88	1.00	0.88	1.00	1.00	1.00	1.00	1.00	1.00						
Maralal	0.40	0.81	0.32	0.44	0.95	0.42	0.40	1.00	0.40	0.47	0.58	0.27	1.00	0.28	0.28
Mathira	0.88	0.76	0.67	0.95	0.88	0.83	0.95	0.86	0.81	0.92	1.00	0.92	0.96	0.94	0.90
MatunguluKangundo	1.00	0.85	0.85				1.00	0.87	0.87	1.00	0.76	0.76	1.00	0.93	0.93
Mavoko	0.92	1.00	0.92	0.94	1.00	0.94	1.00	0.88	0.88	0.86	0.86	0.73	0.83	0.95	0.79
Mawingo	0.89	0.53	0.47	1.00	1.00	1.00	1.00	0.73	0.73	1.00	0.44	0.44			
Mbooni				0.77	0.84	0.65	0.63	0.73	0.46	0.80	0.28	0.22			
Meru	0.69	1.00	0.69	0.80	1.00	0.80	0.80	0.87	0.70	0.68	1.00	0.67	0.85	0.98	0.83
Mikutra	0.13	0.61	0.08	0.17	0.51	0.09	0.24	0.95	0.23	0.44	0.74	0.33	0.42	0.91	0.38
Mombasa	1.00	0.87	0.87	1.00	0.84	0.84	0.90	0.84	0.75	1.00	0.69	0.69	1.00	0.79	0.79
Moyale	0.7	0.1	0.0	0.4	0.7	0.3	0.7	0.4	0.3						

Year Efficiency (e: 0<e<1)	2011 TE	2011 SE	2011 OE	2012 TE	2012 SE	2012 OE	2013 TE	2013 SE	2013 OE	2014 TE	2014 SE	2014 OE	2015 TE	2015 SE	2015 OE
	4	2	9	2	2	1	7	3	3						
Murang'a_South	1.00	0.44	0.44	0.91	0.69	0.63	1.00	0.66	0.66	1.00	0.82	0.82	1.00	0.69	0.69
Murang'a	0.42	0.97	0.41	0.56	1.00	0.56	0.58	0.86	0.50	0.61	0.99	0.60	0.80	1.00	0.80
Murugi_Mugumango	0.59	1.00	0.59	1.00	1.00	1.00	1.00	1.00	1.00				1.00	1.00	1.00
Muthambi4K	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00						
Mwala	0.43	0.86	0.37	0.38	0.88	0.33	0.34	0.93	0.32	0.60	0.80	0.48			
Nairobi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Naivasha	0.56	0.78	0.44	0.59	0.87	0.51	0.80	0.99	0.80	0.75	0.99	0.74	0.81	1.00	0.81
Nakuru	0.92	0.92	0.85				0.88	0.88	0.77	0.90	0.92	0.83	1.00	1.00	1.00
Nakuru_Rural	1.00	0.69	0.69	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
Namanga							0.75	0.93	0.69	0.70	0.84	0.58			
Nanyuki	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.91	1.00	0.91	0.94	0.99	0.93
Narok	0.56	0.94	0.53	0.54	1.00	0.54	0.65	0.96	0.62	0.66	0.98	0.65	0.56	0.91	0.51
Ndaragwa	0.87	0.99	0.86	0.54	0.88	0.48	0.68	0.81	0.55				1.00	0.78	0.78
Ngagaka	0.67	1.00	0.67	0.82	0.96	0.79	0.70	0.96	0.67	0.68	0.99	0.67	0.77	0.99	0.76
Ngandori_Nginda	1.00	0.58	0.58	1.00	0.97	0.97	1.00	0.82	0.82	1.00	1.00	1.00			
Nithi	0.57	0.99	0.56	0.74	0.99	0.73	0.78	0.95	0.73	0.69	0.98	0.68	0.65	1.00	0.65
NolTuresh_Loitokitok	1.00	0.63	0.63	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nyahururu	0.50	1.00	0.50	0.67	1.00	0.67	0.62	0.87	0.54	0.94	1.00	0.93	0.79	1.00	0.79
Nyakanja	0.51	0.29	0.15	0.57	0.85	0.49	0.73	0.83	0.60				1.00	0.62	0.62
Nyanas	0.28	0.89	0.24	0.37	1.00	0.36	0.28	1.00	0.28						
Nyandarua	0.36	0.50	0.18	0.39	0.77	0.30	0.37	0.95	0.35	0.42	0.82	0.35	0.42	0.91	0.38
Nyasare	0.69	0.74	0.51	0.73	0.93	0.67	0.75	0.97	0.72				1.00	0.88	0.88
Nyeri	0.94	0.99	0.94	1.00	1.00	1.00	1.00	0.78	0.78	1.00	0.99	0.99	1.00	1.00	1.00
Nzoia	0.61	0.81	0.49	0.81	0.96	0.77	0.71	0.86	0.61	0.60	0.96	0.57	0.78	0.91	0.71
Olkalou	0.46	0.40	0.18	0.51	0.58	0.30	0.36	0.77	0.28	0.66	0.86	0.57	0.99	1.00	0.99
Olkejuado	0.37	0.78	0.29	0.62	0.70	0.43				0.72	0.42	0.30			
Oloolaiser	0.67	1.00	0.67	0.65	0.99	0.65	0.78	0.94	0.73	0.71	0.97	0.68	0.80	0.92	0.74
Othaya_Mukure	1.0	0.6	0.6	1.0	1.0	1.0				0.9	0.9	0.8	1.0	0.7	0.7

Year Efficiency (e: 0<e<1)	2011 TE	2011 SE	2011 OE	2012 TE	2012 SE	2012 OE	2013 TE	2013 SE	2013 OE	2014 TE	2014 SE	2014 OE	2015 TE	2015 SE	2015 OE
ini	0	1	1	0	0	0				0	1	2	0	5	5
Ruiri_Thau				1.00	1.00	1.00	1.00	1.00	1.00						
Ruiru_Juja	0.84	0.94	0.79	0.94	0.92	0.87	1.00	0.75	0.75	0.81	0.99	0.80	1.00	1.00	1.00
Rukanga							0.80	0.95	0.76	0.70	0.86	0.60	0.90	0.86	0.78
Rumuruti	0.91	0.27	0.25	1.00	0.31	0.31	0.92	0.40	0.37	1.00	0.37	0.37			
Runda	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sibo	0.38	0.99	0.38	0.64	0.94	0.60	0.54	0.92	0.50	0.47	0.99	0.47	0.45	0.99	0.44
South_Nyanza	0.34	0.71	0.24	0.36	0.95	0.34	0.36	0.93	0.34	0.36	0.96	0.34			
Tachasis	0.95	0.71	0.67	0.76	0.84	0.64	0.90	0.80	0.72	1.00	1.00	1.00	1.00	0.73	0.73
Tavevo	0.91	0.99	0.90	1.00	0.90	0.90	1.00	0.95	0.95	0.61	0.99	0.61	0.72	0.94	0.68
Tetu_Aberdare	0.41	1.00	0.40	0.58	0.96	0.56	0.58	0.90	0.53	0.65	0.98	0.63	0.71	0.99	0.71
Thika	0.70	0.90	0.63	0.88	0.95	0.84	0.85	0.93	0.79	0.84	0.93	0.78	0.87	0.98	0.85
Tia_Wira	1.00	0.60	0.60	0.99	0.54	0.54	0.84	0.62	0.52						
Tililbei				0.43	0.91	0.39	0.59	0.85	0.51	0.57	0.95	0.54	0.49	0.96	0.47
Tuuru	0.45	1.00	0.45	0.65	1.00	0.65	0.96	0.92	0.88	0.80	0.98	0.78	0.72	0.97	0.70
Upper Chania	1.00	1.00	1.00	1.00	1.00	1.00									
Wote	1.00	0.43	0.43	1.00	0.45	0.45	0.80	0.72	0.57	0.73	0.76	0.55			
Yatta	0.37	0.45	0.16	0.42	0.92	0.39	0.48	0.96	0.46	0.47	0.68	0.32			
Average	0.69	0.83	0.57	0.75	0.92	0.69	0.75	0.88	0.66	0.74	0.89	0.66	0.80	0.93	0.74
Standard deviation	0.24	0.20	0.24	0.21	0.13	0.22	0.21	0.12	0.20	0.19	0.15	0.20	0.17	0.12	0.17

3.2. Associating Efficiency with other Water Sector Performance Indicators

In the period 2011-2015 correlations of key performance indicators of the water sector with efficiency scores show mixed results (table 3). Water coverage, coverage of operations and maintenance costs (O&M), production per capita and consumption per capita have demonstrated consistence in significance of the degree of association with efficiency scores. Though significant, this relationship is moderate given that most of the correlations are not more than 50 percent, except for O&M coverage. Technical efficiency has positive correlation with water coverage ranging from 25 percent to 44 percent, while coverage of O&M costs (57 percent to 80 percent), production per capita (20 percent to 48 percent) and consumption per capita (14 percent to 39 percent). In other words, Water utilities with higher level of technical efficiency are also demonstrating potential to supply water to a large proportion of people within the surface area, recover costs incurred in operations and maintenance as well as produce enough water for distribution. It is evident that Water utilities with higher technical efficiency have higher metering ratio, with significant correlations ranging between 17 percent and 40 percent.

Table 3: Pearson Correlations of Efficiency with other Performance Indicators

	Constant Returns to Scale Technical Efficiency					Scale Efficiency					Variable Returns to Scale Technical Efficiency				
year	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
nrw	-0.19	0.11	0.13	0.30	-0.13	-0.11	0.13	-0.10	0.18	-0.14	-0.08	0.08	0.20	0.26	-0.04
Prob(sig)	0.07	0.28	0.21	0.01	0.27	0.31	0.20	0.36	0.10	0.22	0.44	0.46	0.06	0.02	0.71
prdcap	0.39	0.20	0.48	0.46	0.34	0.20	0.16	0.19	0.18	0.07	0.32	0.15	0.40	0.38	0.28
Prob(sig)	0.00	0.05	0.00	0.00	0.00	0.06	0.12	0.07	0.11	0.52	0.00	0.15	0.00	0.00	0.01
conscap	0.39	0.31	0.43	0.14	0.33	0.30	0.19	0.16	0.14	0.09	0.26	0.26	0.37	0.06	0.28
Prob(sig)	0.00	0.00	0.00	0.20	0.00	0.00	0.06	0.14	0.21	0.42	0.01	0.01	0.00	0.62	0.02
wcov	0.41	0.44	0.41	0.41	0.42	0.24	0.22	0.02	0.32	0.15	0.28	0.39	0.42	0.29	0.35
Prob(sig)	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.85	0.00	0.20	0.01	0.00	0.00	0.01	0.00
hrs	0.32	0.28	0.22	-0.28	0.36	0.20	0.13	-0.03	-0.33	0.16	0.24	0.27	0.25	-0.11	0.26
Prob(sig)	0.00	0.01	0.03	0.01	0.00	0.05	0.22	0.78	0.00	0.18	0.02	0.01	0.01	0.31	0.03
staffprd	-0.17	-0.32	-0.03	0.32	-0.44	-0.28	-0.27	-0.11	0.08	-0.28	-0.03	-0.22	0.01	0.34	-0.30
Prob(sig)	0.10	0.00	0.81	0.00	0.00	0.01	0.01	0.30	0.49	0.01	0.80	0.03	0.95	0.00	0.01
reveff	-0.13	0.02	-0.06	0.09	0.05	-0.04	0.09	-0.07	0.36	-0.05	-0.09	0.00	-0.02	-0.17	0.09
Prob(sig)	0.23	0.82	0.55	0.44	0.65	0.73	0.37	0.48	0.00	0.66	0.39	0.97	0.85	0.13	0.45
omcov	0.79	0.80	0.69	0.77	0.80	0.54	0.44	0.19	0.52	0.30	0.57	0.68	0.62	0.57	0.65
Prob(sig)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.00
meter	0.40	0.14	0.07	0.24	0.27	0.48	0.10	0.32	0.42	0.19	0.09	0.12	-0.10	-0.02	0.17
Prob(sig)	0.00	0.22	0.50	0.03	0.02	0.00	0.39	0.00	0.00	0.12	0.41	0.30	0.32	0.88	0.16
conndens	-0.03	-0.11	-0.02	-0.12	-0.17	-0.04	0.03	0.09	0.06	0.07	-0.02	-0.13	-0.06	-0.14	-0.21
Prob(sig)	0.7610	0.2643	0.8379	0.2814	0.1551	0.6690	0.8014	0.4112	0.6042	0.5566	0.8343	0.2022	0.5718	0.1927	0.0747

	Constant Returns to Scale Technical Efficiency					Scale Efficiency					Variable Returns to Scale Technical Efficiency				
year	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015

Key: Nonrevenue water (nrw); Production per capita (prdcap); Consumption per Capita (conscap); Water coverage (wcov); Hours of Supply (hrs); Staff productivity (staffprd); Revenue collection efficiency (reveff); Operations and maintenance coverage(omcov); Metering ratio (meter); and Connections density (conndens)

The relationship between efficiency and water losses (nonrevenue water) is not conclusive since it has both positive and negative correlations, but a large proportion of the results indicate that more efficient firms are also losing more water, an indication that minimizing nonrevenue water can spur more growth in the sector. However, it is also noted that higher technical efficiency is not correlated with revenue collection efficiency. The negative correlation between technical efficiency and staff productivity shows that more efficient Water utilities have fewer members of staff per 1000 connections, which shows greater staff productivity. The analysis indicates that production per capita, consumption per capita, water coverage and coverage of O&M costs move together with scale efficiency, recording correlations ranging from (16 to 20), (16 to 30), (22 to 32) and (19 to 54) respectively. It is also noted that with significant positive correlation (19 to 48 percent), the utilities higher scale efficiency is able to register higher metering ratio. In addition, higher scale efficiency is associated with higher staff productivity, since the correlation between scale efficiency and number of staff per 1000 connections is negative.

The analysis also counterchecked the indications of Pearson's correlations (table 3) with Spearman's rank correlations (table 4) to ascertain whether efficiency ranking has a relationship with ranking of the utilities on other performance indicators. It was noted that, Water utilities which have higher technical efficiency also rank highly in terms of water coverage, coverage of operations and maintenance costs, production per capita, consumption per capita and metering ratio. The coefficients of correlation were water coverage (28 percent to 48 percent), coverage of operations and maintenance costs (56 percent to 81 percent), production per capita (20 percent to 46 percent), consumption per capita (24 percent to 44 percent) and metering ratio (15 percent to 43 percent), over the period (24 percent to 48 percent). The rank of Water utilities based on nonrevenue water compared to that of technical efficiency is not conclusive, since it has mixed signs of correlation coefficients (negative and positive). However, in some years the correlations were not significant (table 4).

Water utilities operating at or near full potential (with higher scale efficiency) rank lower in terms of staff per 1000 connections which means they have higher staff productivity, and higher in O&M coverage, water coverage, production per capita and consumption per capita (table 4). Scale efficiency has mixed relationship with hours of supply, due to both negative and positive correlations (table 4).

It is important to assess whether the levels of efficiency are associated with area, technological orientation, region and size. The difference in technical efficiency is significant across regions (table 5). Athi, Tana and the Coast regions lead in terms of technical efficiency while the Lake Victoria South region lags behind. However, the Coast region is on a declining trend on overall efficiency, due to scale inefficiency which is diminishing. The other regions perform moderately (figures 6-8). Regional efficiency may be affected by water resource availability, but this not always the case. Kenya is divided into six water catchment areas whose estimated water availability is at 22.6 billion M3 per year as estimated in the National Water Master Plan 2030 (Water Resources Management Authority, 2013). Tana basin which serves Tana region has the highest share of 29 per cent thus as expected Tana registered high efficiency. Though Athi basin has the lowest share of water resource (7 percent) its utilities recorded relatively high efficiency, competing with Tana region. Lake Victoria South should have performed better in terms of efficiency since it ranks second on water availability with 22 percent share. Northern region is largely served by Ewaso Ng'iro performed moderately above the expectation of its low share of 10 percent on available water, this was better performance compared to Lake Victoria North and Rift Valley which had 21 percent and 11 percent share of water availability respectively. Tanathi region is served partly by Tana and Athi basins and its performance in efficiency below the expectation.

Table 4: Spearman Rank Correlations of Efficiency with other Performance Indicators

	Constant Returns to Scale Technical Efficiency					Scale Efficiency					Variable Returns to Scale Technical Efficiency				
year	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
nrw	-0.20	0.18	0.08	0.27	-0.19	-0.15	0.11	0.02	0.17	-0.39	-0.15	0.12	0.08	0.24	-0.05
Prob (sig)	0.06	0.15	0.44	0.01	0.11	0.18	0.37	0.85	0.12	0.00	0.16	0.32	0.48	0.03	0.67
prdcap	0.41	0.46	0.40	0.44	0.20	0.21	0.29	0.13	0.20	-0.01	0.31	0.36	0.34	0.39	0.21
Prob (sig)	0.00	0.00	0.00	0.00	0.10	0.06	0.02	0.22	0.07	0.93	0.00	0.00	0.00	0.00	0.09
conscap	0.44	0.44	0.35	0.33	0.25	0.28	0.28	0.04	0.18	0.12	0.26	0.34	0.30	0.28	0.24
Prob (sig)	0.00	0.00	0.00	0.00	0.03	0.01	0.02	0.71	0.11	0.31	0.02	0.00	0.00	0.01	0.04
wcov	0.43	0.48	0.40	0.38	0.50	0.36	0.24	-0.10	0.30	0.25	0.28	0.45	0.42	0.28	0.39
Prob (sig)	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.34	0.01	0.04	0.01	0.00	0.00	0.01	0.00
hrs	0.39	0.41	0.20	-0.39	0.36	0.21	0.19	-0.23	-0.35	0.09	0.26	0.34	0.24	-0.26	0.25
Prob (sig)	0.00	0.00	0.06	0.00	0.00	0.05	0.12	0.03	0.00	0.45	0.02	0.00	0.03	0.02	0.03
staffprd	-0.37	-0.43	-0.24	0.33	-0.45	-0.26	-0.23	0.27	0.20	-0.33	-0.23	-0.32	-0.29	0.34	-0.33
Prob (sig)	0.00	0.00	0.02	0.00	0.00	0.02	0.06	0.01	0.08	0.00	0.04	0.01	0.01	0.00	0.00
reveff	-0.09	0.03	-0.27	0.02	0.05	-0.03	0.07	-0.02	-0.05	0.08	-0.08	0.04	-0.19	-0.06	0.06
Prob (sig)	0.44	0.83	0.01	0.84	0.67	0.76	0.58	0.84	0.68	0.49	0.46	0.77	0.07	0.62	0.63
omcov	0.81	0.81	0.71	0.75	0.80	0.49	0.49	-0.08	0.51	0.26	0.56	0.69	0.68	0.58	0.66
Prob (sig)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.03	0.00	0.00	0.00	0.00	0.00
meter	0.44	0.11	0.18	0.14	0.35	0.53	0.15	0.07	0.08	0.39	0.15	0.06	0.13	0.02	0.20
Prob (sig)	0.00	0.36	0.09	0.23	0.00	0.00	0.21	0.50	0.45	0.00	0.17	0.62	0.22	0.89	0.09
conndens	-0.21	-0.10	-0.03	-0.10	-0.14	-0.18	-0.04	0.15	-0.06	-0.06	-0.11	-0.05	-0.03	-0.08	-0.12
Prob	0.05	0.33	0.76	0.36	0.23	0.08	0.72	0.14	0.60	0.59	0.28	0.62	0.77	0.46	0.31

(sig)

Key: Nonrevenue water (nrw); Production per capita (prdcap); Consumption per Capita (conscap); Water coverage (wcov); Hours of Supply (hrs); Staff productivity (staffprd); Revenue collection efficiency (reveff); Operations and maintenance coverage(omcov); Metering ratio (meter); and Connections density (conndens)

Table 5: Assessing Mean Difference in Efficiencies by Region

Region	n	n	n	n	n	OE	OE	OE	OE	OE	SE	SE	SE	SE	SE	TE	TE	TE	TE	TE
Year	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Athi	13	15	15	13	12	0.67	0.78	0.75	0.77	0.85	0.95	0.95	0.90	0.97	0.98	0.71	0.82	0.83	0.79	0.86
Coast	6	7	6	6	6	0.80	0.79	0.75	0.67	0.72	0.96	0.96	0.92	0.87	0.92	0.83	0.83	0.82	0.79	0.80
LVN	6	7	7	7	7	0.46	0.62	0.65	0.67	0.70	0.73	0.92	0.89	0.89	0.91	0.64	0.68	0.74	0.73	0.78
LVS	9	9	9	7	8	0.41	0.52	0.50	0.48	0.60	0.85	0.91	0.92	0.92	0.95	0.47	0.55	0.54	0.52	0.63
Northern	9	9	9	6	5	0.57	0.61	0.57	0.63	0.69	0.78	0.89	0.81	0.81	0.82	0.74	0.69	0.73	0.78	0.87
Riftvalley	16	16	15	10	10	0.53	0.63	0.63	0.60	0.70	0.73	0.85	0.86	0.85	0.90	0.72	0.74	0.73	0.71	0.77
Tana	22	23	21	19	19	0.60	0.81	0.74	0.77	0.78	0.86	0.96	0.89	0.95	0.92	0.71	0.85	0.83	0.81	0.85
Tanathi	13	12	14	15	8	0.53	0.61	0.61	0.57	0.76	0.81	0.89	0.88	0.80	0.97	0.66	0.69	0.70	0.72	0.79
Between groups	(Prob > F)					0.04	0.00	0.02	0.01	0.07	0.05	0.25	0.56	0.04	0.26	0.10	0.01	0.02	0.05	0.11
Bartlett's test for equal variances	chi2(7)					6.13	8.33	4.53	7.10	13.75	39.19	30.69	24.59	50.38	42.35	1.22	6.30	3.59	3.20	5.88
	Prob>chi2					0.52	0.31	0.72	0.42	0.06	0.00	0.00	0.00	0.00	0.00	0.99	0.51	0.83	0.87	0.55

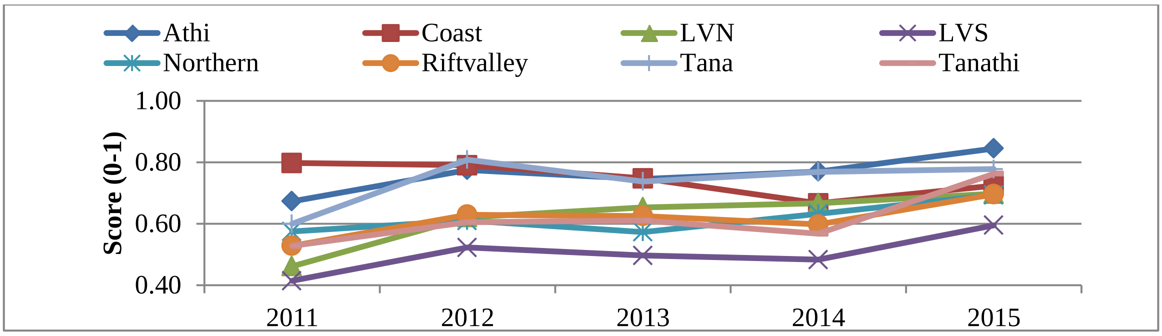

Figure 6: Trends of Overall Efficiency by Region of utilities

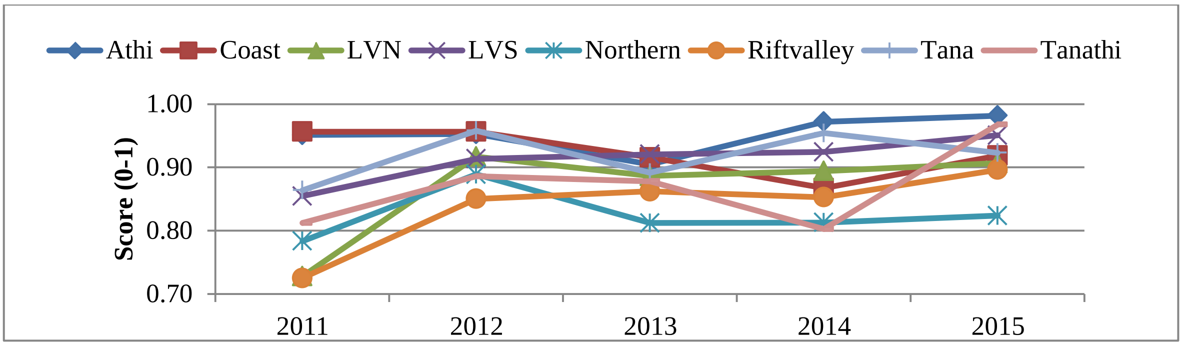

Figure 7: Trends of Scale Efficiency by Region of utilities

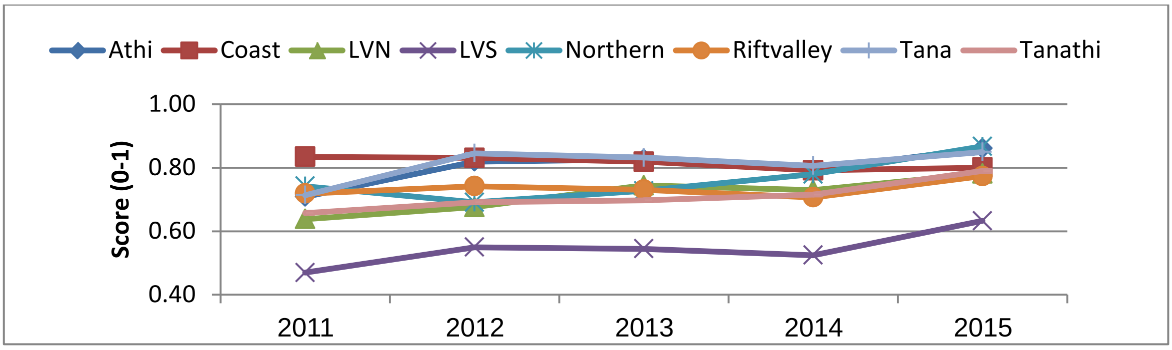

Figure 8: Trends of Technical Efficiency by Region of utilities

There is significant relationship between levels of efficiency and size of the water utility, the difference in their average means significantly vary (table 6). Large sized utilities are relatively most efficient, followed by medium and small sized respectively, however the medium utilities seem to be operating at full capacity than large utilities thus overstretched which stresses the need for expansion (figures 9-11). This means that large sized utilities are able to enjoy economies of scale, because if their size but Medium sized utilities are constrained by resources since they operate near maximum capacity and given their scale efficiency. Small utilities are constrained by both technical and utilization of existing capacity. It is therefore prudent to scale up the utilities especially by encouraging mergers for those utilities sharing water basins, thus their service areas can easily be integrated.

Table 6: Assessing Mean Difference in Efficiencies by Size

Size	n	n	n	n	n	OE	OE	OE	OE	OE	SE	SE	SE	SE	SE	TE	TE	TE	TE	TE
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Large	30	32	30	31	30	0.65	0.78	0.70	0.75	0.78	0.88	0.95	0.87	0.94	0.93	0.75	0.82	0.81	0.81	0.85
Medium	22	22	22	22	21	0.56	0.70	0.69	0.71	0.75	0.91	0.97	0.92	0.98	0.97	0.62	0.73	0.75	0.73	0.78
Small	42	44	44	30	24	0.52	0.62	0.62	0.53	0.68	0.76	0.86	0.88	0.79	0.89	0.68	0.71	0.71	0.69	0.77
Between groups	(Prob > F)					0.07	0.01	0.13	0.00	0.10	0.01	0.00	0.31	0.00	0.06	0.16	0.08	0.13	0.04	0.21
Bartlett's test for equal variances	chi2(7)					6.25	8.04	5.55	2.23	7.03	11.86	66.38	30.89	63.49	27.35	1.89	6.79	3.99	0.86	0.21
	Prob>chi2					0.04	0.02	0.06	0.33	0.03	0.00	0.00	0.00	0.00	0.00	0.39	0.03	0.14	0.65	0.10

Source: Author

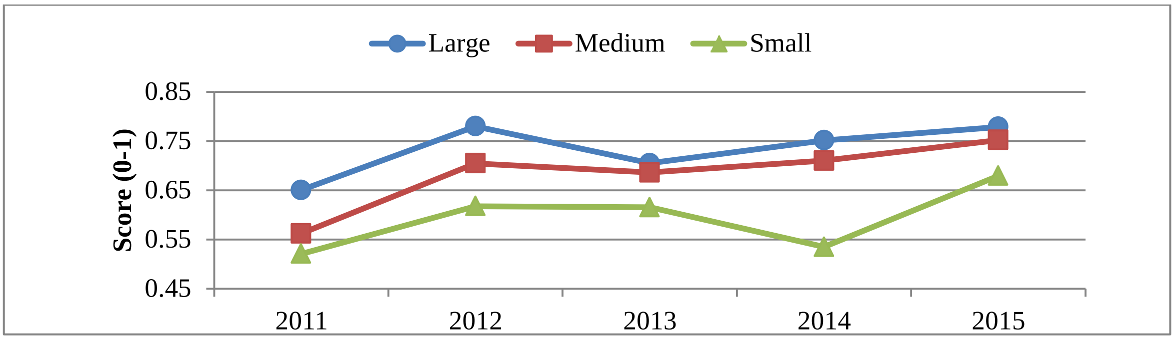

Figure 9: Trends of Overall Efficiency by Size of Utilities

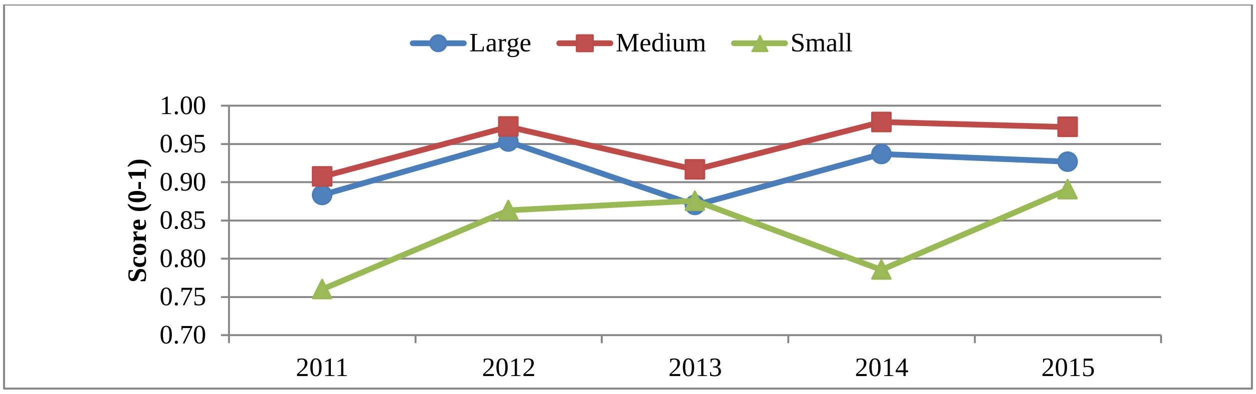

Figure 10: Trends of Scale Efficiency by Size of Utilities

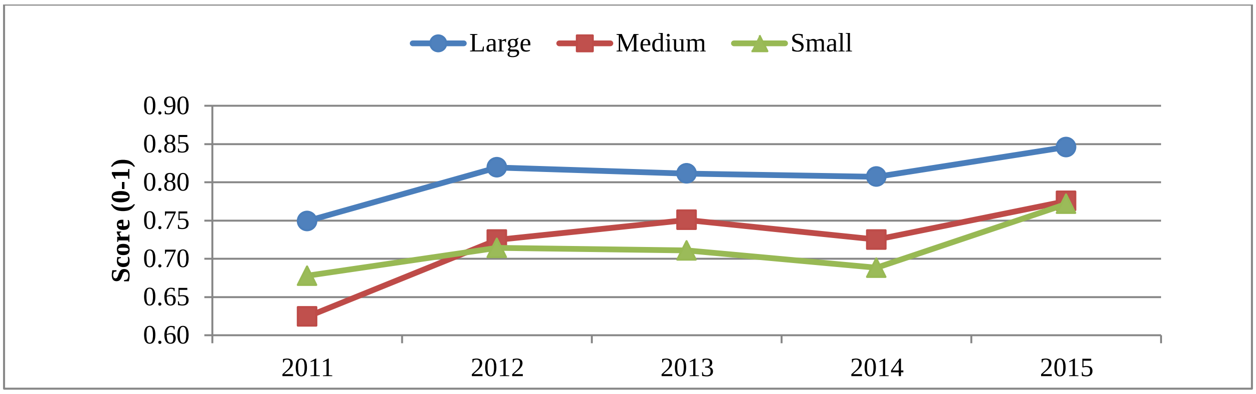

Figure 11: Trends of Technical Efficiency by Size of Utilities

It is also observed that rural utilities are more efficient that urban utilities (table 7). Rural utilities maintained higher averages in technical efficiency than the urban utilities, but they have challenges with scale efficiency, which scales down their overall efficiency, however urban utilities seem to be overstretched in terms of scale since they are performing at the frontier (figures 12-14).

This is against the expectations since urban utilities are more endowed in terms of skills and resources. Urban utilities by nature of establishment and capacity can attract high skilled workforce and adopt modern technologies in the water value chain (production, storage and distribution). However, it points out that resource wastage may be higher in urban than rural utilities, especially due to dynamics of corporate governance.

Rural utilities are largely run as community projects; thus their management is sensitive to the vigilance of the community. On the other hand, urban utilities tend to be dissociated from public vigilance because of free-rider problem, information asymmetry and principle agent problem.

In addition, the urban utilities peg their corporate compliance to public institutions governing the water sector and these institutions may lack the necessary Authority and capacity to enforce corporate governance principles.

Table 7: Assessing Mean Difference in Efficiencies between Rural and Urban

Area		n	n	n	n	n	OE	OE	OE	OE	OE	SE	SE	SE	SE	SE	TE	TE	TE	TE	TE
Year		2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Rural		30	34	32	22	20	0.58	0.74	0.68	0.71	0.73	0.81	0.91	0.86	0.89	0.89	0.72	0.81	0.80	0.80	0.83
Urban		64	64	64	61	55	0.57	0.67	0.65	0.64	0.74	0.84	0.92	0.89	0.89	0.94	0.67	0.72	0.73	0.72	0.79
diff = mean(rural) - mean(urban)	t-value						-0.25	1.53	0.85	1.33	-0.25	-0.68	-0.54	-1.21	-0.14	-1.73	1.01	2.23	1.47	1.80	0.94
	Pr(T < t); diff<0						0.57	0.94	0.80	0.91	0.40	0.25	0.29	0.12	0.44	0.04	0.84	0.99	0.93	0.96	0.82
	Pr(|T| > |t|) =0						0.86	0.13	0.40	0.19	0.81	0.50	0.59	0.23	0.89	0.09	0.32	0.03	0.14	0.08	0.35
	Pr(T > t)>0						0.43	0.06	0.20	0.09	0.60	0.75	0.71	0.89	0.56	0.96	0.16	0.01	0.07	0.04	0.18

Source: Author.

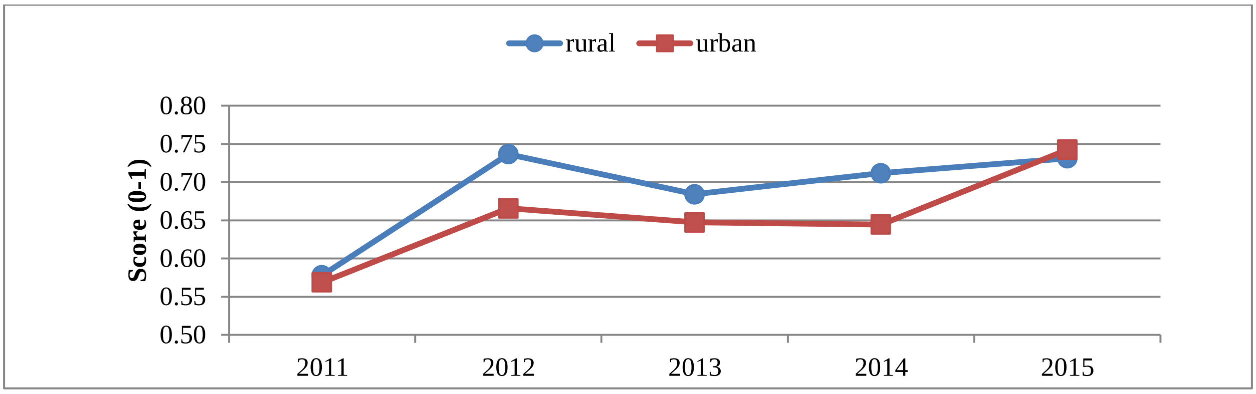

Figure 12: Trends of Overall Efficiency by rural and urban utilities

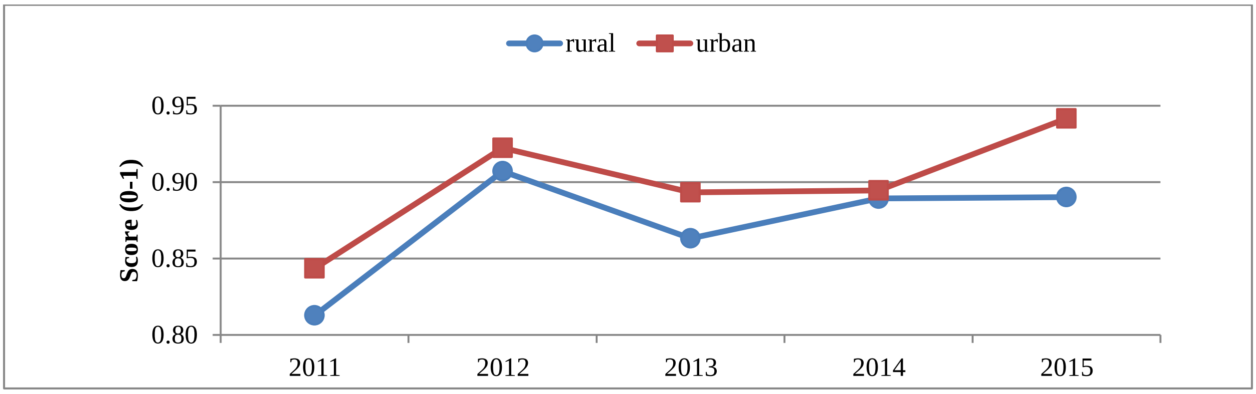

Figure 13: Trends of Scale Efficiency by rural and urban utilities

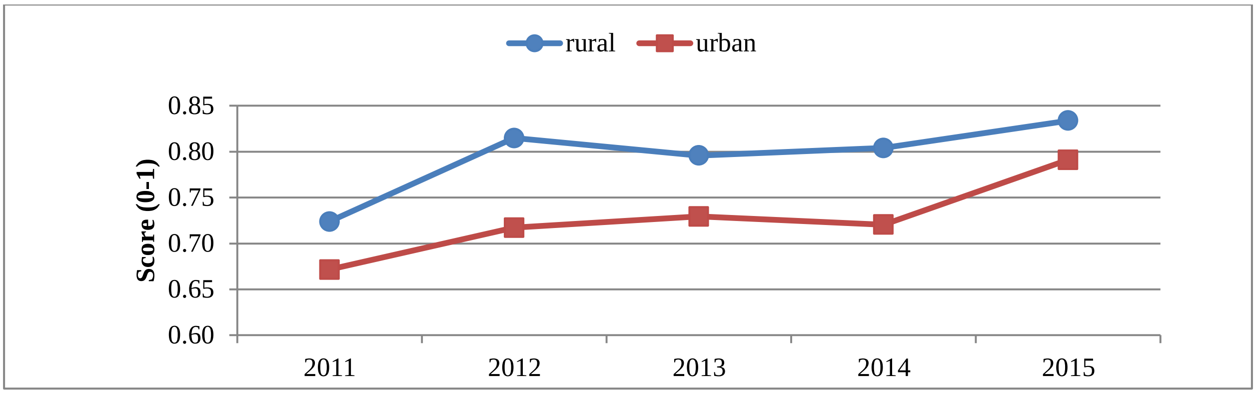

Figure 14: Trends of Technical Efficiency by rural and urban utilities

Table 8: Assessing Mean Difference in Efficiencies by Technological Orientation

Technology		n 2011	n 2012	n 2013	n 2014	n 2015	OE 2011	OE 2012	OE 2013	OE 2014	OE 2015	SE 2011	SE 2012	SE 2013	SE 2014	SE 2015	TE 2011	TE 2012	TE 2013	TE 2014	TE 2015
Composite (Water and Sewer services)		28	28	29	29	28	0.64	0.77	0.72	0.72	0.81	0.89	0.96	0.89	0.96	0.96	0.72	0.80	0.81	0.76	0.85
Specialized (Water Only)		47	47	67	54	47	0.54	0.66	0.63	0.63	0.70	0.81	0.90	0.88	0.86	0.91	0.68	0.73	0.73	0.73	0.78
diff = mean(Composite) - mean(specialized)	t-value						1.91	2.47	1.97	2.05	3.07	1.88	2.33	0.27	2.82	1.96	0.75	1.56	1.84	0.61	1.79
	Pr(T < t); diff<0						0.97	0.99	0.97	0.98	1.00	0.97	0.99	0.61	1.00	0.97	0.77	0.94	0.97	0.73	0.96
	Pr(|T| > |t|) =0						0.06	0.02	0.05	0.04	0.00	0.06	0.02	0.79	0.01	0.05	0.46	0.12	0.07	0.55	0.08
	Pr(T > t)>0						0.03	0.01	0.03	0.02	0.00	0.03	0.01	0.39	0.00	0.03	0.23	0.06	0.03	0.27	0.04

Technological orientation between composite utilities and specialized utilities are bound to differ, and the same is expected of technical efficiency. Composite utilities offer both water and sewerage services while specialized offer water service only. The null hypothesis that the difference between the two groups is statistically insignificant is rejected (table 8). On average composite utilities operated at higher efficiency level than specialized WSPs, both at technical and scale level (figures 15-17). It can be argued that the size of the utility may have correlation with status of technological orientation, thus influence efficiency more than technological orientation. Notwithstanding, that sewer collection and treatment is an expensive technology which would have been expected to cause some productive inefficiencies. Composite utilities would have been expected to use more inputs than specialized relative to revenue collection since the sewer services are not optimally priced, though they receive subsidies. This contradicted the expectation that specialization necessitates effective and efficient use of resources.

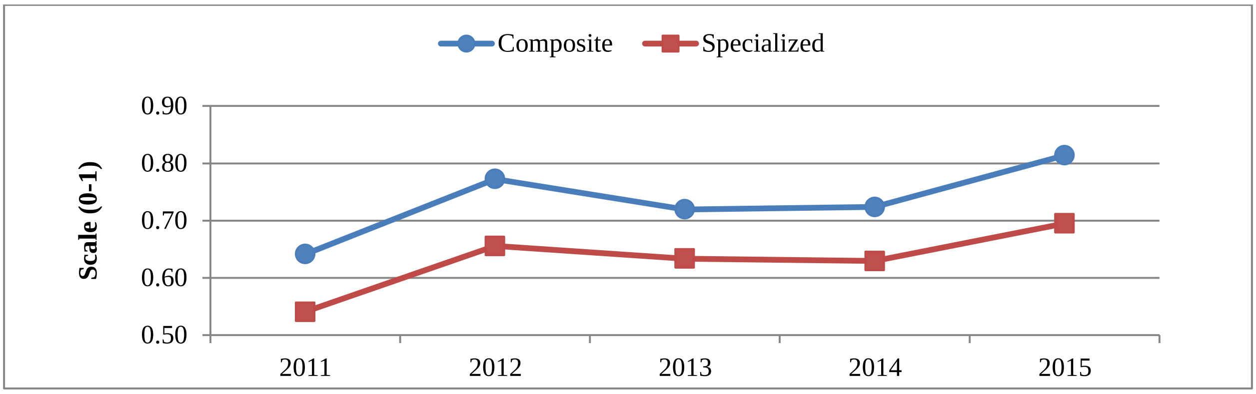

Figure 15: Trends of Overall Efficiency by technological orientation of the utilities

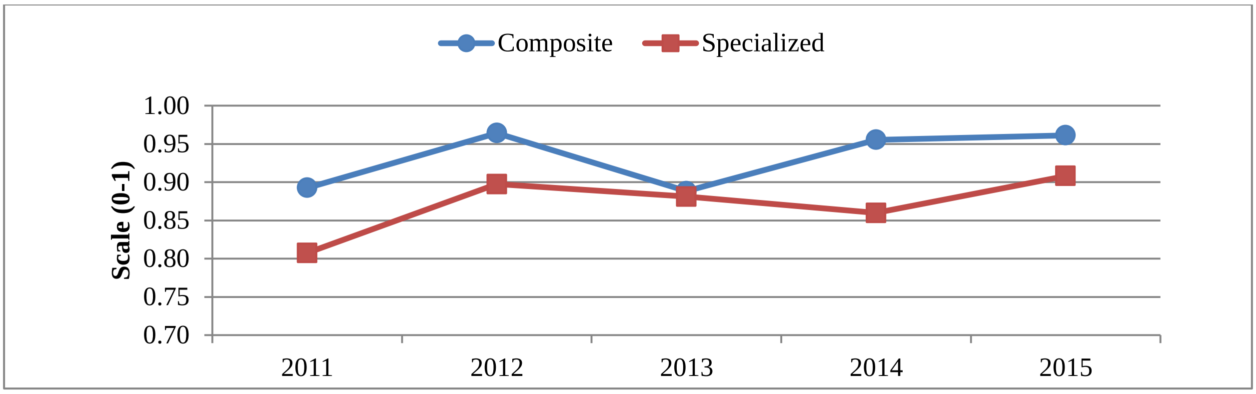

Figure 16: Trends of Scale Efficiency by technological orientation of the utilities

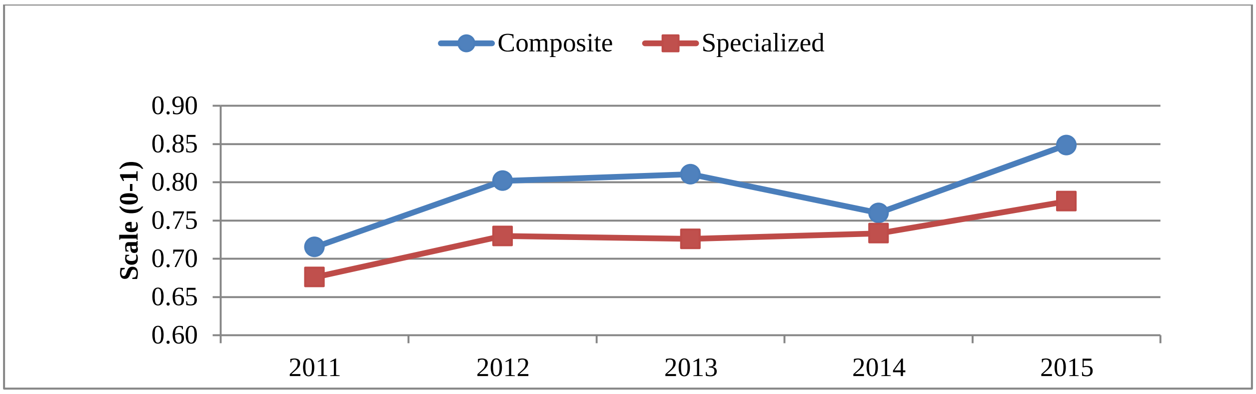

Figure 17: Trends of Technical Efficiency by technological orientation of the utilities

4. Discussion

Improvement on productive efficiency has potential of increasing production, revenue generation and service delivery without any additional resources. It is therefore, necessary for utilities to embark on measures that can minimize inputs as output increases. Such measures may require change in technologies applied towards those which use less inputs. Nevertheless, the sector registered steady improvement in efficiency over time as witnessed through average scores, promising improved water service delivery in future if the trend is sustained. Various factors are associated with overall productivity or efficiency of a water utility. These ranges from geographical features, scale of operation, quality of metering ratio, productivity of staff, revenue collection strategies, and customer concentration and network load.

5. Conclusion

It is important for regulators to trace productive efficiency of firms in their sectors. Productive efficiency requires that firms use resources and capacity optimally. This is a case expected of the water sector in Kenya following the policy and regulatory framework. The study established that in the period 2011-2015 the water utilities in Kenya operated at 66 percent productive efficiency, being a product of 75 percent technical efficiency weighed down by scale inefficiencies (11 percent). This implies that productive inefficiency contributed to over 34 percent of low performance of the water utilities in the various key performance indicators assessed by the Water Service Regulatory Board. Productive efficiency varies significantly across the utilities, as evidenced by high standard deviations of efficiency scores. Higher productive efficiency was associated with rural utilities, large utilities, higher O+M coverage, higher production per capita, higher staff productivity. However, the degree of association is moderate in these indicators indicating that there exist operational factors that distort the strong correlation as expected. In view of the performance of the sector with respect to productive efficiency interventions are critical. This is expected to boost the policy framework on improving performance of the utilities with respect to resource and capacity utilization. There has been high correlation among the targeted indicators for the following policy recommendations.

- Water utilities should expand and fully utilize the existing capacity, and to consider mergers of water utilities in the same region. This is because large Water utilities had higher efficiency than medium and small size Water utilities. It was also observed that scale inefficiency reduced the effect of technical efficiency.
- Capacity building among Lake Victoria South utilities is also critical. This will need also peer learning from the other utilities in other regions, since they lag, and the prevailing technology of production and operations are the same.
- Focus should be on both functionality of meters and increasing metering ratio. This is due to the inconsistent relationship of metering ratio with productive efficiency.
- Increase investment in production of more water and increase connections by the water utilities with low per capita production. This is because per capita production had positive relationship on efficiency.

References

[1]. Fried, H. O., Lovell, C. A., & Schmidt, S. S. (2008). Efficiency and Productivity. In H. O. Fried, C. A. Lovell, & S. S. Schmidt, The Measurement of Productive Efficiency and Productivity Growth (pp. 2-

92). Oxford University Press.

[2]. Berg, C., & Danilenko, A. (2011). The IBNET Water Supply and Sanitation Blue Book: The International Benchmarking Network for Water and Sanitation Utilities Databook. The World Bank.

[3]. Berg, S., & Marques, R. C. (2010). Quantitative Studies of Water and Sanitation Utilities: a Literature Survey. Florida: MPRA, http://mpra.ub.uni-muenchen.de/32891/.

[4]. National Counci for Law Reporting Kenya Law Report. (2012). Laws of Kenya Water Act Chapter 372. Nairobi: National Council for Law Reporting with the Authority of the Attorney-General; http://www.kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/WaterActNo8of2002.pdf .

[5]. Kenya Law Reform Commission. (2016). Water Act 2016. KLRC. http://www.kenyalaw.org/lex//actview.xql?actid=No.%2043%20of%202016 .

[6]. Water Service Regulatory Board (WASREB). (2009b). Water Service Regulations. Nairobi: Water Service Regulatory Board (WASREB).

[7]. Water Service Regulatory Board (WASREB). (2009c). Tariff Guidelines. Nairobi: Water Service Regulatory Board.

[8]. Water Service Regulatory Board (WASREB). (2012-16). Impact 5-9 : A Performance Review of Kenya’s Water Services Sector 2011 - 2015. Nairobi: Water Service Regulatory Board (WASREB).

[9]. United Nations Children’s Fund (UNICEF). (2014). Water & Sanitation Hygiene. Retrieved Sep 15, 2014, from Kenya-UNICEF: http://www.unicef.org/kenya/wes.html

[10]. UN-Water World Water Assessment Programme. (2006). Kenya Water Development Report: Prepared for the 2nd UN World Water Development Report ‘Water: A shared responsibility’. UN-Water.

[11]. World Health Organization (WHO). (2014). Preventing Diarrhoea through Better Water, Sanitation and Hygiene: Exposures and Impacts in Low and Middle Income Countries. World Health Organization.

[12]. Ministry of Water and Irrigation, MWI. (2007). National Water Service Strategy (2007-2015). Nairobi: Ministry of Water and Irrigation of the Government of the Republic of Kenya.

[13]. Government of the Republic of Kenya. (2013). Second Medium Term Plan, 2013 – 2017; Transforming Kenya: Pathway to Devolution, Socio-Economic Development, Equity and National Unity. Nairobi: Government of the Republic of Kenya.

[14]. Coelli, J. T., Rao, P. D., Donnel, C. J., & Battese, G. E. (2005). An Introduction to Efficiency and Productivity Analysis. New York: Springer.

[15]. Diewert, E, & Lawrence, D., (1999). Measuring New Zealand’s Productivity; Treasury Working Paper. Reserve Bank of New Zealand and The Treasury.

[16]. Koopmans, T. C. (1951). An Analysis of Production as an Efficient Combination of Activities. in Activity Analysis of Production and Allocation Ed. by Tjalling Charles Koopmans. New York.

[17]. Debreu, G. (1951). The Coefficient of Resource Utilization. Econometrica: The Econometric Society , Vol. 19, No. 3, pp. 273-292.

[18]. Farrell, M. J. (1957). The Measurement of Productive Efficiency. Journal of Royal Statistical Society. , Series a (General). Vol. 120, NO.3, pp. 253-290.

[19]. Leibenstein, H. (1966). Allocative Efficiency vs. "X-Efficiency". American Economic Review, Vol. 56, Issue 3, pp 392-415.

[20]. Leibenstein, H. (1979). X-Efficiency: From Concept to Theory. Challenge, Vol. 22, No.4, pp 13-22.

[21]. Porcelli, F. (2009). Measurement of Technical Efficiency: A brief survey on parametric and non-parametric techniques. Research Gate.

[22]. Salim, R. A. (2006). Measuring Productive Efficiency Incorporating Firms' Heterogeneity: An Empirical Analysis. Journal of Economic Development. 31(1) 135 – 147.

[23]. International Benchmarking Network for Water and Sanitation Utilities, IBNET. (2005). Benchmarking Methodologies Checklist. Retrieved September 4, 2014, from https://www.ib-net.org/en/texts.php?folder_id=118

[24]. Storto, C. L. (2013). Are Public-Private Partnerships a Source of Greater Efficiency in Water Supply? Results of a Non-Parametric Performance Analysis Relating to the Italian Industry. Multidisciplinary Digital Publishing Institute Water Journal, Vol 5. pp. 2058-2079.

[25]. Nourali, A. E., Davoodabadi, M., & Pashazadeh, H. (2014). Regulation and Efficiency & Productivity Considerations in Water & Wastewater Industry: Case of Iran. 2nd World Conference On Business, Economics And Management. 109, pp. 281 – 289. Procedia - Social and Behavioral Sciences.

[26]. Mahmoud, M. J., Bahram, F., Sajadifar, H., & Shahsavari, A. (2012). Measuring Efficiency of Water and Wastewater Company: A DEA Approach. Research Journal of Applied Sciences, Engineering and

[27]. Cunningham, M. B. (2013). Productivity Benchmarking the Australian Water Utilities. Economic Papers, Vol. 32(2), pp 174–189.

[28]. Zschille, M., & Walter, M. (2011). The Performance of German Water Utilities: A (Semi)-Parametric Analysis. Berlin: Discussion Papers No. 1118, German Institute for Economic Research.

[29]. Zschille, M. (2012). Consolidating the Water Industry: An Analysis of the Potential Gains from Horizontal Integration in a Conditional Effi ciency Framework. Berlin: German Institute for Economic Research.

[30]. Cruz, N. F., Marques, R. C., Romano, G., & Guerrini, A. (2012). Measuring the efficiency of water utilities: a cross-national comparison between Portugal and Italy. IWA Publishing Water Policy, Vol 14, No. 5, pp. 841.

[31]. Bottasso, A., & Conti, M. (2003). Cost Inefficiency in the English and Welsh Water Industry: An Heteroskedastic Stochastic Cost Frontier Approach. University of Essex; http://www.essex.ac.uk/economics/discussion-papers/papers-text/dp573.pdf.

[32]. Worthington, A. C. (2011). Efficiency, technology, and productivity change in Australian urban water utilities. Australia: Griffith University.

[33]. Estache, A., & Kouassi, E. (2002). Sector Organization, Governance, and the Inefficiency of African Water Utilities . World Bank Policy Research Working Paper 2890.

[34]. Mugisha, S. (2013). Technical Inefficiency Effects in a Stochastic Production Function for Managerial Incentives in Public Water Utilities. IWA Publishing Water Science & Technology: Water Supply, Vol 14 No 1 pp 61–72.

[35]. Coelli, T., & Reynaud, S. (2005). Performance Measurement in the Australian Water Supply Industry. Centre for Efficiency and Productivity Analysis.

[36]. Fraquelli, G., & Moiso, V. (2005). Cost Efficiency and Economies Of Scale in the Italian Water Industry. Italian Society of Public Economics, Department of Public Economy and Territorial - University of Pavia.

[37]. Lannier, A. L., & Porcher, S. (2013). Efficiency in the Public and Private French Water Utilities: Prospects for Benchmarking. Discussion Paper Series, Economics of Public-Private Partnerships Chair (EPPP) IAE Sorbonne Business School, pp. EPPP DP No. 2013-01 .

[38]. Correia, T. A. (2008). Efficiency of Water and Sewerage Services in Portugal ; Application of Stochastic Frontier Analysis. Tecnico.Ulisboa .

[39]. Hon, Y, L, & Lee, C., (2009). Efficiency Efficiency in the Malaysian Water Industry: A DEA and Regression Analysis; University of Nottingham. Selangor Darul Ehsan, Malaysia.

[40]. Parker, D., Kirkpatrick, C., & Zhang, Y.-F. (2006). State versus Private Sector Provision of Water Services in Africa: an Empirical Analysis. The World Bank Economic Review, 20(1), p. 143.

[41]. Pascoe, S., Kirkley, J. E., Greboval, D., & Morrison-Paul, D. J. (2003). Measuring and Assessing capacity in Fisheries. Rome: Food and Agriculture Organization of the United Nations.

[42]. Charnes, A., Cooper, W. W., & Rhodes, A. (1978). Measuring the Efficiency of Decision Making Units. European Journal of Operational Research, Vol.2, pp.429-444.

[43]. Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, Vol.30(No. 9), pp.1078-1092.