Kurdish Studies
May 2024
Volume: 12, No: 4, pp. 1353-1360
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

DOI: 10.53555/ks.v12i4.3158

Examining the Relationship between Dynamic Investment decisions and Technical Efficiency of Electricity Distribution Companies: A Case Study of Pakistan

Iqra Mushtaq[1]*, Abre-Rehmat Qurat-ul-Ann[2], Sidra Mushtaq[3], Faisal Mehmood Mirza[4],

[1*]Department of Economics, Government College Women University Sialkot, iqra.mushtaq@gcwus.edu.pk
[2]Department of Economics, University of Gujrat, abre.rehmat@uog.edu.pk
[3]Department of Economics, University of Gujrat, sidra.mushtaq@uog.edu.pk
[4]Dean, Faculty of Social Science, University of Gujrat, faisal.mirza@uog.edu.pk

***Corresponding Author**: Iqra Mushtaq
*Department of Economics, Government College Women University Sialkot, iqra.mushtaq@gcwus.edu.pk

Abstract

This study examines the relationship between investment and technical efficiency of distribution utilities in Pakistan from 2006 to 2020. Stochastic Frontier Analysis is used to predict technical efficiency score of distribution utilities in Pakistan. In the second-stage, Pooled OLS is employed to examine the impact of technical efficiency on investment of distribution utilities. Findings of the study reveal an increase in technical efficiency of distribution utilities in Pakistan. Estimates further indicate that technical efficiency significantly affects the investment decisions of distribution utilities significantly affect the technical efficiency of utilities. Findings of the study provide an effective policy tool to attract private investment in electricity distribution networks.
JEL: D24; L51; L94; L95

Keywords: Electricity; Market Reforms; Efficiency analysis; Stochastic frontier analysis; Investment

Introduction

The provision of electricity with adequate quality, quantity, and fair pricing necessitates substantial investment (Cullmann & Nieswand, 2016). Investment in distribution network and its modernization is crucial for determining long-term prices and quantities, and delaying such investments can result in significant societal costs (Costa, Bento, & Marques, 2017). Regulatory policy is a key factor influencing investment decisions in the electricity market. The strategic behaviors and investment decisions of electricity distribution utilities are greatly inclined by the government through the federal ministry of energy (power division) through market and non-market mechanisms, institutional arrangement, politically motivated subsidies and financial constrained uniform national tariff policy. Furthermore, external factors such as the macroeconomic condition also influences the investment decisions (Abrardi, Carlo & Laura, 2018). Since the 1990s, regulatory frameworks are structurally transformed due to a paradigm shift from traditional rate-of-return (cost-plus) regulation to various forms of innovative incentive regulations.

The purpose of market reform and incentive-based regulation is to improve operational as well investment efficiency of distribution utilities (Jamasb & Pollitt, 2007). Similarly, the utilities performing with low service quality require huge capital investment to improve their performance. In this regard, regulatory reforms play an effective role in directing the investment behavior of distribution utilities (Joskow, 2014). The existing body of theoretical literature significantly favors innovative regulatory and tariff setting mechanisms in order to bring more investments in power sector particularly for distribution utilities (Guthrie, 2006). Empirical studies, such as Cambini and Rondi (2010) and Egert (2009), have shown that incentive-based regulations can lead to higher investment rates in network industries compared to rate-of-return regulations.

Additionally, efficiency analysis has remained the pivotal area of existing literature on the electricity market. In this regard, the pioneer studies focused more on the regulatory consequences of structural policies as a bid to introduce efficiency to distribution utilities (Christensen & Greene, 1976, Christensen & Greene, 1978). However, the introduction of new empirical methodologies and parametric techniques tilted the focus towards the assessment of dynamic efficiency in power market majorly for its distribution component. For instance, the adoption of gamma-distributed Stochastic Frontier model to estimate efficiency scores revolutionized the empirical literature aiming to assess the efficiency of utilities (Greene, 1990). As reported by many policy practitioners and academic researchers such as Soroush et al., 2021, Kumbhakar et al., 2020, Liu et al., 2019, Orea et al., 2018, Mydland et al., 2018 and Kumbhakar & Lien, 2017, the dynamic nature of efficient power utilities has now shifted to another paradigm which aims in reduction of transmission and distribution losses. Efficiency issues aroused in the research has raised the interest of regulators on investment behavior of distribution utilities (Cambini & Rondi, 2010, Cullmann & Nieswand, 2016).

For the case of Pakistan, the debate on assessing efficiency of power utilities from the productivity and technical lens with and without consideration of service quality, has been examined in several studies (Mirza et al., 2021, Mirza et al., 2017, Zakaria & Noureen, 2016, Saleem, 2007). These studies found significant potential for efficiency improvements. However, limited literature is available on investment decision of distribution utilities. This study is the first attempt to examine the impact of technical efficiency on investment decisions of electricity distribution utilities in Pakistan. This study pursues two research objectives. The first is to assess the degree of technical efficiency of power distribution utilities for the case of Pakistan. The second objective peruses the impact of technical efficiency on investment landscape of these utilities to improve their technical efficiency scores. By providing empirical evidence on this relationship, the study aims to inform policymakers and regulators about the potential benefits of adopting incentive-based regulatory regimes to encourage greater investment in network infrastructure.

The relationship between technical efficiency and investment in electricity distribution utilities is crucial for understanding how operational improvements can drive infrastructure development (Guthrie, 2006). Technical efficiency is defined as the ability of distribution utility to produce maximum level of output using given inputs (Coelli et al., 2005). Such practice allows the utilities to minimize distribution loss and optimize resource use. Stating differently, a distribution utility performing efficiently may reduce operational costs and save more financial resources that can further be used for investments in distribution network (Jamasb & Pollitt, 2007).

Literature supports the positive relationship between efficiency and investment. For instance, Guthrie (2006) found that technically efficient firms largely incur capital expenditures in terms of improving system's reliability. Likewise, Cambini and Rondi (2010) found that incentive-based regulatory regime enhances the efficiency, leading toward higher investment in electricity market in European countries. This is because such regulatory frameworks reward utilities for improving their performance, providing them with additional funds and incentives to invest in infrastructure upgrades. Thus, regulatory reforms are critical for financial health of distribution utilities (Egert, 2009). These reforms improve the cost-effectiveness of electricity distribution utilities and create a favorable environment for sustained investment. By adopting incentive-based regulatory regimes, policymakers can encourage utilities to continually improve their efficiency, leading to greater investment in network infrastructure. This, in turn, enhances the reliability and quality of electricity supply, benefiting consumers and supporting economic growth (Nagel & Rammerstorfer, 2008).

Moreover, an increase in technical efficiency signals to investors and stakeholders that the utilities are managing their resources effectively and can deliver better services at lower costs (Cambini & Rondi, 2010). This boosts investor confidence and makes it easier for utilities to attract funding for further investments. Efficient utilities are better positioned to secure favorable financing terms and may become eligible for performance-based incentives under an incentive-based regulatory regime. Incentive-based regulations, unlike rate-of-return regulations, directly encourage utilities to enhance their efficiency. This regulatory approach aligns the interests of the utilities with broader policy goals by providing financial rewards for performance improvements. Consequently, as utilities strive to achieve higher efficiency to reap these rewards, they are more likely to invest in modernizing their infrastructure and adopting new technologies. Therefore, it can be stated that the relationship between efficiency and investment is pivotal. Regulatory reforms may enhance the investment in infrastructure by improving technical efficiency and improving cost-effectiveness of utilities.

This paper structure as follows: section 2 describes electricity market in Pakistan, section 3 explains the empirical methodology and data, section 4 discusses the results while section 5 concludes the paper and provide policy recommendations.

Electricity Market in Pakistan

The electric power market in Pakistan has been experiencing turmoil and consequently various reforms and restructuring phases are introduced since 1994. The purpose of these reforms was to improve generation capacity, encourage investment, and curtail poor governance in the electricity market (Kessides, 2013). The ultimate aim of these structural reforms was liberalizing the market as a bid to bring operational efficiency, enhance managerial quality and technical capacities of the power sector regulators, mangers and operators (Malik, 2012). A fundamental premise of these reforms is the assertion that state-owned monopolies exhibit inherent inefficiencies. The vertical integration of such monopolies is posited to inhibit competition among utilities. By dismantling this integration, it is anticipated that competitive pressures will enhance efficiency and eventually yield minimization of costs (Coelli et al., 1998).

These reforms addressed multiple lynchpins of power sector including but not limited to the elimination of Water and Power Development Authority (WAPDA) which was a vertically integrated public monopoly, the authority was eventually unbundled into one system operator namely National Transmission and Dispatch Company (NTDC). Furthermore, the public sector thermal electricity generation companies (GENCOs), and Private power infrastructure board (PPIB) were also formulated in order to manage publicly owned thermal generation units as well as to increase private procurement of power plants on IPP mode. Moreover, the power distribution component was devolved to ten power distribution utilities (DISCOs). Although, the ultimate objective was to bring liberalization in the sector, but to date the power sector and unbundled entities remained as public enterprises. Additionally, the regulatory control of these entities was assigned to the National Electric Power Regulatory Authority (NEPRA) which was established as an autonomous regulatory authority in 1997 (Khan, 2014).

Data and Methodology

3.1 Stochastic Frontier Analysis

This study employs Stochastic Frontier Analysis to estimate technical efficiency of electricity distribution utilities in Pakistan. Stochastic Frontier Analysis (SFA) as a parametric approach for efficiency benchmarking. SFA, originally proposed by Aigner et al. (1977), and Meeusen and van den Broeck (1977) requires explicitly specifying productions or cost function; It is an extension of the Ordinary Least Squares (OLS) regression but introduces a shift in production function parallel to get into the efficiency frontier. This change is motivated by a belief that the error term can be decomposed into inefficiency and stochastic noise. The production process in SFA can be defined as:

$$Y_{it} = X_{it}\beta + (\varepsilon_{it} - v_{it}) \qquad (1)$$

Where Y refers to output of ith firm, X is the vector of inputs, β is the vector of parameters, ε refers to error term with mean 0 variance constant while v refers half normal distributed variable showing technical inefficiency of distribution utility. The original SFA has been further extended for different distribution of v including truncated normal or gamma distribution. Alongside, the model was then extended for panel data, system of equations as well as time-varying technical efficiencies. SFA is superior to DEA because it allows for multiple input-output in distance function.

The basic idea is that in the case of a given production possibility frontier, for every producer the distance from the production frontier is a function of the vector of inputs used, X , and the level of outputs produced, Y. In the presence of a given production possibility frontier, the distance from the production frontier for each producer is a function of the vector of inputs used X and the level of outputs produced Y. For the output-oriented model, the distance function is defined as:

$$D_0(X,Y) = max\{\vartheta : (X/\vartheta \in I(Y)\} \qquad (2)$$

Input distant function is homogenous of degree one, concave and increasing in input while qusai concane and decreasing in output. The scalar distance ϑ shows the efficiency level while the value of $D_0(X,Y) = 1$ reflects fully efficient production technology while $D_0(X,Y) = 0$ reflects inefficiency. The relationship between input and output and efficiency frontier are estimated to estimate the distance from the frontier. This also applies to multi-input production functions, which can be estimated using a translog production function. As stated earlier, the input distance function is homogenous of degree one (Christensen et al., 1973, See and Coelli, 2013). To maintain homogeneity and symmetry, the following restriction have been imposed on equation.

$$\sum_{n}^{N-1} \beta_n = 1, \sum_{n}^{N-1} \beta_{nj} = 0, \sum_{m}^{M-1} \gamma_{mn} = 0$$
$$\alpha_{mo} = \alpha_{om} \text{ and } \beta_{nj} = \beta_{jn}$$

Along with this, the input distance function should be normalized in order to make it homogenous of degree one (Fare and Primont, 1990).

3.2 Empirical Model

We use tranfslog input distance function because it is simple, linear and easy to impose homogeneity restrictions (Christensen et al., 1973). Imposing homogeneity and symmetry restrictions, normalizing and taking reciprocal of input provides the estimating form of translog input distance function.

$$-lnx_{i,t,d} = \alpha_0 + \sum_m^{M-1} \alpha_m lny_{i,t,m} + \sum_n^{N-1} \beta_n lnx_{i,t,n} + \frac{1}{2}\sum_m^{M-1} \sum_o^{O-1} \alpha_{mo} lny_{i,t,m} lny_{i,t,o} + \frac{1}{2}\sum_n^{N-1} \sum_j^{J-1} \beta_{nj} lnx_{i,t,n} lnx_{i,t,j} + \sum_m^{M-1} \sum_n^{N-1} \gamma_{mn} lny_{i,t,m} lnx_{i,t,n} + \varphi_1 t + \varphi_2 t^2 + \sum_n^{M-1} \tau_m t lny_{i,t,m} + \sum_g^{G-1} \omega_g Z_{i,t,g} + \varepsilon_{it} - v_{it} \qquad (3)$$

In equation 3, ε_i refers to normally distributed error term, $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$ whereas v_{it} is the stochastic noise (technical inefficiency) and assumed to be I.i.d., $v_{it} \sim N^+(0, \sigma_v^2)$. Here, inefficiency is obtained by $v_{it} = \alpha_i + \omega_g Z_{i,t,g}$, where z reflects the exogenous or environmental variables affecting technical efficiency while α_i accounts for unobserved heterogeneity among distribution utilities. Study also used Lembda and Gemma to capture the proportion of technical inefficiency in random error of the model. The technical efficiency is assumed to be constant over time and can be estimated using $v_{it} = v_i(exp\, exp\, \{\varepsilon_i - v_{it}\})$ (Battese & Coelli, 1995). The following empirical model is used to estimate the impact of technical efficiency on investment of distribution utilities.

$$Inv_{it} = \alpha_{it} + \beta\hat{\theta}_{it} + \delta x_{it} + \varepsilon_{it} + v_{it} \qquad (4)$$

Where Inv is dependent variable and is obtained from financial statements of distribution utilities. θ refers to efficiency score while x includes the control variable including network length, revenue, economic growth and service quality parameters.

3.3 Data

We use data of eight electricity distribution utilities for the time span of 2006 to 2020. Currently, ten distribution utilities are operating in Pakistan but two utilities including SEPCO and TESCO have recently been established in 2013 and 2016, respectively and therefore have been excluded from the sample.

The data for input, output, exogenous and other control variables was obtained from State of industry reports, Power system statistics and balance sheets of respective utilities. In our analysis, we use two outputs including unit sold and number of customers. The unit of energy sold has widely been used output variables in the literature on efficiency analysis (Celen, 2013). Literature also used gross energy sold which includes the energy lost during distribution. However, this has not been done in our case because we use distribution losses as input variable because distribution utilities may have control over network losses but have no control over the units of energy demanded. Another important output variable for distribution utilities is the number of customers which is not in the control of utilities but can increase the cost of utilities such as cost of electricity connections, metering, and billing (Senyonga and Bergland, 2015). Together, units sold, and number of customers reflect the perfect mix of output (Poudineh & Jamasb, 2015).

We use three input variables including peak load demand, network length and distribution losses. Several studies on benchmarking analysis have used number of employees, capital expenditure and quality as input variables (Jamasb & Pollitt, 2001), However, due to availability constraints in the data, we restricted our inputs to these three variables. Peak load demand reflects the transformer capacity of distribution utilities (Senyonga, 2014) while network length is used as a proxy for service area of distribution network (Hirschhausen & Kappeler, 2006, Migueis et al., 2012, Azadeh et al., 2009). Network length has been calculated by summing high and low voltage lines. Together, network length, peak load demand and distribution losses contain a larger share in input requirement set of distribution utilities. Besides input and output variables, there are other factors that could affect the performance as well as efficiency of distribution utilities. Following Saleem (2017) and Senyonga (2014), we restricted exogenous variables to customer growth only because we do not find any significant effect of other exogenous variables in our model.

To meet the second objective of the study, we have included the data of technical efficiency, sales revenue, rate of return (Kibor), uncertainty, economic growth, and service quality parameters. The data for customer growth was extracted from World Development Indicator (WDI) while data for Kibor was obtained from State Bank of Pakistan (SBP). Estimated technical efficiency scores have been calculated using (Battese and Coelli, 1995) while data for revenue and service quality parameters has been extracted from State of Industry reports produced by NEPRA. Following Mirza and Mushtaq (2023) and Jamasb, Orea and Pollit (2012), we use three service quality including System Average Interruption Frequency Index (SAIFI), System Average Intruuption Duration Index (SAIDI) and cost of energy lost as service quality parameter. SAIFI and SAIDI are NEPRA's approval quality parameters whereas cost of energy lost has been used because it shows the resilience of distribution system. Cost of energy lost has been obtained by multiplying customer minute lost and number of customers whereas investment is obtained by adding short run and long run investment. The list of variables is shown in table 1.

Table 1: List of Variables for Input Distance Function

	Variables	Units
Output Variables	Unit sold	GWh
	Number of Costumers	Nos
Input Variables	Distribution losses	GWh
	Peak load demand	MW
	Network length	Km
Environmental Variables	Customer growth	Numbers
	Time trend	
List of Variables for Pooled OLS		
Dependent Variable	Investment	Million Rs
Independent Variables	Technical Efficiency	Numbers
	Revenue	Million Rs
	Network length	Km
	Kibor	Percent
	Uncertainty	Percent
	GDP growth	Million
	SAIFI	Numbers
	SAIDI	Numbers
	Cost of energy lost	Minutes numbers

Results and Discussion

4.1 Estimates of Stochastic Frontier Analysis

Input distant function has been normalized by sample mean to interpret the first order coefficients a_k and β_m express the input and output elasticities respectively. Along with this, the variables have been transformed through natural logarithms with the exception of trend variables and exogenous components of input function. Orea (2002) states that the biased scale effect can be avoided if the trans-log cost function fulfills the regularity property. Theoretically, input distance function should be negative (non-increasing) in outputs while for inputs it should show a positive (non-decreasing) association. Hence, the first-order coefficient of a_k and β_m should be negative and positive respectively. Negative parameter shows an increase in the input requirements while positive coefficient shows decrease in input requirement set.

Table 2 reflects the estimates of input distance function of electricity distribution utilities in Pakistan. Lembda indicates the portion of error in the model arises because of inefficiency. For an appropriate model, the value of Lembda should be greater than the one. We find statistically significantly value of Lembda (1.4), indicating that 1.4 % variance of error term is because of inefficiency in the model. The value of Gemma is 0.59 showing that 59 percent variation among distribution utilities is determined by the model whereas the remaining 41 percent are because of statistical noise. These statistics confirm that most of the variation in input requirements and productive performance of electricity distribution utilities are because of inefficiency and not because of statistical noise.

Table 2 shows the first-order parameters of output and input elasticities. For an appropriate input distribution function, first-order output and input elasticities should be non-increasing and non-decreasing, respectively. As evident from table 2, the elasticity of unity sold is negative but statistically insignificance which is confirmed with the findings of Mirza et al. (2017). The parameter of number of customers statistically significant at is negative and statistically significant showing that customer base increases the cost of electricity distribution utilities in Pakistan.

We find positive and statistically significant first-order parameters of input elasticities. The coefficients of peak load demand and network length and distribution losses are 1.08, 0.39 and 0.516[1], respectively. The parameters of input elasticity show that peak load demand has larger cost share in input requirements of distribution utilities in Pakistan followed by distribution losses and network length. In contrast to Mirza et al. (2017), we find the minimum share of network length (39 percent) in input requirements of distribution utilities.

To examine the output oriented technical change, we have included the interaction of time with output variables. However, we did not find evidence of output oriented technical change as the variable remained statistically insignificant. Considering the impact of exogenous variables on the input requirements of electricity distribution utilities, we included customer growth as an exogenous variable that could affect the efficiency of distribution utilities. Customer growth is statistically significant at the 1 percent level, demonstrating a positive effect on the efficiency of distribution companies. Contrary to the belief that higher customer growth increases input requirements and operating expenses, our findings suggest that customer growth enhances the efficiency of distribution utilities. To capitalize on this, distribution utilities need to expand their networks to support increased customer growth.

Table 2: Estimated Input Distance Function and its Parameters

Variables	Parameters	Coeff	Variables	Parameters	Coeff
Unit sold (lny$_1$)	α_1	-0.0542 (0.343)	(1ny$_2$)(lnx$_1$)	ϕ_1	0.127 (0.361)
Number of customer (lny$_2$)	α_2	-1.550*** (0.474)	(lny$_2$)(lnx$_2$)	ϕ_2	-0.501 (0.535)
Peak load demand (lnx$_1$)	β_1	1.088*** (0.317)	(lnx$_1$)(lnx$_2$)	φ_1	-0.247 (0.448)
Network length (lnx$_2$)	β_2	0.396** (0.163)	time (t)	ξ_1	0.00511 (0.0353)
Distribution losses (-lnx$_3$)	$\beta 3$	0.516	(t)^2	ξ_2	0.00455 (0.00289)
(lny$_1$)^2	α_{11}	2.291** (1.110)	t(lny$_1$)	Ω_1	0.0440 (0.0306)
(lny$_2$)^2	α_{22}	1.151 (0.939)	t(lny$_2$)	Ω_2	0.0244 (0.0360)
(lnx$_1$)^2	β_{11}	0.676** (0.291)	Constant	δ_1	-4.3510 (.630)
(lnx$_2$)^2	β_{22}	2.252*** (0.730)	Customer growth	δ_2	1.028* (0.556)
(lny$_1$)(lny$_2$)	ω_1	-1.658*** (0.578)	Sigma (u) ∂_u^2		0.113 *** (0.035)
(lny$_1$)(lnx$_1$)	η_1	-0.328 (0.361)	Sigma (v) ∂_v^2		0.078*** (0.010)
(lny$_1$)(lnx$_2$)	η_2	-0.806 (0.804)	Lambda $\lambda = \partial_u^2/\partial_v^2$		1.447*** (0.039)
			Gemma $\gamma = \partial_u^2/(\partial_u^2+\partial_v^2)$		0.59

4.2 Estimates of Technical Efficiency

First objective of the study is to estimate the technical efficiency score of electricity distribution utilities in Pakistan and mean efficiency scores are shown in figure 1. Findings of the study reported an increase in the technical efficiency scores from 0.80 to 0.95 from 2006 to 2020. The year 2013 evident higher technical efficiency score of 0.95 while 2012 reported a lower average efficiency score of 0.80.

---

[1] As input distribution function is homogenous of degree one, therefore the coefficient distribution losses are estimated using formula $\beta 3= 1- \beta_1 - \beta_2$ which is 0.516.

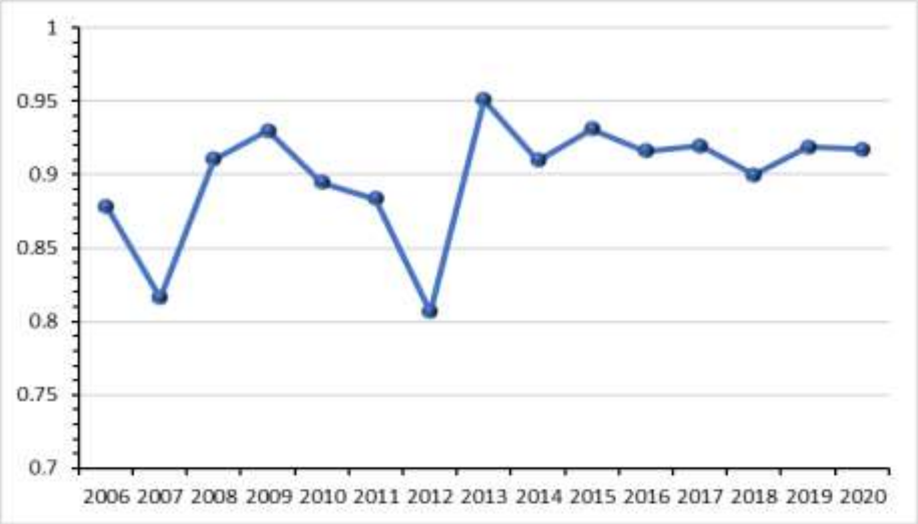

Figure 1: Estimated Average Efficiency Score of Electricity Distribution Utilities (2006-2020)

Figure 2 shows that the minimum efficiency score of electricity distribution utilities increased from 0.33 to 0.89 throughout the study period. The maximum efficiency score reported a slight change between 0.95 to 0.97 between 2006 to 2020 (see figure 2). On average, the increase in technical efficiency score is supported by the previous findings (See Zakria et al. 2016, Mirza et al. (2021, 2017). The increase in the efficiency scores during the study period shows that policies have had an impact on the cost adjustment behavior of electricity utilities. It is further believed that the regulatory reforms of utilities are supported by increase in overall satisfactory services quality which could be possible if utilities continuously upgrade system lines and update the infrastructure. To confirm this hypothesis, we have examined the impact of technical efficiency on investment behavior of distribution utilities in Pakistan. Table 4 shows the results of Pooled Ordinary Least Square (POLS).

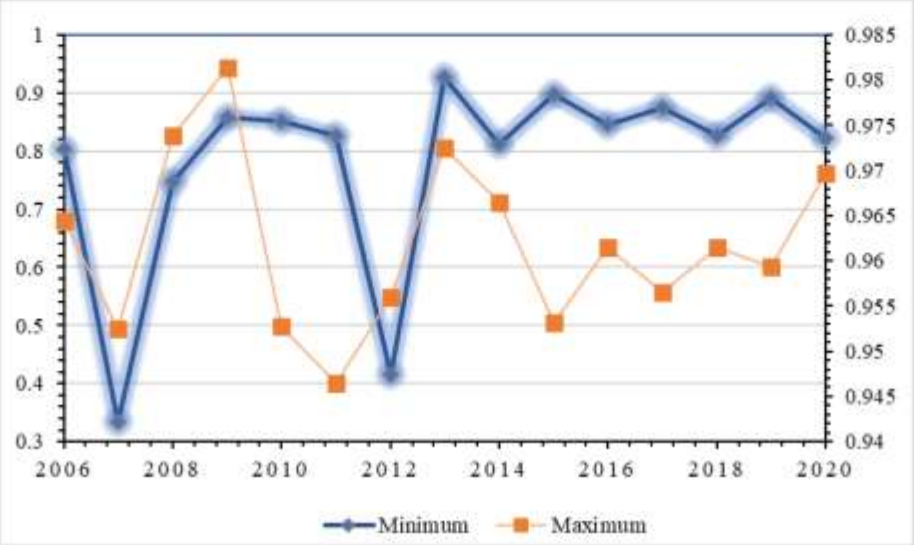

Figure 2: Estimated Minimum and Maximum Efficiency Score of Electricity Distribution Utilities (2006-2020)

Table 3 shows the mean efficiency scores of electricity distribution utilities during 2006 to 2020. Efficiency scores lie between 0 and 1 where the score values closer to zero indicate technical inefficiency while 1 shows technically efficient distribution utility. On average IESCO reported the highest efficiency score of 0.92 showing that IESCO has the potential to improve its efficiency by 8 percent. FESCO and HESCO observed minimum technical efficiency score of 0.88 indicating that these distribution utilities could perform well by increasing their efficiency by 12 percent. Table 3 shows a little difference in the performance of distribution utilities as average efficiency score varies between 0.88 to 0.92, indicating similar managerial and operating structure of distribution utilities in Pakistan. While the only difference in the performance could be because of how well utilities manage peak load demand and customer growth.

Table 3: Estimated Technical Efficiency Score of Electricity Distribution Utilities (2006-2020)

	Mean	Minimum	Maximum
GEPCO	0.916	0.847	0.967
PESCO	0.896	0.802	0.981
LESCO	0.910	0.831	0.973

IESCO	0.923	0.872	0.971
FESCO	0.881	0.333	0.969
MEPCO	0.873	0.415	0.972
QESCO	0.900	0.747	0.961
HESCO	0.888	0.509	0.966

4.3 Estimates of POLS

The second objective of the study is to examine the impact of technical efficiency on investment of distribution utilities. Table 4 reports a positive and statistically significant effect of technical efficiency on investment indicating that 1 percent increase in the technical efficiency increases the investment of distribution utilities by 72 percent. The highly significant and larger impact of technical efficiency implies that as distribution utilities become efficient, they would be able to spend more resources for investment in terms of maintenance and network up-gradtion. An improved technical efficiency implies the cost saving of distribution utilities which may be redirected toward investment to upgrade network and improve quality. Another possible reason is that an efficient distribution utility delivers optimal service quality leading to high customer satisfaction as well revenue collection enabling utilities to invest additional revenue in further improvement in quality.

Table 4: Estimates of Pooled OLS

	Coefficients
Technical efficiency	0.725*
	(0.399)
Revenue	0.472***
	(0.118)
Network Length	0.175*
	(0.0970)
Kibor	-0.0630***
	(0.0203)
Uncertainty	-0.168**
	(0.0836)
GDP growth	0.0500
	(0.0641)
Saifi	-0.00780
	(0.0364)
Saidi	0.00335
	(0.0247)
Cost of Energy lost	0.272***
	(0.0673)
Constant	1.469
	(1.133)
Wald test	190.62
P-Value	0.000
R-Square (Overall)	0.6745
R square (Within)	0.511

Electricity market reforms in Pakistan adhere to rate-of-return regulations rather than incentive-based regulatory regime. Our results provide strong evidence that adopting an incentive-based regulatory regime may enable regulators to encourage greater investment in the network. The pronounced impact of technical efficiency on investment behavior highlights the critical role of regulatory reforms in enhancing efficiency within the utilities sector. By fostering efficient practices, these reforms not only improve the operational performance of utilities but also enable significant investments in infrastructure, thereby ensuring the reliability of the electricity supply. Adopting incentive-based regulations could further enhance these benefits by directly motivating utilities to increase both their efficiency and their investment in infrastructure, thereby aligning regulatory incentives with desired outcomes.

We find positive and statistically significant effects of revenue collection on investment showing that a percent increase in revenue increases investment of distribution utilities by 47 percent. These results are consistent with Camnini and Rondi (2010) who found significant impact of sales on capital investment in European electricity distribution utilities. Kibor and uncertainty shows negative and significant impact on investment showing that market uncertainty and rate of return restrict utilities to investment. The insignificant effect of GDP shows that the investment decision of distribution utilities is not determined by the economic condition of the country. To examine the impact of services quality SAIFI, SAIDI and cost of energy lost. Among service quality variables, cost of energy lost shows significant impact on investment while SAIFI and SAIDI remained statistically insignificant. The coefficient of cost of energy lost shows that one percent increase in service quality increases investment of distribution utilities by 27 percent, indicating that increase in loss associated cost urge distribution utilities to investment on system maintenance and upgradation.

Conclusion and Policy Recommendation

This study examines the impact of technical efficiency on investment decision of electricity distribution utilities in Pakistan. We use input distance function and employs stochastic frontier analysis to measure efficiency among utilities. The estimate of True Fixed Effect shows that number of customers is a significant cost driver of electricity distribution utilities in Pakistan. The analysis reveals that peak load demand and network length are larger share in input requirement set of distribution utilities in Pakistan. Based on the estimates, technical efficiency has been obtained showing that on average distribution utilities have reported an increase in efficiency scores from 0.80 to 0.95 from 2006 to 2020. Furthermore, IESCO observed highest efficiency score of 0.92 showing that IESCO has the potential to improve its efficiency by 8 percent. To measure the impact of technical efficiency on investment of utilities, we proceed with Pooled OLS. Our findings reveal that 1 percent increase in the technical efficiency increases the investment by 72 percent indicating that an efficient performance of distribution utilities strongly affect their investment behavior. This implies that increase in technical efficiency increase cost savings of distribution utilities which may be redirected toward investment to upgrade network and improve quality. Along with this, investment of distribution utilities significantly determined by firm revenue, kibor and market uncertainty. We also find significant impact of service quality on investment, when it is measured with cost of energy lost. Rest of the service quality variables including SAIFI and SAIDI remained statistically insignificant. Based on the analysis, this study proposes following policy recommendations to improve the performance and investment of distribution network in Pakistan. Firstly, a possible way of improving investment in distribution network is to pass their ownership to private sector. As shown by the coefficient of kibor and uncertainty, we believe that private investment rightly responds to market condition as compared to public entities. The privatization of distribution utilities would provide an incentive to private owner to compete and invest on system up-gradation. Secondly, network length increases the cost burden of distribution utilities. Therefore, we suggest NEPRA to increase the number of distribution utilities which would help to reduce these costs and improve service quality. Further, allowing utilities to invest on distribution network. The insignificant impact of SAIFI and SAIDI on investment confirms the believe that distribution utilities do not respond to power interruption to losses. Another possible reason is that utilities are penalized for losses not for interruptions. This we suggest NEPRA to revisit its services quality parameters and include the cost of energy lost in the standards because the investment decisions of distribution utilities are highly sensitive to this measure. We also propose the regulatory body to switch regulatory regime from rate-of-return regulations to incentive-based regulations because monetary incentives urge utilities to incur capital expenditures for system maintenance and up-gradation.

References

1. Abrardi, L., Carlo, C., & Laura, R. (2018). The impact of regulation on utilities' investments: a survey and new evidence from the energy industry. *De Economist*, *166*, 41-62.
2. Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*, *6*(1), 21-37.
3. Azadeh, A., Ghaderi, S. F., Omrani, H., & Eivazy, H. (2009). An integrated DEA–COLS–SFA algorithm for optimization and policy making of electricity distribution units. *Energy Policy*, *37*(7), 2605-2618.
4. Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics*, *20*, 325-332.
5. Cambini, C., & Rondi, L. (2010). Incentive regulation and investment: evidence from European energy utilities. *Journal of regulatory economics*, *38*, 1-26.
6. Çelen, A. (2013). Efficiency and productivity (TFP) of the Turkish electricity distribution companies: An application of two-stage (DEA&Tobit) analysis. *Energy Policy*, *63*, 300-310.
7. Christensen, L. R., & Greene, W. H. (1976). Economies of scale in US electric power generation. *Journal of political Economy*, *84*(4, Part 1), 655-676.
8. Christensen, L. R., & Greene, W. H. (1978). An econometric assessment of cost savings from coordination in US electric power generation. *Land Economics*, *54*(2), 139-155.
9. Christensen, L. R., Jorgenson, D. W., & Lau, L. J. (1973). Transcendental logarithmic production frontiers. *The review of economics and statistics*, 28-45.
10. Coelli, T. J., Rao, D. S. P., O'donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. springer science & business media.
11. Coelli, T., Rao, D. P., Battese, G. E., Coelli, T., Rao, D. P., & Battese, G. E. (1998). Efficiency measurement using data envelopment analysis (DEA). *An introduction to efficiency and productivity analysis*, 133-160.
12. Costa, P. M., Bento, N., & Marques, V. (2017). The impact of regulation on a Firm's incentives to invest in emergent smart grid technologies. *The Energy Journal*, *38*(2), 149-174.
13. Cullmann, A., & Nieswand, M. (2016). Regulation and investment incentives in electricity distribution: An empirical assessment. *Energy economics*, *57*, 192-203.
14. Egert, S., Bosy-Westphal, A., Seiberl, J., Kürbitz, C., Settler, U., Plachta-Danielzik, S., ... & Müller, M. J. (2009). Quercetin reduces systolic blood pressure and plasma oxidised low-density lipoprotein concentrations in overweight subjects with a high-cardiovascular disease risk phenotype: a double-blinded, placebo-controlled cross-over study. *British journal of nutrition*, *102*(7), 1065-1074.
15. Färe, R., & Primont, D. (1990). A distance function approach to multioutput technologies. *Southern Economic Journal*, 879-891.
16. Guthrie, G. (2006). Regulating infrastructure: The impact on risk and investment. *Journal of Economic Literature*, *44*(4), 925-972.

17. Jamasb, T., & Pollitt, M. (2007). Incentive regulation of electricity distribution networks: Lessons of experience from Britain. *Energy Policy*, *35*(12), 6163-6187.
18. Jamasb, T., Nillesen, P., & Pollitt, M. (2004). Strategic behaviour under regulatory benchmarking. *Energy Economics*, *26*(5), 825-843.
19. Jamasb, T., Orea, L., & Pollitt, M. (2012). Estimating the marginal cost of quality improvements: The case of the UK electricity distribution companies. *Energy Economics*, *34*(5), 1498-1506.
20. Joskow, P. L. (2014). Incentive regulation in theory and practice: electricity distribution and transmission networks. *Economic regulation and its reform: What have we learned?*, 291-344.
21. Joskow, P. L. (2014). Incentive regulation in theory and practice: electricity distribution and transmission networks. *Economic regulation and its reform: What have we learned?*, 291-344.
22. Kessides, I. N. (2013). Chaos in power: Pakistan's electricity crisis. *Energy policy*, *55*, 271-285.
23. Khan, A. J. (2014). The comparative efficiency of public and private power plants in Pakistan's electricity industry.
24. Kumbhakar, S. C., & Lien, G. (2017). Yardstick regulation of electricity distribution—disentangling short-run and long-run inefficiencies. *The Energy Journal*, *38*(5), 17-38.
25. Kumbhakar, S. C., Parmeter, C. F., & Zelenyuk, V. (2020). Stochastic frontier analysis: Foundations and advances I. *Handbook of production economics*, 1-40.
26. Liu, Y., Wu, L., & Li, J. (2019). Peer-to-peer (P2P) electricity trading in distribution systems of the future. *The Electricity Journal*, *32*(4), 2-6.
27. Malik, A. (2012). *Power crisis in Pakistan: a crisis in governance?* (No. 2012: 1). Pakistan Institute of Development Economics.
28. Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*, 435-444.
29. Miguéis, V. L., Camanho, A. S., Bjørndal, E., & Bjørndal, M. (2012). Productivity change and innovation in Norwegian electricity distribution companies. *Journal of the Operational Research Society*, *63*, 982-990.
30. Mirza, F. M., & Mushtaq, I. (2022). Estimating the marginal cost of improving services quality in electricity distribution utilities of Pakistan. *Energy policy*, *167*, 113061.
31. Mirza, F. M., Mushtaq, I., & Ullah, K. (2017). Assessing the efficiency dynamics of post reforms electric distribution utilities in Pakistan. *Utilities Policy*, *47*, 18-28.
32. Mirza, F. M., Rizvi, S. B. U. H., & Bergland, O. (2021). Service quality, technical efficiency and total factor productivity growth in Pakistan's post-reform electricity distribution companies. *Utilities Policy*, *68*, 101156.
33. Mydland, Ø., Haugom, E., & Lien, G. (2018). Economies of scale in Norwegian electricity distribution: A quantile regression approach. *Applied Economics*, *50*(40), 4360-4372.
34. Nagel, T., & Rammerstorfer, M. (2009). Modeling investment behavior under price cap regulation. *Central European Journal of Operations Research*, *17*, 111-129.
35. Nagel, T., & Rammerstorfer, M. (2008). Investment decisions under market concentration and price regulation. *Working Paper Series.*
36. Orea, L. (2002). Parametric decomposition of a generalized Malmquist productivity index. *Journal of Productivity Analysis*, *18*, 5-22.
37. Orea, L., Álvarez, I. C., & Jamasb, T. (2018). A spatial stochastic frontier model with omitted variables: electricity distribution in Norway. *The Energy Journal*, *39*(3), 93-116.
38. Poudineh, R., Tobiasson, W., & Jamasb, T. (2015). Electricity distribution utilities and the future: More than just wires. *The routledge companion to network industries*, 317-331.
39. Saleem, M. (2007). Benchmarking and regulation for the electricity distribution sector in Pakistan: Lessons for developing countries. *South Asia Economic Journal*, *8*(1), 117-138.
40. Senyonga, L., & Bergland, O. (2015). Quality of service regulation, firm size, technical efficiency, and productivity growth in electricity distribution utilities.
41. Soroush, G., Cambini, C., Jamasb, T., & Llorca, M. (2021). Network utilities performance and institutional quality: Evidence from the Italian electricity sector. *Energy economics*, *96*, 105177.
42. Von Hirschhausen, C., Cullmann, A., & Kappeler, A. (2006). Efficiency analysis of German electricity distribution utilities–non-parametric and parametric tests. *Applied Economics*, *38*(21), 2553-2566.
43. Zakaria, M., & Noureen, R. (2016). Benchmarking and regulation of power distribution companies in Pakistan. *Renewable and Sustainable Energy Reviews*, *58*, 1095-1099.