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Uncovering Hidden Costs: an Empirical Study on the Impact of Quasi-Fiscal Activities on Pakistan's Electricity Supply

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Sabeel Khan[*], Fazale Wahid[**]

Abstract

Electricity is widely regarded as a clean and secure form of energy, playing a pivotal role in various aspects of modern life. In Pakistan, the electricity sector grapples with the challenge of quasi-fiscal activities (QFA), comprising tariff differential subsidies, transmission and distribution losses, and bill arrears, which hinder electricity supply. This study investigates the impact of hidden costs on Pakistan's electricity supply using 50 years of data from 1973-2022, employing Johansen cointegration and Vector Error Correction Model (VECM) analyses. The findings reveal a negative influence of hidden costs on electricity supply in both short and long run. Similarly, a negative impact is observed for input prices (oil prices) on electricity supply. While electricity prices and GDP positively affect electricity supply in the long run, GDP exhibits no significant impact in the short run. Transmission and distribution losses (TDLT) have a negative but insignificant effect on electricity supply, suggesting technological obsolescence in Pakistan. To ensure uninterrupted power supply in the country, the government should prioritize addressing hidden costs/QFAs in the sector, including privatizing Distribution Companies (DISCOs), integrating GIS and Artificial Intelligence (AI) technologies, and promoting renewable energy sources to reduce dependence on imported fuels for electricity generation.

Keywords: Electricity Supply in Pakistan, Quasi-Fiscal Activities, Hidden Cost in State Owned Enterprises (SOEs), Electricity Sector of Pakistan, Johansen Test and VECM

JEL: Q43, Q49,

1. Introduction

Electricity is widely regarded as a clean and secure form of energy, playing a pivotal role in various aspects of modern life. Its importance can be judged from that fact that in contemporary society, individuals' well-being and prosperity are frequently evaluated based on their access to and utilization of electrical power, with the International Energy Agency (IEA) establishing a benchmark of 120 kWh per person annually to define energy poverty (Ruppel & Althusmann, 2016). The increasing integration of technology across diverse fields has substantially increased the global demand for electricity (Abbas et al, 2024; NEPRA,

[*] Department of Economics, Islamia College Peshawar, Pakistan
[**] Department of Economics, Islamia College Peshawar, Pakistan

2023). In the face of this growing demand, ensuring a reliable and sustainable electricity supply becomes paramount, highlighting the need for strategic planning and investments to meet current and future energy requirements. A major challenge to the reliable, sustainable and affordable electricity supply in Pakistan is the existence of Quasi-Fiscal Activities (QFA) in the power sector.

Quasi-fiscal activities represent the transfer of resources from the public to private individuals or state-owned Enterprises through non-budget mechanisms. Sometimes the term Hidden cost is also used for it. In non-financial sector these activities account for the additional expenses of the production of a commodity that are not covered through the price of the commodity and thus necessitate an implicit government subsidy (Saavalainen & Ten Berge, 2006). QFA mostly arises from the inefficient operations of SOEs. There can be many components of QFAs like: overemployment, delay payment surcharge, exchange rate devaluation, keeping price or interest rate below market level etc., but this study takes three components of QFAs in the electricity sector of Pakistan: Tariff Differential Subsidy, Transmission and Distribution losses, and tolerance of unpaid bills.

Each year, the government of Pakistan allocates a specific amount for electricity subsidies to shield low-income households from high electricity tariffs. These subsidies are structured to provide greater assistance to domestic consumers using fewer units and less assistance to those using more units. Such explicit subsidies are not classified as Quasi-Fiscal Activities (QFAs); however, any subsidy amounts exceeding these explicit allocations can be considered QFA. A similar situation applies to transmission and distribution losses. In developed countries, advanced technology in the power sector limits unavoidable transmission and distribution losses (TDL) to around 5% of the total supply, whereas in developing countries like Pakistan, this limit is about 10%. TDL exceeding this 10% threshold are regarded as QFA. Additionally, electricity theft and unpaid bills fall under QFAs, as in both instances, electricity is consumed without corresponding payment, leading to an accumulation of costs for utilities, ultimately shifting the financial burden to the government.

Around two billion people worldwide do not have access to electricity. This makes it crucial to increase electricity generation (Shah et al, 2023). Globally, there is high demand for energy in emerging economies due to their high growth rate and drastic structural and demographic changes. In the developed countries of the world increase in demand for energy is offset by energy efficiency gains (extensive use of energy efficient technology) and energy conserving infrastructure. While developing countries strive for increasing generation capacity, and diversifying their energy sources by investing in infrastructure through public- private partnership (Pakistan Economic Survey, 2018). Energy is considered as in important inputs like other inputs such as labour and capital in the production function. Energy use not only promotes domestic output but also maintains living standard of nation via income effect. Being a developing country, Pakistan's demand for electricity is increasing day by day, due to its ambitions for high growth rate. In order to meet the requirement of development, the government should ensure the availability and sustainability of electricity supply in the economy (Pakistan Economic Survey, 2022).

In order to strengthen the Pakistan economy, the first step that the government should take is to tackle the energy problems in the country. Pakistan is facing electricity crises, where demand for electricity exceeds electricity supply (Wahid et al, 2021). Power outage has severely hit the social life of the people in Pakistan (Aziz & Ahmad, 2015). Pakistan has not been successful in increasing electricity generation on pace to meet with the growing demand from last two decades.

In 1994 when, for the first time, Pakistan faced electricity shortage in the country, it allowed Independent Power Producers (IPPs) to generate and supply electricity in the country. At that time, it was a feasible decision because of: low oil prices, the short span of time IPP requires from installation to generation of electricity, and its easy connection with the national power grid system. However, later, due to a surge in global oil prices, the shift towards furnace-oil power plants was deemed one of the reasons for the current electricity crisis (Hali et al, 2017).

The literature identifies various factors influencing electricity supply. This study focuses on specific determinants, namely hidden costs, GDP, fuel prices, the price of electricity, and technology—as independent variables in our model, with electricity supply serving as the dependent variable. Notably, hidden costs emerge as a key determinant affecting electricity supply in Pakistan.

Many studies have pointed out the inefficiencies of the electricity sector of Pakistan. But a study on Hidden cost or quasi-fiscal activities is missing, no one determined the impact of hidden cost on the total electricity supply of Pakistan. The main objectives of this study are: to determine the impact of hidden cost/quasi fiscal activities on electricity supply in Pakistan, and to provide insights for policy makers to make informed decisions when formulating sector-specific policies, thereby fostering a more effective and sustainable electricity supply system.

After the introduction the review of literature will be discussed in the second section. The third section will present the data and methodology. The results and discussion will be elaborated in section four. The fifth section will incorporate the conclusion, while policy recommendation and future research will be provided in the final sections of the study.

2. Review of literature

The literature on the quasi-fiscal activities within non-financial enterprises is limited. QFAs mostly prevails in different SOEs, but especially in the electricity sector of developing countries, these QFAs/hidden costs not only strain electricity supply but also exert pressure on their constrained budgetary resources. Although some studies have examined specific components of quasi-fiscal activities —such as transmission and distribution losses, electricity theft, and subsidized electricity prices—and their effects on electricity supply. This study stands out as the first of its kind to specifically address the impact of QFAs (the amalgamation of various inefficiencies of the power sector) on the electricity supply in Pakistan. The study reviews literature related to the QFAs in the electricity sector, and the main determinants of electricity supply.

Research on QFA/hidden costs in non-financial enterprises have primarily been the focus of international financial institutions (Tchaidze, 2007). Various papers have studied the implications of QFAs across developing countries, especially in former Soviet Union states. For instance, Petri et al (2002), one of the poineer study on the topic, studied QFAs in the power sector of Ukraine and Azerbaijan. The study found that the energy sector QFAs in Ukraine were 6.5% of GDP, with mispricing and arrears being the major contributing factors. While, in Azerbaijan, the energy sector QFAs were 26.7% of GDP. Saavalainen and Ten Berge (2006) examined QFAs in the Kyrgyz Republic, Moldova, and Uzbekistan. They discovered that Tajikistan and Uzbekistan had the highest QFAs, amounting to 21.4% and 15.9% of GDP, respectively. In contrast, Armenia had the lowest QFAs at just 1.1% of GDP.

Ebinger (2006) employed a hidden cost calculator model to assess the extent of quasi-fiscal activities in Europe and Central Asian (ECA) countries. The study revealed that hidden costs in the ECA region were 4.4% of GDP. Tariff Differential Subsidies (TDS) constituted 67% of the total hidden costs, while transmission and distribution losses and bill arrears made up 22% and 11% of the total hidden costs, respectively. Shalikashvili (2016) analyzed the causes and effects of QFAs in Georgia's electricity and gas sectors. The study found that the gas sector has the largest proportion of QFAs, primarily due to a significant disparity between actual prices and market prices. Trimble et al. (2016) explored QFAs of the electricity sector in 39 African nations. Camos Daurella et al (2017), quantified QFA through the end-product method for 14 countries in the Middle East and North Africa region (MENA). The average QFA of the 14 countries was 4.4% of GDP. These diverse studies collectively underscore the widespread occurrence and significant economic ramifications of QFAs in the non-financial sectors, especially the power sector, across different geographical regions.

When electricity utilities fail to collect the full amount of bills and experience higher transmission and distribution losses, they often find themselves lacking the necessary revenue. Consequently, they may postpone essential repairs of plants and machinery and forego crucial investments. This shortfall, as shown by Khan &Wahid (2023), has a negative effect on the electricity sector in Pakistan. Similar results were found in the economies where transmission and distribution losses are prevalent due to outdated technology or lengthy transmission lines. Such inefficiencies result in substantial wastage of electricity, thereby constraining electricity supply (Nababan, 2016). A pertinent case study is observed in Pakistan, where high rates of transmission losses and electricity theft significantly diminish electricity supply (Wahid et al, 2021). However, it's worth noting that technological advancements in the sector can have a positive impact on the electricity industry. These advancements can help improve efficiency and mitigate losses, ultimately enhancing supply and the overall performance of the electricity sector, as demonstrated by studies conducted by (Kwakwa & Alhassan, 2017; Kwakwa, 2015).

Asratie, (2022) studied determinants of electricity production from renewable sources excluding hydro electricity in five East African Countries, employed the panel ARDL approach for the period 1998-2019. The study found that GDP per capita growth, population growth, energy consumption per capita and energy imports have a positvie and significant effect on electricity production, while political instablility, electricity production from hydropower, and electricity production from oil, gas and coal have a negative and statistically significant impact, both in the short and long run.

Arafat et al, (2022) explored the relationship between factors influencing energy productivity. The study utilized an Autoregressive Distributed Lag (ARDL) model. The findings suggest that Foreign Direct Investment (FDI), labor productivity, and energy balance have a significant and positive impact on energy supply by Independent Power Producers (IPPs) both in the short and long term. However, oil prices exert a negative and significant influence on energy supply in the long run. The Gross Fixed Capital Formation exhibited a positive but statistically insignificant result in both the short and long run concerning energy supply.

Wahid et al, (2021) investigated the main determinants of electricity supply in Pakistan. The study used the OLS technique for specifying determinants and ARMA for forecasting electricity supply. The result of the study showed that T&D losses, fuel prices and technology have a statistically significant impact on the electricity supply in Pakistan, while electricity price and rainfall are statistically insignificant.

Empirical studies consistently demonstrate a direct correlation between a nation's GDP growth rate and its electricity supply. As an economy experiences higher GDP growth, the government must augment electricity provision to meet the escalating demand. This symbiotic relationship extends to population growth as well. Increased population growth rates, as evidenced in numerous studies, further underscore the necessity for expanded electricity supply infrastructure to accommodate rising demands (Ali et al, 2020; Hali et al, 2017).

The supply of any commodity is positively related with its price and negatively related with input price, as suggested by the law of supply. In the electricity sector many empirical studies have shown this relationship between electricity supply, electricity price and input prices (Khan & Wahid, 2023; Ahmed & Ahmed, 2019; Kwakwa & Alhassan, 2017; Nababan 2016). Jamil and Ahmad (2014) studied the factors which effect electricity theft from electricity distribution companies in Pakistan for the period 1988 - 2010. The Fixed Effects Model, employing the Least Squares Dummy Variable (LSDV) method, indicates a negative correlation between electricity theft and per capita income, conversely, electricity theft is positively related with electricity price and extreme temperature in Pakistan.

In their study titled *"An Econometric Analysis of the Determinants of Electricity Supply in Nigeria,"* Ubi et al. (2012) analyzed the key economic and structural factors influencing electricity supply in Nigeria using time series data from 1970 to 2009. This analysis employs contemporary econometric techniques, including tests for stationarity, cointegration, and ordinary least squares regression. The findings of this research highlight that technology, government financial support, and the extent of power loss are statistically significant determinants of electricity supply in Nigeria and about 40% of the power generated is wasted in transmission every year. The study proposes that the government should allocate more resources to the power sector. These funds should be directed towards the completion of power projects that incorporate advance technology, with the ultimate goal of bolstering the availability of electricity.

This study is novel in that it empirically tested the collective impact of multiple inefficiencies in the power sector (Quasi-Fiscal Activities). While all other studies have focused on the impact of individual components of QFAs on electricity supply, as evident from literature. This study will fill the crucial gap by examining the effect of QFAs on electricity supply in Pakistan. The current study offers new insights and contributes significantly to the existing literature on the subject.

3. Data and Methodology

3.1. Model

The model utilized in this study is based on the classical law of supply, wherein supply depends upon various factors including the price of the product, factor costs, technology, and prices of related goods. Analogously, the supply of electricity hinges upon its own price, input costs, technological advancements, and broader economic conditions, among other factors.

Formally, the model representing electricity supply (ES) is expressed as a function of several key variables:

Electricity Supply = f (electricity price + hidden cost + GDP + input price + technology)

Econometrically, this is represented as:

$$ES = \alpha + \beta 1\, Pe + \beta 2\, HC + \beta 3\, GDP + + \beta 4\, IP + \beta 5\, TDLT + \mu$$

Where abbreviation ES is electricity supply, Pe is price of Electricity Per unit, HC is Hidden cost, GDP is Gross Domestic Product, IP is input price (price of crude oil for electricity production), and TDLT is trended values of transmission and distribution losses is used as a proxy for technology. While α is constant and $\beta 1 - \beta 5$ are coefficients to be estimated and μ is an error term.

3.2. Data Collection

The secondary data chosen spans from 1973 to 2022, encompassing a total of 50 data points for all relevant variables. The data for each variable is presented in annual frequency. It is important to note that all numerical data has been transformed into a natural logarithmic form for analysis, except for the technology variable, TDLT.

The hidden cost (HC) comprises three main elements: tariff differential subsidies, transmission and distribution losses, and outstanding bill payments. Quantification of HC is facilitated through a hidden cost calculator (Khan and Wahid, 2023) [1], with values presented in billion rupees. Gross Domestic Product (GDP) at constant prices, measured in billion rupees, was sourced from various editions of the Pakistan Economic Survey.

Electricity Supply (ES): Electricity supply refers to source-wise electricity generation in gigawatt-hours (GWH) from all sources. The data is collected from various editions of the NTDC Planning System of Statistics. The price of crude oil (Ip) serves as the input cost for electricity generation. This crude oil price is based on the OPEC Reference Basket in nominal oil prices ($/b), converted to Pakistani currency by applying the exchange rate.

Technology (TDLT) plays a crucial role in influencing electricity supply. Various studies have employed different variables as proxies for technology. In this study, trended values of transmission and distribution losses are utilized as a proxy for technology. Enhanced technology corresponds to lower T&D losses. The negative/indirect relationship of the variable with electricity supply indicates an

[1] Our first published paper in a series of papers addresses the quantification of QFA/Hidden costs. DOI: 10.52131/pjhss.2023.1103.0620

improvement in technology over time within the system. To mitigate temporary fluctuations in T&D losses, trended values are considered.

3.3. Analytical Techniques

To analyze the economic relationships among electricity supply, hidden costs, electricity prices, GDP, input costs, and technology, a supply model is employed. The widely used Johansen Maximum Likelihood approach for cointegration analysis allows us to assess the long-term equilibrium relationships among the variables (Johansen & Juselius, 1990). The Vector Error Correction Model (VECM) is then utilized to capture short-term dynamics and adjust for any deviations from long-term equilibrium. This approach is particularly useful for handling cointegrated and non-stationary time series data, providing robust estimates of the relationships among the variables. Furthermore, the Impulse Response Function (IRF) is employed to elucidate the dynamic responses of the system to external stimuli. By analyzing the IRF, we can discern how shocks to one variable propagate through the system over time, providing valuable insights into the system's behavior and interdependencies.

Prior to model estimation, it is imperative to scrutinize the data for variables' order of integration and cointegration. Hence, the Augmented Dickey-Fuller (ADF) test is employed to determine the stationary or non-stationary nature of the data at its base level.

4. Results and Discussion

4.1. Unit Root Test

To ascertain the stationarity level of the target variables, the Augmented Dickey-Fuller (ADF) test was conducted (Dickey & Fuller, 1979). It can be observed in table 1 that all variables under investigation, namely LNES, LNPE, LNHC, LNGDP, LNIP, and TDLT—expressed in logarithmic form with the exception of TDLT, representing trended values of percentage transmission and distribution losses—demonstrate non-stationarity at the 5% significance level. However, upon conducting first differencing at a 5% significance level, a notable shift occurs. Subsequently, all variables manifest stability, indicating stationarity. This pivotal transformation suggests that all series possess an integration order of one, denoted as I(1).

Table 1. ADF Unit root test

Variables	Test Statistics	Probability	Lag	5% Critical value	Intercept/trend	Order
LNES	-5.75*	0.00	1	-3.51	Intercept	I (1)
LNPE	-5.75*	0.00	0	-2.97	Intercept	I (1)
LNHC	-6.74*	0.00	0	-1.95	None	I (1)
LNGDP	-5.16*	0.00	0	-2.92	Constant	I (1)
LNIP	-7.18*	0.00	0	-1.95	None	I (1)
TDLT	-4.09*	0.00	0	-1.95	None	I (1)

* Shows significance at 5% level.

Source: Author's own calculation using E. view 10

4.2. Johansen Cointegration Test

Using the cointegration test requires that all variables are stable and have the same order of integration. As seen in Table 1 of our study, all variables are proven to be stable at I (1). The next step is to check if there's cointegration among these variables. For this purpose, we use the Johansen maximum likelihood cointegration test. The results of the Unrestricted Cointegration Rank test are in Table 2. The Trace Statistic compares the Eigenvalues against critical values to determine the number of cointegrating equations. The null hypothesis assumes a certain number of cointegrating equations, and rejection of this hypothesis indicates the presence of a different number of cointegrating equations. Table 2 indicates that, according to Trace Statistics, the null hypothesis of two cointegrating vectors is rejected in favor of the alternative of three cointegrated vectors. However, the null hypothesis of three cointegrating relationships cannot be rejected compared to the alternative of four cointegrated equations. So, according to trace statistics, there are three cointegration equations at a 5% level of significance.

Turning to Table 3, which presents the results of the Unrestricted Cointegration Rank Test using the Maximum Eigenvalue statistic, a similar analysis is conducted. Here, the

Table 2. Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.767219	170.8640	117.7082	0.0000
At most 1 *	0.530932	102.3543	88.80380	0.0037
At most 2 *	0.404956	66.77486	63.87610	0.0280
At most 3	0.312389	42.37620	42.91525	0.0566
At most 4	0.282600	24.77320	25.87211	0.0681
At most 5	0.177139	9.163480	12.51798	0.1705

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 3. Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.767219	68.50979	44.49720	0.0000
At most 1	0.530932	35.57940	38.33101	0.1001
At most 2	0.404956	24.39866	32.11832	0.3229
At most 3	0.312389	17.60300	25.82321	0.4082
At most 4	0.282600	15.60972	19.38704	0.1628
At most 5	0.177139	9.163480	12.51798	0.1705

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Max-Eigen Statistic is compared against critical values to determine the number of cointegrating equations. In this table 3, the null hypothesis of having no cointegrating equations is rejected at a 5% significance level. However, the null hypothesis of at most 1 cointegrating equation cannot be rejected compared to the alternative of 2 cointegrated equations. Thus, according to the Maximum Eigenvalue statistic, there is one cointegration equation at a 5% significance level.

These results collectively suggest a long-term relationship among the studied variables. Considering the optimal lag length, the cointegration results are found at lag interval 02. Optimal lag length 2 were selected through Akaike info criteria.

Table 4 provides the results of the Johansen Cointegration Test, offering further details on the cointegrating equation(s). Table 4 presents the log likelihood and normalized cointegrating coefficients, along with their standard errors. The normalized coefficients indicate the long-term relationships among the variables, where positive coefficients signify inverse associations, and negative coefficients indicate positive relationships.

The outcomes of the cointegration analysis using the Johansen maximum likelihood approach are outlined in Table 4. The normalized equation indicates a long-term connection, showcasing that electricity price, and GDP are positively and significantly associated with electricity supply. In contrast, hidden costs and input prices, demonstrate an inverse and statistically significant relationship with electricity supply. The representation of technology in the form of trended values of transmission and distribution losses (TDLT) in the equation indicates a negative association with electricity supply, though it is statistically insignificant. This proxy variable suggests that as technology advances, TDLT decreases, subsequently leading to an increase in electricity supply. This negative and insignificant relationship of TDLT with electricity supply in this study is attributed to outdated technology issues in Pakistan. Similarly, other studies (Ubi et al, 2012, Nababan, 2016, Adom, 2016, Wahid et al, 2021) found similar, but statistically significant results for T&DL as a proxy for technology. According to Aziz and Ahmad (2015), inadequate investment in electricity generation and distribution networks is the primary reason for high power outages in Pakistan.

The direct impact of electricity price on electricity supply is evident, where a one unit increase in price corresponds to a 0.59 unit increase in electricity supply. A similar finding regarding the positive impact of electricity prices on electricity supply is also noted by Kwakwa and Alhassan (2017) in the case of the Ethiopian economy, Nababan (2016) in the context of the Indonesian economy, and Ali et al, (2020) for the Malaysian economy. Similarly, the study found a positive and statistically significant relationship of GDP with electricity supply. A one unit rise in GDP is linked to more than one unit increase in electricity supply. Azam et al (2020) also found that GDP and electricity supply are cointegrated in the long run in Pakistan.

A one unit increase in hidden costs results in a 0.22 units reduction in electricity supply. When hidden costs increase, electricity entities experience revenue deficits, leading to delays in important repairs and plant upgrades. This, in turn, diminishes electricity supply and generation capacity. According to the Ahmad et al, (2023) study, investing in infrastructure contributes to an increase in electricity supply and facilitates revenue recovery in Karachi.

The hidden cost has an inverse and significant long-term impact on electricity supply in Pakistan. Many studies have highlighted this relationship in various ways. For example, Jamil and Ahmad (2014) stated that electricity theft annually causes million-dollar losses to the power sector of Pakistan. Similarly, Adom (2016) demonstrated that transmission and distribution losses are considerably higher in developing countries compared to developed countries, with Pakistan being no exception. Higher line losses negatively affect electricity supply.

The high hidden costs within the electricity sector have entangled the country in a circular debt trap, adversely affecting electricity supply and generation. In the current situation, circular debt—a condition where consumers, electricity distribution companies, electricity producers, and oil suppliers owe each other and cannot settle their dues—results in reduced oil imports and electricity generation. Consequently, it is considered a major contributing factor to the electricity shortage in Pakistan.

The hidden cost in this study comprises three main components: tariff differential subsidies, transmission and distribution losses, and bill arrears. Various other factors, such as overstaffing, surcharges for delayed payments, and exchange rate depreciation, were not quantified in this study due to the unavailability of data. If these factors were quantified, they would likely contribute to an even greater magnitude of the QFAs/hidden cost coefficient than it is 2.6% of the GDP of the Pakistan economy in 2021-22 (Khan & Wahid, 2023).

Reducing these hidden costs is imperative to ensure an uninterrupted power supply to the people.

In a similar fashion, Table 4 shows a negative and statistically significant relationship of fuel price with electricity supply. A one unit increase in input prices leading to a reduction of 0.11 units in electricity supply. In Pakistan almost 60% of electricity is generated from thermal sources, especially oil, so input price/fuel price has a significantly negative impact on electricity supply. An increase in the cost of production, as suggested by economic theory, has an adverse impact on the supply of everything, and electricity supply is no exception. A similar inverse impact of the cost of production on electricity production has been validated by (Arafat et al, 2022; Kwakwa & Alhassan, 2017; Nababan, 2016).

4.3. Vector Error Correction Model

The Vector Error Correction Model (VECM) is employed to identify the causal long-term or equilibrium connections among the model's variables. Furthermore, when an unforeseen deviation temporarily steers any variable

Table 4. Result of Johansen Cointegration Test

1 Cointegrating Equation(s):Log likelihood 322.4886						
Normalized cointegrating coefficients (standard error in parentheses)						
LNES	**LNPE**	**LNHC**	**LNGDP**	**LNIP**	**TDLT**	**@TREND(74)**
1.000000	-0.590676	0.219790	-3.255500	0.106247	0.006395	0.100479
	(0.13388)	(0.06373)	(0.27119)	(0.02069)	(0.01783)	(0.01389)

Source: Author's own estimation using E-View 10

away from its equilibrium trajectory, the model enables us to assess the short-term dynamic adjustments. The summary of the VEC model is provided in Table 5. The Error Correction Coefficient (ECT) is particularly noteworthy as it indicates the speed of adjustment, illustrating how swiftly the model restores equilibrium after disturbances. The ECT coefficients associated with electricity supply and hidden costs as dependent variables exhibit a negative and statistically significant relationship. This suggests convergence from short-run dynamics towards long-run equilibrium. Specifically, the adjustment coefficient for electricity supply stands at 0.97 percent per unit time, while the hidden cost's adjustment coefficient is 0.90 percent per unit time in situations of disequilibrium. This suggests that, during periods of imbalance, both QFAs/hidden costs and electricity supply contribute substantially to the model's adjustment, facilitating a resolution towards long-run equilibrium within the short run.

On the contrary, for other variables such as the price of electricity, GDP, input prices, and trended values of transmission and distribution losses, their coefficient signs are negative but statistically insignificant. This implies that a percentage change in these variables does not contribute significantly to resolving long-run equilibrium. GDP has no short run causality. This result is opposite to the result of Azam et al, (2020), who found unilateral causality running from GDP to electricity supply. While input prices, and TDLT show no short-term causality. The same result

Table 5. Result of VECM

Error Correction:	D(LNES)	D(LNPE)	D(LNHC)	D(LNGDP)	D(LNIP)	D(TDLT)
CointEq1	-0.974866	-0.391867	-0.905357	-0.012480	-0.125988	-0.888220
	(0.13815)	(0.21472)	(0.35570)	(0.04643)	(0.66702)	(0.56894)
	[-7.05670]	[-1.82503]	[-2.54525]	[-0.26878]	[-0.18888]	[-1.56119]

Source: Author's Own Estimation Using E-View 10

Table 6. Result of Wald Test

Method: Least Squares (Gauss-Newton / Marquardt steps)			
D(LNES) = C(1)*(LNES(-1) - 0.590675923003*LNPE(-1) + 0.219789883986*LNHC(-1) - 3.25550045404*LNGDP(-1) + 0.106247422961*LNIP(-1) + 0.0063949743883*TDLT(-1) + 0.100478792108*@ TREND(73) + 37.5424276238) + C(2)*D(LNES(-1)) + C(3)*D(LNES(-2)) + C(4)*D(LNPE(-1)) + C(5)*D(LNPE(-2)) + C(6)*D(LNHC(-1)) + C(7)*D(LNHC(-2)) + C(8)*D(LNGDP(-1)) + C(9) *D(LNGDP(-2)) + C(10)*D(LNIP(-1)) + C(11)*D(LNIP(-2)) + C(12) *D(TDLT(-1)) + C(13)*D(TDLT(-2)) + C(14)			
Name of Variable	**Null Hypothesis**	**Chi square**	**Probability**
Electricity Price	C (4) = C (5) =0	20.53	0.0003
Hidden Cost	C (6) = C (7) =0	18.72	0.0001
GDP	C (8) = C (9) =0	2.13	0.3451
Input Price	C (10) = C (11) =0	23.03	0.0000
TDLT(Technology)	C (12) = C (13) =0	15.90	0.0004

Source: Author's own estimation using E-View 10

for input prices in the short run is founded by (Arafat et al, 2022). All this underscoring the unique roles played by electricity price and hidden costs in the dynamic adjustments toward long-term equilibrium.

4.4. Wald test

The Wald test results are presented in Table 6, indicating the outcomes of the VECM short run analysis. The Wald test conducted for the electricity price reveals that null hypothesis of the combined coefficients, represented by C(4)*D(LNPE(-1)) = C(5)*D(LNPE(-2))=0, is rejected at a 5% level of significance. This rejection suggests the existence of short-term causality stemming from electricity price to electricity supply. Similarly, the null hypothesis asserting no causality from hidden costs to electricity supply (C(6) = C(7) = 0) is rejected, with probability values less than 0.05%. This implies that QFAs/hidden costs exert an impact on electricity supply in the short term.

Contrarily, the null hypothesis pertaining to the absence of short-term causality from GDP to electricity supply, as indicated by the combined coefficients C(8) = C(9) = 0, fails to be rejected. Consequently, it is accepted that there is no short-term causality from GDP to electricity supply. In a comparable manner, the null hypotheses concerning no causality from input price and TDLT (C(10) = C(11) = 0, C(12) = C(12) = 0) are also rejected, indicating that both input price and technology have a short-term impact on electricity supply.

4.5. Impulse Response Function

Figures 1 and 2 below display the impulse responses for the six variables considered in the research. The response is depicted across ten periods on the horizontal axis. The vertical axis indicates the magnitude of the responses for each variable, measured in the same units (logarithms) as the variables themselves.

The electricity supply shows a negative reaction to its own shock till the 4^{th} period, then becomes positive and stabilizes. QFAs/Hidden cost initially responds negatively and continues to increase for the next two periods. After initial increase, the response becomes stable. This implies that there is a temporary negative impact on QFAs/hidden cost, but it eventually levels off. The TDLT response is negative and exhibits fluctuations. This implies that hidden cost and TDLT influence electricity supply in the opposite direction. The observed inverse impact of hidden cost and TDLT on electricity supply is consistent with the findings from the long-run coefficient of cointegration.

In response to an exogenous disturbance in hidden costs, a negative reaction is observed in electricity supply. The response of electricity prices is noteworthy and positive. This suggests that when electricity prices are higher, there is typically a significant difference between the average and subsidized prices of electricity, resulting in an increase in hidden costs. Meanwhile, the response of GDP is positive and of considerable magnitude. Input prices (IP) show a positive response, while TDLT reacts negatively with a lower magnitude, see figure 2.

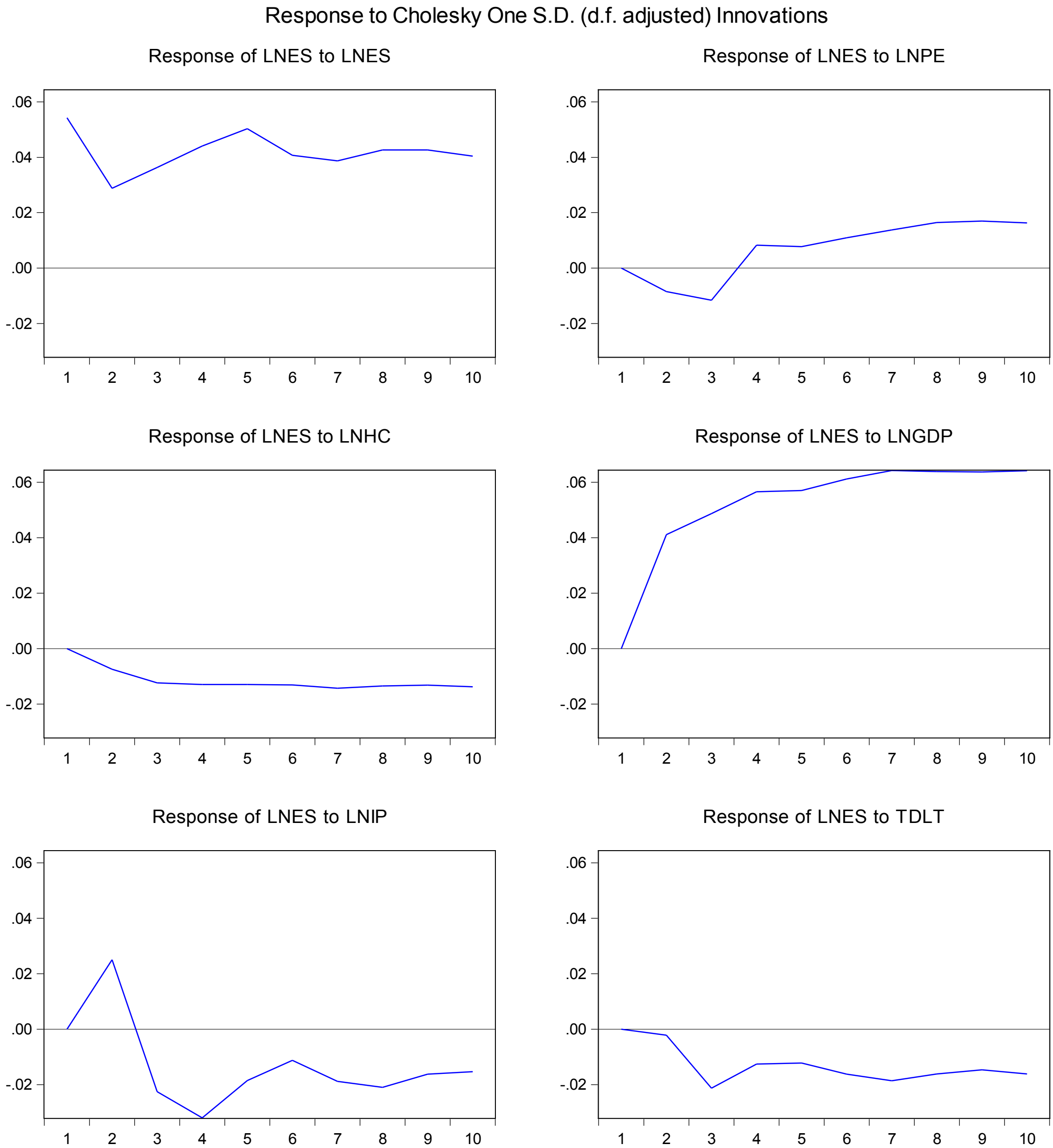

Figure 1. Impulse Response Function of ES
Source: Author's Own Estimation using E-View 10

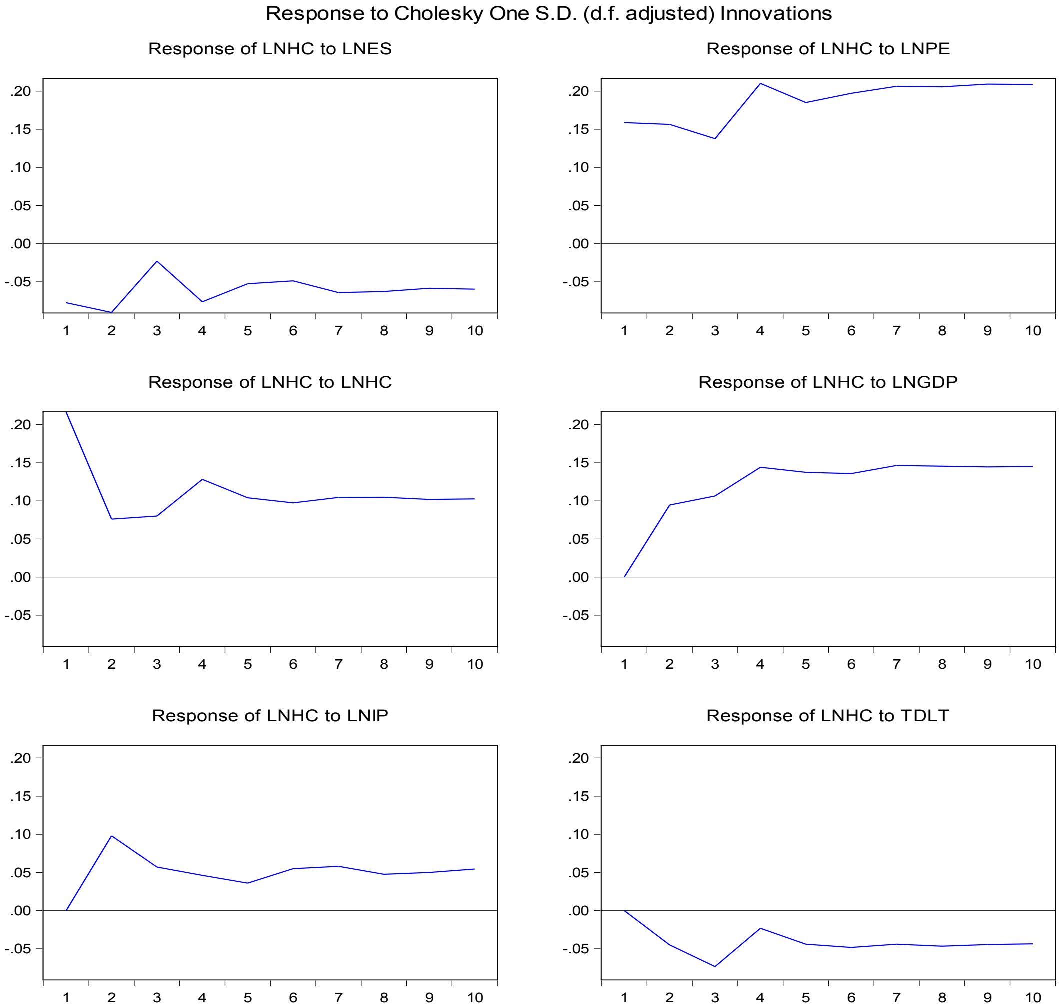

Figure 2. Impulse Response Function of HC
Source: Author's Own Estimation Using E-View 10

4.6. Diagnostic Tests

Normally when R-Square value is > than 60%, we accept that model. In this model R-square value is 71 percent. Value of F-statistic is 6.32 and value of prob (F-statistic) is 0.00, it means that our model data is good fitted and the used variables are appropriate.

For testing serial correlation in the model, we tested Breusch-Godfrey Serial Correlation LM Test. The null hypothesis of no serial correlation cannot be rejected at a 5% level of significance.

The null hypothesis of no heteroskedasticity is accepted at a 5% level of significance, and rejects the alternative hypothesis of heteroskedasticity. So there is no heteroskedsticity in the model.

5. Conclusions

This study aims to empirically analyze the impact of hidden costs on electricity supply. A model based on the law of supply is proposed, incorporating electricity price, hidden costs, GDP, input prices, and trended values of transmission and distribution losses (serving as a proxy for technology). Time series data from the period 1973-2022 are utilized.

The Johansen maximum likelihood cointegration test is employed to identify the long-term relationship among the variables. All the variables are transformed into stationary at first difference at a 5% significance level, indicating an integration order of one (I(1)). The trace statistics revealed 3, while the maximum Eigenvalue indicated one cointegrated equation at a 5% significance level. Optimal lag length of 2 was selected based on the Akaike information criteria. This suggests the presence of long-term cointegration among the model's variables.

All variables exhibit the expected sign and statistically significant coefficients, except for TDLT, where the coefficient displays the expected sign but lacks statistical significance.

This study concludes that all the examined variables are cointegrated in the long run. Notably, hidden cost/QFAs are found to have a significant and negative relationship with electricity supply in Pakistan. As hidden costs increase, they hinder the electricity supply in the country. Similarly, rising fuel prices, which are critical inputs for electricity generation, adversely affect power supply. In contrast, the price of electricity and GDP both have a positive relationship with electricity supply in Pakistan. Technological advancements have a direct and beneficial impact on electricity supply by reducing losses and wastage within the system. However, the proxy variable used to represent technology in this study shows an insignificant effect on electricity supply, indicating the presence of outdated technology in Pakistan's power sector.

The ECT coefficients associated with electricity supply and hidden costs as dependent variables exhibit a negative and statistically significant relationship. This

Table 5.8. Result of Serial Correlation Test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.630969	Prob. F(3,30)	0.2030
Obs*R-squared	6.590640	Prob. Chi-Square(3)	0.0862

Source: Author's own estimation using E-View 10

Table 5.9. Result of Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.803467	Prob. F (18,28)	0.0784
Obs*R-squared	25.23441	Prob. Chi-Square (18)	0.1186
Scaled explained SS	20.01302	Prob. Chi-Square (18)	0.3321

Source: Author's own estimation using E-View 10

suggests that, during periods of imbalance, both QFAs/hidden costs and electricity supply substantially contribute to the model's adjustment, facilitating a resolution towards long-run equilibrium within the short run. Conversely, the coefficient signs for other variables, such as the price of electricity, GDP, input prices, and trended values of transmission and distribution losses, are negative but statistically insignificant. This implies that percentage changes in these variables do not significantly contribute to resolving long-run equilibrium.

In the short run, electricity price and hidden costs demonstrate a significant impact on electricity supply. Causality in the short run stems from electricity price and hidden costs to electricity supply, with no significant impact from other variables. The impulse response function corroborates these findings. An innovation in electricity supply causes hidden costs, input prices, and TDLT to react inversely, while GDP and electricity prices respond positively to a shock to electricity supply. Similarly, a one standard deviation shock to hidden costs causes electricity supply and TDLT to respond negatively, while GDP, electricity prices, and input prices respond positively.

To sum up, this study concludes that QFAs are a major issue in Pakistan's power sector, adversely affecting electricity supply both in the short and long term. The presence of QFAs/hidden costs prevents energy entities from earning profits, which in turn hinders their ability to invest in upgradation of infrastructure and enhance electricity supply.

6. Policy Recommendations

Privatization of distribution companies could significantly address electricity theft and billing challenges while improving service quality. Similarly, in this era of technology, the government of Pakistan should integrate GIS and Artificial Intelligence into the electricity sector to modernize operations, reduce corruption, and boost transparency. Provincial governments should actively engage in DISCO decision-making to maximize revenue and minimize theft. Pakistan should prioritize clean, affordable energy sources like hydro, solar, and wind to reduce reliance on imports, cut costs, and promote sustainability.

7. Future Research

The future researchers should consider exploring the expansive domain of quasi-fiscal deficits within State-Owned Enterprises (SOEs) across various sectors of Pakistan's economy. This is essential to ascertain their ramifications on sectoral performance and their broader adverse effects on the economy.

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