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ASSESSMENT OF THE IMPACT OF CORRUPTION AND CIRCULAR DEBT ON ENERGY CRISIS IN PAKISTAN

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Abstract. The main purpose of this study was to explore the impact of corruption and circular debt on energy crises in the case of Pakistan. For this purpose, the study used annual time series data and employed an ARDL F-bounds test approach to achieve the determined objectives. The findings of the ARDL model reported that corruption, circular debt, and population have a positive impact, while industrial GDP and distribution and transmission contribute negatively to short- and long-term energy crises. Consequently, this study helps policy makers to focus on the issue of corruption and circular debt in the energy sector of Pakistan.

Keywords: corruption, circular debt, energy crisis, ARDL bounds testing.

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Introduction

The economy is the backbone of a country's progress. The economy can remain healthy if industrial, agricultural, and domestic energy demand is sufficiently met by the government. It cannot be overemphasized that energy is one of the most important factors which fulfilled human needs. The world in the 21st century faces so many oppositions when it comes to energy, such as the availability of sufficient, affordable, and environmentally friendly energy. To overcome the problem of poverty, improve human well-being and raise the standard of living, there are achievable and sufficient energy needs. The South Asia region is rich in natural resources. The energy production of this region depends on the natural resources of coal, oil, natural gas and hydroelectric energy (Iqbal et al., 2019; Nawaz et al., 2013). Natural resources are drained with every tick of the clock, so the chance of turning natural resources into electrical energy becomes low. The energy sector is underdeveloped in Pakistan due to poor planning, supervision and management (Faheem, 2016). Electricity is one of the important sources for providing social services such as education, health, water purification and sanitation and medicine refrigeration. Electricity plays a vital role in generating income opportunities. Electricity is a service of monopolistic quality and social importance due to the problem of governance in the electricity sector. In many countries, only one company is responsible for providing electricity, so customers cannot switch to another company. Some countries have made their energy market competitive to overcome the governance problem in the electricity sector (Halpern et al., 2008). The crisis is not only the gap between demand and supply, but also these emerging crises due to poor governance, outdated technologies, and administrative problems, as well as circular debt damaged the supply chain (Heli et al., 2017). The energy sector that holds monopoly power is subject to corruption. Strong relationship exists between energy efficiency and corruption; greater corruptibility will reduce energy efficiency (Sekarfi and Sghaier, 2018; Qazi et al., 2020). The electricity sector in developing countries is mainly under public control. Public authorities use electricity as an instrument to achieve social, economic and political goals. The public sector holds in concessionaires, which leads to corruption and inefficiency in generation and distribution (Jamil and Ahmad, 2013). Corruption is pervading the electricity sector and imposes significant costs. Rehman and Deyuan (2018) examined the relationship between economic growth, population growth, energy use and access to electricity in Pakistan using the ARDL bounds testing approach.

Pakistan has been struggling with the problem of power shortage for several years. Electricity crisis occurs in the country, and then country initiative to find long-term effective solutions for power supply is strong as compared to now. The main purpose of this study is to gain knowledge about the outcomes of circular debt on Pakistan's electricity crisis. The study will help the policy makers to overcome the corruption problem in the electricity sector of Pakistan and help the manufacturers to mitigate the crisis by controlling population growth and line losses. This study is different from the previous study, because no previous study has examined the effect of circular debt, population growth and industrial growth on electricity crisis in case of Pakistan. In addition, this study also focuses on distribution and transmission losses in the electricity sector. Therefore, this study helps the policy makers to address the issue of corruption and circular debt in the energy sector of Pakistan.

Literature review

Many studies have been done to explore the electricity crisis and its causes. Abbas (2015) discussed that the socio-economic growth of a country is affected by the performance of the energy sector. The energy sector has generated growth and development in the agricultural, industrial, and the defense sectors, as well as in the domestic sector. Sekrafi and Sghaier (2016) investigated how political stability, environmental quality, energy consumption, and corruption affected the economic growth of 13 MENA regions. They used a static and dynamic panel data approach over the period from 1984 to 2012. Their empirical results showed that an increase in corruption, directly affects environmental quality, economic growth and energy consumption, while economic growth is indirectly affected by corruption through environmental quality and energy consumption. Therefore, carbon emissions and energy consumption also affect economic growth. Furthermore, Imam et al. (2018) found no evidence regarding performance in technical, economic and welfare terms, and these reforms do not reduce or increase corruption. They conducted a study to estimate the impact of corruption on two aspects of electricity reform, having three indicators such as, revenue, access to electricity, and technical efficiency using a new panel dataset from 47 sub-Saharan African countries, for the period from 2002–2013. The study concluded that corruption mitigated technical efficiency and created a barrier to access to energy use and national income. They suggested that well-planned reforms not only influence the economic development, but also indirectly reduce negative institutional deficiencies in the form of corruption, both at the micro and macro levels.

In recent years, Pakistan is facing a drastic energy shortage. One of the reasons for this remarkable power outage, is the tackling in the use of resources. The situations caused not only an energy mix for electricity generation, but also circular debt has contributed to the crisis. The government of Pakistan has paid over one trillion rupees as Differential Tariff Subsidy (TDS) to protect people from the rising cost of generating electricity. The TDS not only overcomes the financial burden, but also the consequence of the loss of well-being. Ali and Badar (2010) examined the problem of circular debt in the energy sector of Pakistan. They presented an overview of the energy sector in the case of Pakistan. According to the study, they explained why circular debt arises in the energy sector. Their study identified the main reasons for the circular debt problem. Firstly, the consumer tariff was unsatisfactory to recover the increasing cost of electricity production and government did not compensate for the losses. The second reason highlighted by the researcher that PEPCO failed to recover dues from consumers. To solve the circular debt problem, the government should accept the cost of power subsidies in the budget and adjust power tariffs. Similarly, Qasim and Kotani (2014) addressed the shortage of electricity in the case of Pakistan. They studied the energy shortage by using both an index comparing the demand for electricity, oil and gas and the public supply of electricity. They used a time series approach over the period 1971–2010. Their result suggested that price adjustment is not an effective policy to deal with power shortage, rather the government should improve the utilization rate and redirect the use of oil and gas for electricity generation. Awan et al. (2019) developed a different structure to estimate the impact of direct transfer mechanism of the Tariff Differential Subsidy (TDS) on social welfare from Pakistan perspective. The basic structure was to compare the welfare of poor households that paid the TDS directly, with the impact on the fiscal deficit after targeting the subsidies and evaluate the impact on circular debt. The study investigated these impacts by using the 2010–2011 Social Accounting Matrix (SAM) and the Computed General Equilibrium (CGE) model developed by IFPRI. Their results will not only help the policymakers to formulate a long term sustainable result of power outage but help to reduce negative social and economic impacts.

The remainder of the article includes "Data sources and Methodology" where data, data sources and empirical techniques are used to discover the impact of corruption and circular debt on the electricity crisis. The finding is presented in the "Results and discussion" section and the conclusions of the study are given in the "Conclusion" section of the article.

Methodology

Pakistan is a developing country where electricity gap is very high due to the obstruction in electricity supply and the increase in electricity demand. In this study, electricity gap was used as electricity crisis. Some of the problems like corruption and circular debt increase the demand for electricity. Therefore, it is necessary to analyze the impact of corruption and circular debt on Pakistan electricity crisis. In this study time series data over the selected time period from 1990 to2018 was used. The data were taken from the Pakistan Energy Year Books database of HDI (Pakistan Hydrocarbon Development Institute), the World Bank (2020) and Pakistan Economic Research. The Descriptions of the variables are given in Table 1.

Table 1

Description of the data series

Variables	Definitions	Measurement units	Data sources
EC	Electricity crisis	Billion KW/h	World Bank (2020)
CPI	Corruption perception index	Index	The Global Economy (2020)
CD	Circular debt	Billion PKRs	Energy Year Books (2020)
POP	Population	Number of persons	World Bank (2020)
IGDP	Industrial gross domestic product	PKRs	World Bank (2020)
DT	Distribution and transmission losses	% of electric power output	World Bank (2020)

Sources: Compiled by the authors.

This study employed augmented Dickey and Fuller (1981) and Phillips and Peron (1988) test to examine the data series for stationarity. Using ADF test for checking the autocorrelation in the error term by taking the lagged difference terms of the dependent variable. While Phillips and Peron (1988) used nonparametric statistical methods to deal with the autocorrelation in the error term without taking lags of difference terms. The ADF and PP tests are unit root tests for checking stationarity of the variables. The ADF test could be used with autocorrelation. The ADF test is used for more complex models, while the Dickey Fuller test is used for simple models and this test is also more powerful. In the ADF and PP tests, we can have no constants, or we can have constants, or we can have these constants and a tendency to agree with the different possibilities. The ADF hypothesis for the unit root test is as follows:

$H_0 = y = 1$ (There is unit root)
$H_1 = y < 1$ (Series is stationary)

The ADF and PP tests used three basic regression models

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i-1}^{p} \phi t \, \Delta Y_{t-i} + \mu_t \tag{1}$$

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \sum_{i-1}^{p} \phi t \Delta Y_{t-i} + \mu_t \tag{2}$$

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \beta_0 T + \sum_{i-1}^{p} \phi t \Delta Y_{t-i} + \mu_t \tag{3}$$

The above equations γ denotes the slope coefficient of the lag value of the taken variables and ϕ_i denotes the slope coefficients of the descriptive variables, α_0 indicates the intercept term, β_0 indicates the slope coefficient of the trend; μ_t indicates the error terms at time *t,* and summation *i* indicates the length of the lags starting from 1 up to *p.* Phillips and Peron (1988) developed a number of unit root tests that have become widely used in the analysis of financial time series. The PP test for unit roots differs from the ADF tests mostly in the way it handles autocorrelation and heteroscedasticity in the error terms. The PP tests ignore autocorrelation in the test regression. The test regression for the PP tests is as follows:

$$\Delta Y_t = \gamma Y_{t-1} + \mu_t \tag{4}$$

$$\Delta Y_t = \beta_0 + \gamma Y_{t-1} + \mu_t \tag{5}$$

$$\Delta Y_t = \beta_0 + \gamma Y_{t-1} + \beta_1 T + \mu_t \tag{6}$$

Where β_0 represents the constant terms, while γ denotes the slope coefficients, β_1 indicates that the coefficient of the trend variable, and e_t represents the error term at time *t*. The PP test has the advantage over the ADF test that it is robust to the general form of heteroskedasticity in the error term μ_t. The second advantage of PP is that researchers do not need to specify a lag length for the test regression.

To achieve the proposed objectives, this study used time series data for analysis and estimations of the results; E-views version 10 was used. In this study the ARDL model was used to determine the long-run cointegration between dependent and independent variables, across different levels of integration (Pesaran et al., 2001, Pesaran and Shin, 1999). The reparametrized result provides the short-run dynamics and long-run cointegration of the considered variables. The Pesaran et al. (1996) and Pesaran and Shin (1995) suggested Autoregressive Distributed Lag (ARDL) model for co-integration for a long run co-integration, ignoring weather the taken variables are stationary at level, stationary at 1st difference, or a combination of both. All variables are transformed into logarithmic form, we used log-log model which will reduces the sharpness of the time series data:

$$\Delta logEC_t = \gamma_o + \sum_{i=1}^{p} \gamma_{1i}\, \Delta logEC_{t-i} + \sum_{j=0}^{q} \gamma_{2j}\, \Delta logCPI_{t-j} + \sum_{k=0}^{r} \gamma_{3k}\, \Delta logCD_{t-k}$$
$$+ \sum_{l=0}^{s} \gamma_{4l} \Delta logPOP_{t-l} + \sum_{m=0}^{t} \gamma_{5m}\, \Delta logIGDP_{t-m} \sum_{n=0}^{u} \gamma_{6n}\, \Delta logDT_{t-n}$$
$$+ \pi_1 logCPI_{t-1} + \pi_2 logCD_{t-1} + \pi_3 logPOP_{t-1} + \pi_4 logIGDP_{t-1} + \pi_5 logDT_{t-1}$$
$$+ \delta_1\, ECT_{t-1} + e_t \quad (7)$$

Where Δ is for differentiation. If there is at least one non-zero coefficient, the alternative is accepted, and rejected the null hypothesis; and it is concluded that the relationship is long-term. We used the F-bound co-integration test. If the calculated Wald statistics which follows the F statistic and the value of the F statistics is less than the lower bound, we concluded that there is no co-integration. If Wald's F statistic is greater than the upper bound of Narayan (2004) or Pesran et al. (2001) at 5%, we conclude that there is a long run relationship. Finally, if the value of the F statistic is between the lower and upper limits, the result is inconclusive.

The study also employed other diagnostic tests to check the predictability, reliability, and constancy of the parameters used in the F-bound test approach. The tests used in this study include the White test to identify the heteroscedasticity problem (White, 1980), the Jarque-Bera (JB) test for the normal distribution of the data (Jarque and Bera, 1987), and the Breusch-Pagan-Godfrey LM test to detect the serial correlation problem (Breusch, 1978; Godfrey, 1978). The research checks the stability of the short-run and long-run coefficients of the ARDL model; we used CUMSUM (Cumulative Sum) of the residuals (Brown et al., 1975).

Results and discussion

The study focused on the impact of corruption and circular debt on Pakistan electricity crisis. For this purpose, the study used time series data and selected time was from 1990 to2018. The section begins with the descriptive statistics of the variables. Table 2 shows the descriptive statistics of variables used in the study. It also provides the basic characteristics of the variables. Table 2 shows basic data information including data standard deviation, maximum, minimum, mean, and median of the data. The mean data value shows the mean of the data. The median shows the mid value of the data. The standard deviation shows the value spread from its mean value.

Table 2

Descriptive statistics of the data series

	EC	CPI	CD	POP	IGDP	DT
Mean	5.50	0.88	14.0	4.43	3.22	3.3
Median	5.8	0.9	17.1	4.44	3.2	3.13
Maximum	6.17	1.2	20.7	4.9	3.9	5.33
Minimum	2.9	0.7	6.5	4.05	2.6	2.8
Std. Dev.	1.0	0.14	6.0	0.23	0.4	0.7

Sources: Compiled by the authors based on their own calculations (-hereinafter, unless otherwise noted).

Figure 1 represents the trends of the data series. Trends show the impact of time on the data. Trends can be positive or negative. In the figure, most variables show an increasing trend. The values of each data series increase over time. Therefore, the energy crisis shows a fluctuating trend with values increasing in some phases and decreasing in others. Overall, we can conclude that most economic variables increase over time.

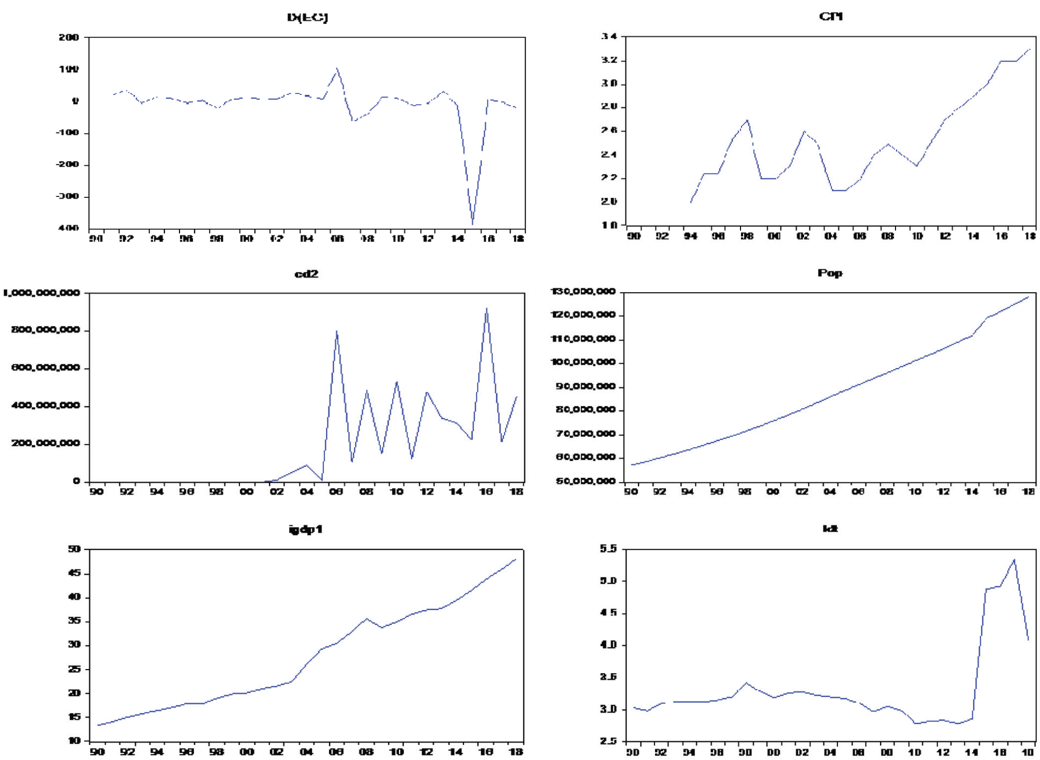

Figure 1: **Trends of variables used in the model.**

The unit root is the problem in time series data where the variance, mean, and covariance of the data are not constant. Before applying the co-integration technique, we make our data stationary. To eliminate the stationarity problem, we use two tests, which are the Augmented Dickey Fuller (ADF) (Dickey and Fuller, 1984) and Phillips and Peron (1988). For these tests, we can use three types of equations (i) taking without intercept and trend (ii) with intercept and without trend (iii) with intercept and trend. Table 3 displays the results of the unit root tests. According to the results, all variables in the ADF and PP tests are stationary at the first difference.

Table 3

Unit root tests results

Variables		ADF			PP		
		Without	Constant	Constant and Trend	Without constant and Trend	Constant	Constant and Trend
EC	Level	-0.832	-0.770	-1.20	-0.848	-0.857	-1.096
CPI		-1.115	-0.808	-2.654	-1.627	-0.333	-2.356
CD		-0.602	-1.176	-1.971	-0.805	-0.333	-2.083
POP		-0.924	-0.207	-3.803	-2.25	-0.506	-2.77
IGDP		-2.232	-0.506	-3.155	-1.954	-2.02	-1.97
DT		-0.085	-1.815	-3.155	-0.167	-1.096	-2.22
EC	1st Difference	-5.489*	-5.514*	-5.945*	-5.490*	-5.525*	-6.137*
CPI		-4.483*	-4.414*	-4.95*	-4.431*	-4.718*	-5.175*
CD		-6.004*	-6.138*	-6.004*	-5.942*	-5.731*	-6.02*
POP		-21.17*	-3.160*	-5.349*	-13.60*	-4.206*	-5.36*
IGDP		-6.47*	-4.97*	-4.166*	-5.90*	-4.644*	-4.10*
DT		-4.670*	-5.25*	-4.166*	-4.716*	-6.15*	-4.45*

Note: * T-stat. shows significance.

The ARDL model requirements are selected on the basis of model selection criteria which include five indicators, namely, the Schwarz-Bayes information criterion (SBC / BIC), log-likelihood, Hannan-Quinn criterion (HQ), adjusted R-squared, and Akaike information criterion (AIC). The model selection criteria define the most appropriate model for the study. The most appropriate model is selected on the basis of length of the lags. In the case of the adjusted R-squared, the model with the highest value is preferred. In the case of other selection criteria, e.g., AIC, log likelihood, SBC / BIC, and HQ criteria, the model with the lowest value is preferred. In this study, the best model is selected on the basis of AIC (Khan and Ullah, 2019), that contains a value of -1.51. The best model is used in the research has the specification (1, 0, 0, 0, 0, 0). We chose the top 20 models in Table 4.

Table 4

Model selection criteria

Model	LogL	AIC*	BIC	HQ	Adj. R-sq	Specification
91	28.19	-1.51	-1.02	-1.38	0.94	ARDL(1, 0, 0, 0, 0, 0)
59	28.94	-1.49	-0.95	-1.35	0.95	ARDL(3, 0, 0, 1, 0, 1)
27	29.933	-1.49	-0.90	-1.34	0.94	ARDL(4, 0, 0, 1, 0, 1)
83	28.71	-1.47	-0.93	-1.33	0.95	ARDL(2, 0, 1, 1, 0, 1)
19	30.69	-1.47	-0.83	-1.31	0.95	ARDL(4, 0, 1, 1, 0, 1)
89	28.57	-1.46	-0.92	-1.32	0.94	ARDL(2, 0, 0, 1, 1, 1)
17	31.50	-1.46	-0.77	-1.27	0.95	ARDL(4, 0, 1, 1, 1, 1)
75	28.49	-1.46	-0.91	-1.32	0.94	ARDL(2, 1, 0, 1, 0, 1)
123	26.38	-1.44	-1.01	-1.33	0.94	ARDL(1, 0, 0, 1, 0, 1)
51	29.33	-1.44	-0.85	-1.30	0.95	ARDL(3, 0, 1, 1, 0, 1)
81	29.29	-1.44	-0.85	-1.28	0.95	ARDL(2, 0, 1, 1, 1, 1)
43	29.09	-1.42	-0.83	-1.27	0.94	ARDL(3, 1, 0, 1, 0, 1)
73	29.05	-1.42	-0.83	-1.26	0.94	ARDL(2, 1, 0, 1, 1, 1)
25	30.05	-1.42	-0.78	-1.25	0.95	ARDL(4, 0, 0, 1, 1, 1)
11	29.99	-1.41	-0.77	-1.25	0.95	ARDL(4, 1, 0, 1, 0, 1)
121	26.94	-1.41	-0.92	-1.28	0.95	ARDL(1, 0, 0, 1, 1, 1)
57	28.94	-1.41	-0.82	-1.25	0.95	ARDL(3, 0, 0, 1, 1, 1)
115	26.92	-1.40	-0.92	-1.28	0.95	ARDL(1, 0, 1, 1, 0, 1)
67	28.85	-1.40	-0.82	-1.25	0.95	ARDL(2, 1, 1, 1, 0, 1)

To achieve the proposed objectives, time series data were used for the analysis and estimation of the results; Version 10 of E-views was used. In this research the ARDL bounds testing method, and the ARDL F-bounds co-integration method were used to determine the long-term correlation between series with different orders of integration (Pesaran et al., 2001; Pesaran and Shin, 1999). The reparameterization result provides the short-term dynamics and the long-term correlation of the variables considered. Pesaran and Shin (1995) and Pesaran et al. (1996) offered the ARDL model for cointegration or the F-bound technique for a long-run cointegration, ignoring whether the variables are integrated at all levels, intergraded at 1st difference, or a combination of both. It has previously said that the integration process (making data stationary by the unit root method) does not allow a simple Ordinary Least Squares (OLS)) approach to give long-term relationship. Therefore, it is also compulsory to make the data stationary, because the data with unit root problems give results that we cannot rely on and this regression is called spurious regression. The spurious regression results are unreliable and predictable, and an efficient and effective decision cannot be made (Granger and Newbold, 1974). This approach includes two parts, the first part is called the F-bound test, which generally specifies the cointegration in the model and the other part is known as the ARDL model, which allows individual short- and long-term results to be obtained. Table 5 presents the results of the ARDL bounds test. The value of the F statistic is 5.68 > then the upper critical limit (4.25) at 5% and K = 5. We accept the alternative hypothesis against null hypothesis and conclude that there is long-term cointegration between Electricity Crisis (EC) with corruption, circular debt, population, industrial gross domestic product and transmission and distribution losses.

Table 5

Results of Bound test for co-integration

Test statistics	**Value**	**K**
F-statistics	5.68*	5
Critical Value Bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	2.75	3.79
5%	3.12	4.25
2.5%	3.49	4.67
1%	3.93	5.23

Note: * 5% shows significance.

Table 6 shows the results of the ARDL model, the variables with Δ sign show the short-term impacts, while the variables without Δ provide the long-term results. As the double log model was used the coefficients of the variables represent the short- and long-term elasticities, respectively. The selection of lags is based on the Akaike Information Criteria. AIC was used to determine the most appropriate length of lags in the model (Khan and Ullah, 2019). We compare the p-value to decide when the p-value < 0.05 (5%) or P < 0.01 (1%). We accept the alternative hypotheses and conclude that there is a short-term relationship. We also consider the t statistics > critical value t, so we accept that there is a short-term relationship for individual coefficients. Here we use the F values to combine the result, because we selected the model based on the AIC, if the F-statistic > F-tab statistics we accept the alternative hypothesis and conclude that there are short-term impacts.

The coefficient of Corruption Perception Index (CPI) is 1.36; the probability value of CPI is 0.001, which is significant at 5%. Therefore, a 1% increase in CPI causes a 1.3% increase in the electricity crisis in the short term, keeping other factors constant. The value of CPI coefficient 1.3% > 1% is elastic in the short term reveals that when a 1% corruption increases it will bring a 1.3% increase in the electricity crisis. The CPI coefficient is highly influential in the long term. The long-term CPI coefficient is 0.973, which is significant at 1%. The long-term elasticity is also less than 1, which shows that CPI is also long-term inelastic. A1% increase in CPI will bring a 0.973% increase in the electricity crisis in Pakistan. The circular debt (CD) coefficient is 0.02, containing 0.02 probability values, which is significant at 5%. CD is inelastic in the short term, i.e., 0.02 <1. The results showed that a 1% increase in CD will bring a 0.02% increase in the electricity crisis in the short term, keeping other factors constant. The CD result is different in the long run. The long-term coefficient is 0.014, which is significant as it contains the p-value 0.01. Long-term elasticity is inelastic, which is less than 1%, i.e., 0.014 <1%. A 1% increase in circular debt in Pakistan leads to a 0.014% increase in electricity crisis in energy sector. The population (POP) coefficient is 0.995 with a probability value of 0.001, which is significant at 5%. Population is inelastic in the short term i.e., 0.995 <1% reveals that population growth is less affected by electricity consumption. Statistics have shown that a 1% increase in population leads to a 0.995% increase in the electricity crisis, keeping other factors constant. Pakistan's population growth has the greatest long-term impact.

The increase in population is directly and significantly related to electricity consumption as stated by Jones (1991), Shiu (2004), Shehbaz (2012), and Imran and Naseem (2015) in the case of Pakistan. The long-term coefficient is 27.23, containing a probability of 0.0004, which is significant at 5%. The population is inelastic in the long term, that is, 27.23 > 1% showed that population growth has a great influence on the electricity crisis. A 1% increase in population leads to a 27.2% increase in Pakistan's electricity crisis (Heli et al., 2017). The industrial gross domestic product is one of the important factors causing the electricity crisis. The transport coefficient of the result -0.44 with a p value of 0.5, which is not significant at 5% and at 1%. The short-term elasticity of the IGDP is inelastic less than 1, that is, -0.44 <1. The results revealed that a 1% increase in industrial growth leads to a 0.44% reduction in the electricity crisis, keeping other factors constant. The result of industrial growth is different in the long run. The IGDP coefficient is -0.32 with a significance of 5% having a probability value of 0.03. The long-term IGDP is inelastic at a 1%, i.e., -0.32 > 1. A 1% increase in industrial growth will ease the -0.32% electricity crisis while keeping other factors constant. The consistent study was employed by Imoro Brainmah (2012) in Ghana, Nwankwo (2013) in Nigeria, and Kiran (2016) in Pakistan (Juneju and Khoso, 2018). Distribution and transmission losses in the energy sector have less impact compared to the long term. The distribution and transmission losses coefficient (DT) () is 2.07 and significant because the p-value is 0.001. A 1% increase in DT leads to a a 2.07% change in the electricity crisis. In the short term, distribution and line losses at each point cut off electricity (Bhatti et al., 2015). In the long run, DT causes a crisis. The coefficient is 1.5, which is significant as it contains the p-value of 0.001. DT is elastic in the long run. The small change in DT means Pakistan's line losses because of technical or non-technical causes of load shedding in the country. In the long run, a 1% increase in DT leads to a 1.5% increase in the electricity crisis, keeping other factors constant (Bhatti et al., 2015). The error correction term (ECT) discovers the dynamic stability of a model in the study. Dynamic stability means that the short-term imbalance in a model automatically leads to long-term equilibrium. The ECT also shows by period (e.g., by year, by month, etc. that depends on the period of the data collected) the model's fit effect and specifies the time period in which the model will enter an equilibrium position. For dynamic stability, the ECT coefficient must be negative and significant. In our results, the value of the ECT coefficient is -1.40, which satisfies the condition of a negative values of the coefficient. The probability value of 0.001 of the ECT coefficient is highly significant at 1%, showing that our model is dynamically stable. The value of the ECT coefficient shows that there is a 140% adjustment effect in the model indicating that the short-term equilibrium is adjusted by 0.71% in one year.

Table 6

Results of ARDL model

Variables	Short run Elasticities		
	Coefficient	**t-statistics**	**p-value**
ΔLCPI	1.365*	2.33	0.001
ΔLCD	0.02	1.16	0.20
ΔLPOP	0.995*	3.866	0.0012
ΔLIGDP	- 0.44	- 0.7	0.540
ΔLDT	2.07*	11.3	0.001
ECT_{t-1}	-1.4*	- 14.9	0.001
	Long run Elasticities		
LCPI	0.973*	2.431	0.026
LCD	0.014*	1.190	0.0128
LPOP	27.231*	4.380	0.0004
LIGDP	-0.320*	-0.625	0.0365
LDT	1.5*	17.34	0.001
Constant	-99.440*	-3.991	0.0009
Log likelihood		28.195	
AIC		-1.5163	
BIC		-1.025	
HQ		-1.38608	
Adj. R^2		0.94	
ARDL (1,0,0,0,0,0)			

Note: * shows significance.

In this study, different diagnostic tests were used to check the stability, reliability, and predictability of the series. Table 7 shows the results of the diagnostic tests. The White test (White, 1980) was employed to check the heteroscedasticity problem. The heteroscedasticity problem indicates that the variance of the error terms is not constant. It follows the chi-square (χ^2) distribution. The rule for making decision is, if the probability value of the χ^2 statistic is less than 0.05, we accept the alternative hypothesis H_1, which states that there is a heteroskedasticity problem in the model. If the probability value of the χ^2 statistic is greater than 0.05, we accept the null hypothesis H_0 showing that there is homoscedasticity (no heteroscedasticity problem) in the data. In the results of this study, the probability value of the χ^2 statistic is 0.98, which is greater than 0.05. This means that we accept the null hypothesis H_0, which states that homoscedasticity exists, i.e., there is no heteroscedasticity problem in the model. The Breusch-Pagan-Godfrey LM test (Breusch, 1978; Godfrey, 1978) is employed to check the serial correlation problem. The serial correlation also shows the existence of a relationship between the residuals. In this case, the correlation must exist between the error terms of two consecutive periods. The chi-square distribution (χ^2) follows. Table 7 shows the results of the Breusch-Pagan-Godfrey LM test. The decision rule is that, if the probability value of χ^2-statistic is less than 0.05, we accept the alternative hypothesis H_1, which shows the existence of the problem of serial correlation whereas, if the probability value of χ^2-statistic is greater than 0.05, we accept the null hypothesis H_0, which indicates that there is no serial correlation problem in the data. The result of our study indicates that, the probability value of χ^2-statistic is 0.45 which is greater than critical value at 5% (i.e., 0.45 > 0.05). It expresses that we will accept the null hypothesis H_0, which designates that the model does not have the problem of serial correlation. The study also used the Jarque-Bera test (Jarque and Bera, 1987) for testing normal distribution of the data. The normal distribution exposes that the data are equally distributed on both sides of their mean value. The Jarque–Bera test follows the F-distribution. The decision rule is that, if the probability value of the F-statistic is less than critical value at 5% (< 0.05), then we accept the alternative hypothesis H_1 showing that the data are not normally distributed and if the probability value of the F-statistic is greater than critical value at 5% (> 0.05), then we accept the null hypothesis H_0 showing that the data are normally distributed. The outcomes of this study, the probability value of F-statistic is which is greater than critical value at 5% (i.e., 0.46 > 0.05). This shows that we will accept the null hypothesis H_0, which states that our data are normally distributed.

Table 7

Results of Diagnostic Test

Test Type	Statistics	Value	DF	Probability
White Test	χ2-statistic	0.57	23,1	0.98
Breusch–Pagan-Godfrey LM test	χ2-tatistic	0.82	23,1	0.45
Jarque–Bera test	F-statistic	1.54	–	0.46

Figure 2 explains the results of the CUSUM test, which is used to test the stability of the model (Brown et al., 1975). If the results of both used techniques are significant at 5%, we accept the alternative hypothesis H_1, which states that the parameters are stable if the results of both tests are insignificant at 5%, this specifies that the acceptance of the null hypothesis H_0 showing that the parameters are unstable. Figure 2 shows that the results of the CUSUM test are significant at 5%. Therefore, we reject the null hypothesis and accept the alternative hypothesis H_1, which proves that the parameters are stable.

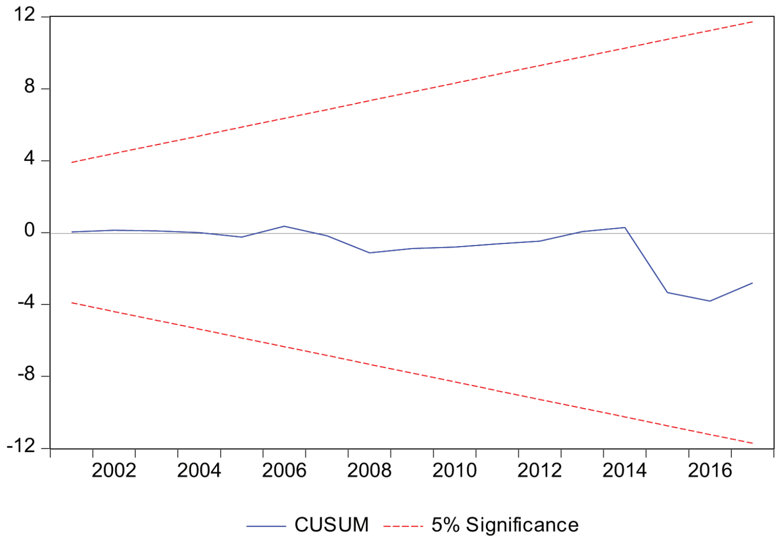

Figure 2: **Result of CUSUM test**

Conclusions and recommendations

The aim of this research was to examine the impact of corruption on the electricity crisis in Pakistan. This study used annual time series data from 1990 to 2018. The study used electricity crisis as the dependent variable, the electricity crisis is measured by the difference of electric power consumption and electric power production in KWh, the five independent variables namely corruption, circular debt, population and distribution and transmission losses. At first, the ADF test and PP test were used to examine the problem of unit root and made series stationary. Both tests were applied to three types of equations such as (i) without intercept and trend, (ii) with intercept and without trend (iii) with intercept and trend. Based on the ADF test, decided that all variables are stationary at 1st difference i.e., I (1) or at level. The results of the ADF without intercept and trend were stationary at the first difference having different lags, as well as the results of the ADF with intercept were also stationary at the first difference while the variable POP (Population) was stationary at level having intercept and trend factor. To eliminate the problem of unit root, the study checks short run and long run impact of variables using the ARDL F- bound test. The outcome of ARDL reveals that corruption and circular debt have positive and significant impact on electricity crisis. corruption has high influence on the electricity sector in Pakistan. The amount of circular debt in the power sector rises per year due to non-payment to IPPs the electricity shortage arises in each sector in Pakistan. The corruption in the power sector and bribery causes less amount of electricity crisis in the short run. In addition, the circular debt also affects the electricity crisis. Corruption in the power sectors highly influenced all areas of the power sector. Many reasons cause the electricity crisis. This study used population growth as the cause of the crisis, when the result had a positive and significant impact on the power sector in both the short and long term. With industrial growth more machinery was used for operation, so the electricity demand increased. Industrial growth has a negative and significant impacts on the electricity crisis which means that when the industry expanded the supply of electricity decreases, leading to a reduction in the production. The industrial gross domestic product carries negative and significant impacts electricity crisis, both in the long and short term. Distribution and transmission losses in Pakistan were also one of the important determinants that caused the electricity crisis. In the short run, the distribution and transmission losses of power lines have a strong impact on the supply of electricity to the population. While in the long run the distribution and transmission losses have less impact as compared to short run. The distribution and transmission losses are of technical and non-technical nature, the result of this study showed that both types of losses cause electricity crisis. The result of the ARDL F-bound test also shows that all the variables used in the model are co-integrated. The proper lags length in the ARDL model was determined based on AIC. After testing co-integration in the model, to investigate the reliability, stability and predictability of parameters, some of the diagnostic tests were used. The findings of the White test showed that the selected ARDL model is free from the problem of heteroscedasticity. The Breusch–Pagan-Godfrey LM test confirmed that the model is free from problem of autocorrelation/serial correlation. The results of the Jarque–Bera test confirmed that the data employed in this study are normally distributed. The study also used CUSUM test to check the stability of model's parameters. The CUSUM test confirmed that parameters are stable.

The results of the study proved that corruption is one of the reasons for load shedding and electricity outage in Pakistan. This study concluded that circular debt is one of the main drivers of Pakistan's electricity crisis, which could be traced back to the area where payment disruption arises and to reduce the debt burden of the electricity sector. Some recommendations based on the findings of this study can be suggested:

1. Strict government policies against corruption can be a vital in the energy sector. Bribery is also a part of corruption. It also needs considerable steps to eradicate corruption.
2. Circular debt is an extra burden on the economy. Each institution in the electricity sector should make sure to clear its dues.
3. The introduction of electrically efficient equipment will reduce the energy crisis. Rapid population growth will not be a major cause of the energy crisis. It will also allow the commercial sector to use energy more efficiently.

4. The efficient use of electricity through the introduction of advanced devices will encourage the industrial sector to contribute more to Pakistan's GDP.
5. New electricity production projects are needed to overcome the energy crisis. CPEC project will be one of the government's major initiatives to overcome the problem of Pakistan's electricity crisis. It is important to note that green projects will be more beneficial for both people and economy.

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