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Energy Crisis, Exchange Rates, and their Influence on South Africa's Gross Domestic Product

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Abstract:

Purpose: *This study investigates the long-term and short-term impacts of South Africa's energy crisis and exchange rate fluctuations on its Gross Domestic Product (GDP) from 2013 to 2023. The analysis focuses on key macroeconomic indicators such as employment, productivity, energy prices, and economic growth.*
Design/Methodology/Approach: *Utilising time series econometric techniques, including unit root tests for stationarity, the Johansen cointegration test, the CUSUM and CUSUMSQ stability tests, the Vector Error Correction Model (VECM), and Granger causality analysis, the research identifies significant relationships among the variables.*
Findings: *The findings reveal that GDP, energy prices (as a proxy variable), the real exchange rate, and investment (as a control variable) exhibit a long-run equilibrium relationship. Specifically, changes in any of these variables significantly influence the others over time. In the short run, VECM results indicate that energy prices and investment positively affect GDP, while the real exchange rate has a negative impact.*
Practical Implications: *The study emphasises the need to mitigate the adverse effects of high electricity tariffs on exchange rates through the promotion of foreign direct investment (FDI).*
Originality/value: *The study advocates for dismantling Eskom's monopoly to foster competition within South Africa's energy sector, thereby enhancing operational efficiency and energy market performance.*

Keywords: *GDP, South Africa, VECM, Granger causality, Cointegration, Eskom.*

JEL classification: *E23, O55, C32, Q43.*

Paper type: *Research paper.*

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1. Introduction

This study aligns with the United Nations (UN) Sustainable Development Goal 7, which ensures all access to affordable, reliable, sustainable, and modern energy (SDG, 2023). South Africa, like other developing countries, has been experiencing energy imbalances and blackouts since the mid-2000s (Oliphant, 2023).

In 2021, Limpopo citizens complained about energy shortages for more than 8 hours daily. Residents claim the electricity company exploits them because they live in rural areas (Malesele, 2021). Energy is considered a vital force that powers businesses, manufacturing, transportation, households, and service delivery, enabling real GDP growth and stability in modern living (Department of Energy, 2019).

The COVID-19 pandemic and the Russian invasion of Ukraine have caused significant inflation and a global economic slowdown, leading to large exchange rate adjustments around the world, with the US dollar index appreciating by around 10 per cent since the beginning of this year, reaching its highest level in nearly four decades (Hofmann, Mehrotra and Sandri, 2022).

However, South Africa, a leading exporter in Africa, has faced negative financial practices in the last five years due to its flexible exchange rate regime since 2000. The devalued Rand and interest rate pressure have made monetary policy interventions impractical, causing inflationary pressure and affecting small businesses and indebted citizens (Muzekenyi, Zuwarimwe, Kilonzo and Nheta, 2018).

The availability of energy is significant in the production capacity and consumption of goods and services and a country's growth prospects, and it determines the shape and lifestyle of individuals and the economy (Coyle and Simmons, 2014). Conversely, the exchange rate significantly influences a country's economy, with imports, exports, and exchange rates being critical determinants of economic growth and influenced by it (Habanabakize, 2020). The robustness of an energy crisis has enabled unprecedented economic growth, prosperity, and globalisation, particularly during the past century (Coyle and Simmons, 2014).

South Africa relies on imports for its energy, particularly oil and gas. As a result, exchange rate movements tend to affect the energy process in South Africa (Oliphant, 2023). Due to the drop in domestic production activities, imports and exports also dropped, affecting exchange rates.

Firms are forced to cut their output, and household consumption does not change much; exports of goods and services would decrease (Timilsina, Sapkota, and Steinbuks, 2018). Energy power cuts directly affect the real GDP, and a higher domestic currency boosts imports but negatively impacts exports and decreases

overseas asset values. In contrast, a low home currency promotes exports but decreases imports (PSA, 2023; Maxwell, 2018; Pociovalisteanu *et al.,* 2010).

2. Literature Review

2.1 Theoretical framework

The Harrod-Domar growth model explains how investment leads to growth, highlighting the need for domestic saving for targeted GDP growth rates and national capital-output ratios (Todaro and Smith, 2020). However, in South Africa, Eskom's financial instability contributes to the energy crisis, negatively impacting the organisation. Increased savings can boost productivity, but a higher capital-output ratio can decrease productivity, especially in coal production. The Harrod-Domar model, which only considers investments and savings, lacks the role of the labour force in the production phase (Lenoka, 2017).

The Purchasing Power Parity (PPP) theory states that the exchange rate between two countries' currencies is the ratio of their prices, including most goods and services produced in each country. It assumes the 'Law of One Price,' where the price of a commodity remains constant for both countries (Nápoles, 2004).

CPI-based PPP can also be biased due to the difference in the productivity of non-tradable goods between countries (Harada, 2024). Changes in exchange rates can significantly affect the profitability of exporters and the prices paid by consumers, complicating the comparison of the economies of different countries (Vo and Vo, 2023; Bilal *et al.,* 2025).

The photovoltaic effect theory predicts the optimal characteristics of a semiconductor for solar energy transduction, which is determined by the semiconductor's optical characteristics and electrical attributes (Loferski, 1956). Solar energy variability is crucial for life on Earth, with solar radiation being the most essential source. To optimise surface orientation, estimating the amount of solar energy collected by different orientated surfaces is essential (Widén and Munkhammar, 2019).

2.2 Empirical Review

Previous studies highlighted the impacts of energy supply and exchange rates on South Africa's GDP. Mpatane's (2015) research examines South Africa's manufacturing sector output and found a positive long-term relationship between manufactured output and manufacturing employment and between manufactured output and electricity supply, using cointegrated VAR methodology.

Similarly, Oliphant's (2023) study on South Africa's energy prices found high exchange rate volatility, with a positive long-term relationship between energy

prices, trade openness, real exchange rate volatility, and money supply. However, inflation rate and interest differentials negatively affect prices. The study recommends that the government and central banks intervene to manage exchange rates and reduce deviations. The study seeks to bridge the gap by investigating the extent of the energy crisis and exchange rate fluctuations across South Africa's GDP.

Rao (2023) studied the impact of foreign exchange rates on macroeconomic variables in India. The study used the Ordinary Least Squares (OLS) method to regress the dependent variable on the independent variables and found that a currency's depreciation increases foreign exchange reserves and economic expansion. The study's findings were validated using software, econometric tests, and data from the World Bank's World Development Indicators and the International Monetary Fund's International Financial Statistics.

Nyathi (2017) used data that ranges from 1970 to 2014 to estimate a long-run co-integration relationship between the real effective exchange rate and its fundamentals. The lack of evidence for the PPP hypothesis suggests that, in the long run, various variables affect actual exchange rates and lead to movements that have deviated from their original equilibrium value but do not enable them to return.

Thus, a study examining the relationship of actual exchange rates with energy prices in South Africa is appropriate because further factors can impact these values over time.

In generalised equations, Yonar and Iyit (2018) modelled the causality relationships between GDP/GNI and electricity consumption according to countries' income levels. The study investigates the causal relationship between GDP values and energy consumption at five income levels. The Granger causality test determined the relationship between GDP and energy consumption. The results showed only one causal relationship between high-income countries and their GDP.

The generalised estimating equations (GEE) method was used to model the data, finding the smallest QIC and QICC information criteria values in the direction of causality relationships. The same causality assessment was done between the gross national incomes (GNI) of countries categorised by income levels and energy consumption. The findings suggest that the causality test is useful when there is insufficient knowledge of determining dependent and independent variables before fitting regression models to the data.

3. Methodology

This study uses a quantitative research design to examine the long-term effects of the energy crisis and exchange rate fluctuations on South Africa's GDP, ranging from 2013 to 2023. The study uses Javed *et al.'s* (2022) theoretical framework to analyse the impact of the energy crisis and exchange rates on GDP in SA. Data is collected

from the South African Reserve Bank, Federal Reserve Economic Data, and Statistics South Africa. The analysis focuses on quarterly data, with the dependent variable being the Economic Growth Rate (EGR) and the independent variables being Energy Price (EPR), Real Exchange Rate (RER), and Investment (INV).

Various econometric techniques are employed, including stationarity tests, Johansen cointegration tests, Vector Error Correction Models (VECM), and Granger causality tests. The study aims to provide insights into how energy supply issues and exchange rate volatility affect South Africa's economic performance and contribute to policy discussions for sustainable economic recovery.

3.1 Model Specification

Economic growth rate = f (energy price, real exchange rate, investment)
Expressing the model in the estimable form:

$$EGR_t = \beta_1 + \beta_2 EPR + \beta_3 RER_t + \beta_4 RER_t + \beta_5 RER_t + \mu \quad (1)$$

Where

EGR	=	Economic Growth Rate
EPR	=	Energy price
RER	=	Real exchange rate
INV	=	Investment
μ	=	The error term in the model represents factors that lead to variations in the energy crisis not considered in the model.
β_1	=	denotes the intercept,
β_2–β_5	=	partial regression coefficients.
't'	=	indicates time series data.

3.2 Johansen Cointegration Tests

Before conducting the Johansen cointegration test, all variables—Gross Domestic Product (GDP), Energy Price (EPR), Real Exchange Rate (RER), and Investment (INV)—were confirmed to be integrated of the same order, I (1), via unit root testing. Given this, the Johansen procedure was implemented to test the existence of a long-run equilibrium relationship among the variables.

Table 1. *Johansen Cointegration Rank Test (Trace and Max-Eigenvalue)*

Hypothesised No. of CE(s)	*Eigenvalue*	*Trace Statistic*	*0.05 Critical Value*	*p-value*	*Max-Eigen Statistic*	*0.05 Critical Value*	*p-value*
*None **	0.6133	61.3396	47.8561	0.0017	38.9555	27.5843	0.0011
At most 1	0.2521	22.3840	29.7971	0.2776	11.9120	21.1316	0.5564
At most 2	0.1921	10.4720	15.4947	0.2462	8.7446	14.2646	0.3080
At most 3	0.0413	1.7274	3.8415	0.1887	1.7274	3.8415	0.1887

Source: *Author's computation using E-Views (2024).*

The Trace and Maximum-Eigenvalue tests reject the null hypothesis of no cointegration at the 5 per cent level for the first rank (None). The trace statistic (61.34) exceeds the 5 per cent critical value (47.86), and the associated p-value is 0.0017. Likewise, the Max-Eigen statistic (38.96) is greater than the critical value (27.58), with a p-value of 0.0011.

However, for subsequent ranks (At most 1, At most 2, and At most 3), both the trace and maximum eigenvalue statistics are below their corresponding critical values, and p-values exceed 0.05. Therefore, the null hypothesis of no additional cointegrating relationships cannot be rejected.

The Johansen test results provide evidence of one cointegrating vector, suggesting a stable long-term relationship among GDP, EPR, RER, and INV. This implies that the variables move together in the long run, and deviations from the equilibrium relationship are likely to be temporary.

In economic terms, this confirms that energy price, real exchange rate, and investment are significant long-run determinants of GDP. The existence of cointegration justifies the application of a Vector Error Correction Model (VECM) to capture both short-run dynamics and the speed of adjustment toward long-run equilibrium.

3.3 Normalised Cointegrating Coefficients

The long-run relationship on GDP, Energy Prices (EPR), Real Exchange Rate (RER), and Investment (INV) is represented by the normalised cointegrating coefficients.

Table 2. *Normalised Cointegrating Coefficients*

Variable	Coefficient	Standard Error
GDP	1.000000	—
EPR	-3.3739	(0.7060)
RER	0.1257	(0.0790)
INV	1.15E-05	(1.2E-05)

Source: *Author's computation using EViews (2024).*

The results show that energy prices (EPR) have a statistically significant and negative impact on GDP in the long run. Specifically, a one-unit increase in energy prices leads to a 3.37-unit decrease in GDP, ceteris paribus. This negative relationship is consistent with economic theory, as higher energy prices typically increase production and operational costs, suppressing economic output.

Conversely, the real exchange rate (RER) has a positive long-run impact on GDP. A one-unit increase in RER increases GDP by 0.1257 units, suggesting that an appreciation in the real exchange rate (potentially indicating currency strength or lower import costs) contributes positively to economic growth.

Investment (INV), although positively related to GDP, has a small coefficient (0.0000115), indicating a negligible impact on long-term growth. This may suggest inefficiencies or lagged effects in investment returns over the long run.

3.4 Vector Error Correction Model (VECM).

Following the establishment of cointegration, the Vector Error Correction Model (VECM) was estimated to examine the short-run dynamics and speed of adjustment toward the long-run equilibrium.

The Error Correction Term (ECT) is found to be -0.2876 and is statistically significant at the 5 per cent level, with a t-value of -2.0616, which exceeds the critical value of ±1.96 in absolute terms.

Table 3. *VECM Estimation Results*

Variable	Coefficient	Standard Error	T-value
ECT	-0.2876	0.1395	-2.0616
EPR	0.5162	0.1869	2.7616
RER	-0.5913	0.7251	-0.8155
INV	0.0001	0.0001	1.3059
R-squared	0.75	—	—
F-statistic	21.8200	—	—

Source: *Author's computation using EViews (2024).*

The ECT indicates that approximately 28.8 per cent of deviations from the long-run equilibrium are corrected within a quarter, suggesting a moderate speed of adjustment. Among the independent variables, only energy prices (EPR) are statistically significant in the short run, with a positive coefficient of 0.5162.

This implies that, in the short term, rising energy prices may reflect higher production activity, which in turn boosts GDP, potentially due to increased energy consumption in growing sectors (André, Costa, Demmou, and Franco, 2023.

The real exchange rate (RER) shows a negative short-run impact on GDP (-0.5913), though the effect is not statistically significant (t = -0.8155) (Panshak, Civcir, and Ozdeser, 2019). Investment (INV) remains positively related to GDP, but its impact is both economically and statistically insignificant in the short run (Mofrad, 2012).

3.5 Granger Causality Tests

The Granger causality test was conducted to explore causality relationships.

Table 4. *Granger Causality Test Results*

Null Hypothesis	P-value
EPR does not Granger cause GDP	0.9515
GDP does not Granger cause EPR	0.1718
RER does not Granger cause GDP	0.8023
GDP does not Granger cause RER	0.7211
INV does not Granger cause GDP	0.3634
GDP does not Granger cause INV	0.1964
RER does not Granger cause EPR	0.9106
EPR does not Granger cause RER	0.0214
INV does not Granger cause EPR	0.2887
EPR does not Granger cause INV	0.4866
INV does not Granger cause RER	0.9134
RER does not Granger cause INV	0.2874

Source: *Author's computation using EViews (2024).*

The results suggest no significant Granger causality between GDP and the independent variables (EPR, RER, and INV), as all p-values exceed the 0.05 significance level. Hence, we fail to reject the null hypotheses, indicating that none of the independent variables Granger cause GDP, and vice versa, in the short run (Massa and Rosellón, 2020).

However, a unidirectional causality is observed from EPR to RER, with a p-value of 0.0214 (Mohammed Suliman and Abid, 2020). This finding implies that fluctuations in energy prices can predict future movements in the real exchange rate, which could reflect the energy cost's influence on trade balances, inflation, and ultimately, currency valuation. This result offers critical policy implications for managing energy markets and macroeconomic stability.

3.6 Diagnostic Tests

Three key diagnostic tests were performed to validate the estimated growth model's robustness and reliability: the Lagrange Multiplier (LM) test for serial correlation, the White test for heteroscedasticity, and the Jarque-Bera (JB) test for normality.

Table 5. *Diagnostic Test Results*

Test	Null Hypothesis	P-value
LM Test	No serial correlation	0.2200
White Test	No conditional heteroscedasticity	0.8729
JB Test	Residuals are normally distributed	0.0000

Source: *Author's computation using EViews (2024).*

Serial correlation (LM test):

The LM test result yields a p-value of 0.2200, which exceeds the 5 per cent significance level. Thus, we fail to reject the null hypothesis of no serial correlation, indicating the residuals are not autocorrelated.

Heteroscedasticity (White test):

The White test for heteroscedasticity reports a p-value of 0.8729, well above the 0.05 threshold. Hence, the null hypothesis of homoscedastic residuals is not rejected, confirming constant variance in the error
terms.

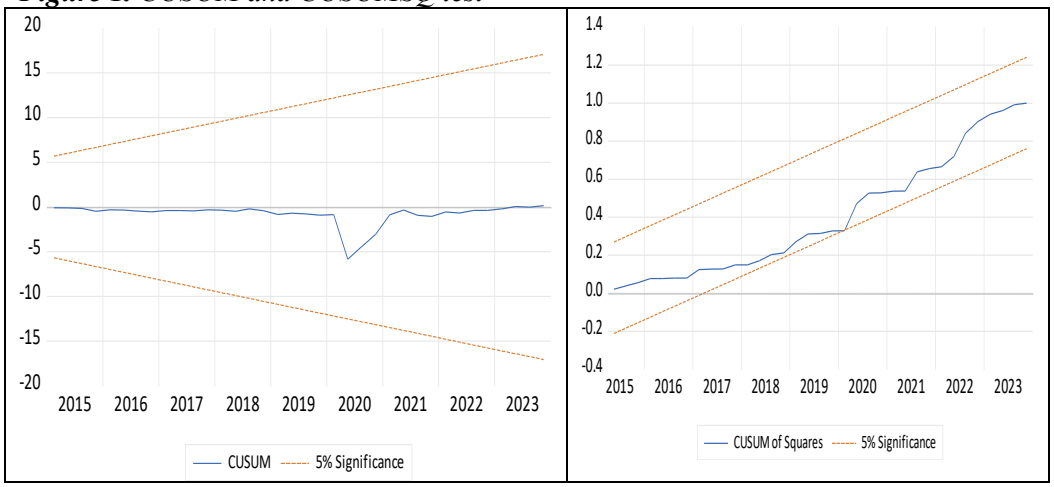
Normality (Jarque Bera (JB) test):

The JB test returns a p-value of 0.0000, which is below the 5 per cent significance level, indicating that the residuals deviate from normal distribution. Nevertheless, Schmidt and Finan's (2018) model with more than 10 observations per variable is robust to violations of the normality assumption. Given that each variable in this model satisfies that criterion, the model's results remain valid and reliable.

3.7 Stability Tests: CUSUM and CUSUMSQ.

The CUSUM and CUSUM of Squares (CUSUMSQ) tests were employed to evaluate the parameter stability of the estimated model over time. These tests are crucial in assessing whether the estimated coefficients remain stable across the sample period.

Figure 1. *CUSUM and CUSUMSQ test*



Source: *Author (Compiled from E-views).*

Both the CUSUM and CUSUMSQ plots fall within the 5 per cent confidence bounds, which implies that the parameters of the model are structurally stable throughout the estimation period. This affirms the reliability of the model's estimates and further validates its suitability for both policy analysis and forecasting.

4. Conclusion and Recommendations

4.1 Conclusions

This study aimed to assess the impact of load shedding on South Africa's economic growth, proxied by GDP, using energy prices (EPR) as a key indicator of the energy crisis. Real exchange rates (RER) and investment (INV) were incorporated to capture macroeconomic dynamics, with investment serving as a control variable.

Stationarity of the series was confirmed using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. All variables were found to be integrated of order one, I (1), indicating suitability for cointegration analysis. The PP test results were consistent with those of the ADF, strengthening the reliability of findings.

Lag length selection based on the Akaike Information Criterion (AIC), which had the lowest value of 33.4784 among competing criteria, informed the optimal lag structure for the VAR model. The Johansen cointegration test results using both the trace and maximum-eigenvalue statistics confirmed the existence of at least one long-run cointegrating relationship among GDP, EPR, RER, and INV at the 5 per cent level. This indicates a common stochastic trend and supports the use of the Vector Error Correction Model (VECM).

The long-run normalised cointegrating coefficients reveal a significantly negative relationship between energy prices and GDP, suggesting that rising energy prices hinder economic growth by increasing production costs, reducing consumption, and dampening aggregate output. In contrast, a positive long-run relationship was observed between GDP and the real exchange rate, implying that a stronger currency supports GDP growth through lower import costs and inflation stabilisation. Investment, however, exhibited a negligible long-run impact on GDP.

In the short run, VECM estimates show that energy prices and investment exert a positive influence on GDP, while the real exchange rate has a negative effect. Nevertheless, only energy prices are statistically significant in predicting GDP variations in the short run, as reflected by their t-value exceeding the 1.96 threshold at the 5 per cent level.

Granger causality tests revealed no causal relationships between GDP and any of the independent variables (EPR, RER, INV). However, a unidirectional causal relationship was detected from EPR to RER, indicating that energy price shocks can

predict exchange rate movements. This finding is relevant for monetary and trade policy formulation.

The diagnostic tests confirmed the robustness of the estimated model. The LM test indicated no serial correlation, and the White test revealed homoscedastic residuals. Although the Jarque-Bera test pointed to a non-normal distribution of residuals, this does not significantly affect the model's reliability given the sufficiently large sample size per variable, as per Schmidt and Finan (2018). Additionally, stability tests using CUSUM and CUSUMSQ confirmed the structural stability of the model throughout the study period.

4.2 Policy Recommendations

Given the study's findings, the following policy recommendations are proposed:

Energy Policy Reform:
Diversification of energy sources is critical. Eskom should expand capacity through the construction of additional power plants and investment in renewable energy sources such as solar and hydroelectric power. Government support in the form of solar panel provision to schools and businesses would reduce grid dependency and alleviate pressure on the national energy infrastructure. The government should enforce stricter quality control in coal procurement to prevent the supply of substandard materials, which damage equipment and reduce generation efficiency.

Liberalisation of the Energy Sector:
The current energy supply monopoly held by Eskom should be restructured. Removing exclusive rights and encouraging market entry through subsidies and capital support to domestic companies (e.g., Phuzamanzi Electrical and Adenco Construction) can foster competition, efficiency, and increased energy supply, ultimately supporting GDP growth.

Exchange Rate Management:
Given the link between energy prices and exchange rate volatility, the government should implement real-time monitoring systems to anticipate and manage currency shocks. Businesses should be encouraged to diversify revenue streams and adopt hedging strategies to mitigate exchange rate risks. The promotion of financial literacy and risk management tools will empower firms and individuals to make informed decisions amid currency volatility.

Economic Diversification:
Overreliance on energy-intensive sectors should be reduced by promoting diversified industrial growth. This will improve macroeconomic resilience and contribute to stable, long-term GDP growth. Firms should be incentivised to adjust strategies related to pricing, sourcing, and investment planning to better navigate currency and energy shocks.

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