

THE EFFECT OF ELECTRICITY CONSUMPTION, PRICE AND
COAL EXPORTS ON ECONOMIC GROWTH IN SOUTH AFRICA

by

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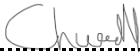
2025

DECLARATION

I declare that the dissertation titled **“THE EFFECT OF ELECTRICITY CONSUMPTION, PRICE AND COAL EXPORTS ON ECONOMIC GROWTH IN SOUTH AFRICA”** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institution.

Natasha Tihologelo Chuene

Full names



Signature

10/02/2025

Date

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ABSTRACT

Coal, recognized as a significant energy source, is a mineral commodity that is traded among countries. As a developing nation, South Africa is among the wealthiest and most dependent on coal as an input for electricity generation. Electricity consumption is a crucial contributor to GDP, and conversely, GDP plays a pivotal role in driving electricity consumption. However, the country faces a critical issue with electricity rationing and escalating electricity prices, sparking growing concerns as tons of coal are being exported. The study analyzed the effect of electricity consumption, electricity price, and coal exports on South Africa's economic growth using quarterly data from 2016 to 2023. Through the Autoregressive Distributed Lag (ARDL), the study examined the long-run along with the short-run relationships. Secondly, to further inform policy, the Granger causality test was incorporated to evaluate the variables' causal relationship. Lastly, upon detecting existing causality, the economy's future path was forecasted through the Impulse Response Function (IRF) and Variance decomposition. In the long run, electricity consumption and price positively correlate with GDP at a 1% significance level, while coal exports negatively correlate with GDP at a 5% significance level. Electricity consumption aids productivity enabling seamless operations in various sectors. High electricity prices can drive businesses and households to invest in energy-efficient technologies and practices. This can lead to innovations and advancements in energy-saving solutions, fostering new industries and job creation. The export of coal in South Africa contradicts the export-led growth hypothesis as it has not resulted in significant economic benefits which is questionable due to the dire state of the country of having loadshedding. And as seen, load shedding has been detrimental to the economy. Thus, the findings of this study will provide policymakers with useful insights for making strategic decisions to enhance long-term economic growth and strengthen South Africa's energy sector.

Key words: GDP, electricity consumption, electricity price, coal exports, ARDL, South Africa.

TABLE OF CONTENTS

DECLARATION	i
ACKNOWLEDGEMENTS	ii
ABSTRACT	iii
ACRONYMS	ix
LIST OF FIGURES	x
LIST OF TABLES	xi
CHAPTER 1	1
ORIENTATION OF THE STUDY	1
1.1 INTRODUCTION AND BACKGROUND	1
1.2 PROBLEM STATEMENT	4
1.3 RESEARCH AIM AND OBJECTIVES	5
1.4 RESEARCH QUESTIONS	5
1.5 SIGNIFICANCE OF THE STUDY	5
1.6 DEFINITION OF KEY CONCEPTS	6
1.7 ETHICAL CONSIDERATIONS	7
1.8 STRUCTURE OF THE STUDY	7
CHAPTER 2	8
OVERVIEW OF ECONOMIC GROWTH, ELECTRICITY CONSUMPTION, PRICE AND COAL EXPORTS	8
2.1 INTRODUCTION	8
2.2 AN OVERVIEW OF ECONOMIC GROWTH	8
2.3 OVERVIEW OF ELECTRICITY SECTOR IN SOUTH AFRICA	14
2.4 AN OVERVIEW OF ELECTRICITY PRICE IN SOUTH AFRICA	20
2.5 OVERVIEW OF COAL EXPORTS	25

2.6 GOVERNMENT AND POLICY INTERVENTION	28
2.7 CHALLENGES AND IMPEDIMENTS TO POLICY IMPLEMENTATION	32
2.8 SUMMARY	33
CHAPTER 3	36
LITERATURE REVIEW	36
3.1 INTRODUCTION	36
3.2 THEORETICAL FRAMEWORK	36
3.2.1 The Solow growth model	36
3.2.2 The export-led growth hypothesis	38
3.2.3 Resource Curse Theory	39
3.3 EMPIRICAL LITERATURE	40
3.3.1 The impact of electricity consumption and price on economic growth.....	40
3.3.2 The effect of coal exports on economic growth	43
3.3.3 Causality effect among the variables	43
3.3.4 The economic growth forecast from shock effects of electricity consumption and prices, and coal exports	45
3.4 SUMMARY	46
CHAPTER 4	47
RESEARCH METHODOLOGY	47
4.1 INTRODUCTION	47
4.2 DATA	47
4.3 MODEL SPECIFICATION	47
4.4 ESTIMATION TECHNIQUES	48
4.4.3 Unit root/ stationarity test	49
4.4.3.1 Augmented Dickey-Fuller test.....	50

4.4.3.2 Phillips Perron test.....	51
4.4.4 Lag length criteria	52
4.4.5 Cointegration test (Bounds Test).....	52
4.4.5.1 Autoregressive Distributed Lag Model (ARDL).....	53
4.4.5.2 Error Correction Model	55
4.4.6 Pairwise Granger causality test.....	56
4.4.7 Diagnostic tests.....	57
4.4.7.1 Normality test.....	57
4.4.7.2 Serial Correlation Test.....	58
4.4.7.3 Heteroskedasticity test	58
4.5 SUMMARY	60
CHAPTER 5.....	61
DISCUSSION/ PRESENTATION/ INTERPRETATION OF FINDINGS.....	61
5.1 INTRODUCTION.....	61
5.2. EMPIRICAL TEST RESULTS.....	61
5.2.1 Descriptive statistics results	61
5.2.2 Correlation analysis.....	63
5.2.3 Unit root/ stationarity test results.....	64
5.2.4 Lag Length Selection Criteria.....	66
5.2.5 Cointegration test results	66
5.2.6 Autoregressive Distributive Lag (ARDL) results	67
5.2.7 Error correction model.....	69
5.2.8 Pairwise Granger Causality Results.....	70
5.2.9 Diagnostic test results	71
5.2.10 Stability test results	73

5.2.11 Impulse Response Function	73
5.2.12 Variance Decomposition	75
5.3 SUMMARY	77
CHAPTER 6	79
SUMMARY, RECOMMENDATIONS, CONCLUSION	79
6.1 INTRODUCTION	79
6.2 SUMMARY AND INTERPRETATION OF FINDINGS	79
6.3 CONCLUSION AND RECOMMENDATION.....	82
6.4 CONTRIBUTIONS OF THE STUDY	83
6.5 LIMITATIONS OF THE STUDY	84
6.6 AREA OF FUTURE RESEARCH.....	84
REFERENCES.....	85
APPENDICES	103
APPENDIX A: DATA.....	103
APPENDIX B: DESCRIPTIVE STATISTICS.....	105
APPENDIX C: CORRELATION ANALYSIS	105
APPENDIX D: UNIT ROOT TESTS RESULTS	105
APPENDIX D1: AUGMENTED DICKEY FULLER TEST RESULTS	105
APPENDIX D2: PHILLIPS PERRON TEST RESULTS	109
APPENDIX E: LAG LENGTH CRITERION	114
APPENDIX F: COINTEGRATION TEST (BOUNDS TEST) RESULTS	114
APPENDIX G: ARDL MODEL	114
APPENDIX H: ERROR CORRECTION MODEL	115
APPENDIX I: GRANGER CAUSALITY RESULTS	115
APPENDIX J: DIAGNOSTIC TESTS RESULTS	116

APPENDIX K: STABILITY TEST RESULTS	119
APPENDIX L: IMPULSE RESPONSE FUNCTION	121
APPENDIX M: VARIANCE DECOMPOSITION RESULTS.....	121

ACRONYMS

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARCH	Autoregressive Condition Heteroscedasticity
ARDL	Autoregressive Distributed Lag
CUSUM	Cumulative Sum
DMRE	Department of minerals, resources and energy
DoE	Department of Energy
DPE	Department of Public Enterprises
ECM	Error Correction model
ESKOM	Electricity supply commission
EViews 12	Econometric Views 12
FPE	Final Prediction Error
GDP	Gross Domestic Product
HG	Hanna-Quinn Information Criterion
IRF	Impulse Response Function
MPRD	Mineral and Petroleum Resources Development Act
MYPD	Multi-Year Pricing Determination
NEMA	National Environmental Management Act
NERSA	National Energy Regulator of South Africa
PP	Phillips Perron
SA	South Africa
SC	Schwarz Information Criterion
TFP	Total Factor Productivity
VAR	Vector Autoregression
VECM	Vector Error Correction Model

LIST OF FIGURES

Figure 2.1: Comparative GDP growth trends.....	9
Figure 2.2: Load shedding over the past 5 years, 2019-2023.....	12
Figure 2.3: Volume of electricity produced from 2000 to 2020.....	16
Figure 2.4: Historical trends of electricity consumption from 2016 to 2023.....	18
Figure 2.5: Historical trends of electricity price from 2016 to 2023.....	22
Figure 2.6: Eskom average tariff Vs inflation from 1988 to 2024.....	23
Figure 2.7: Coal Exports in South Africa from 2009 to 2022.....	26
Figure 2.8: Prices of exported coal from 2006 to 2015.....	27
Figure 5.1: Normality test results.....	71
Figure 5.2: CUSUM test.....	73
Figure 5.3: CUSUM of squares test.....	73
Figure 5.4: Impulse response function.....	74

LIST OF TABLES

Table 2.1: Descriptive statistics of GDP growth.....	11
Table 2.2: Percentage change in volume of electricity produced in South Africa.....	17
Table 2.3: Percentage change in electricity consumption in South Africa.....	19
Table 4.1: Data Source.....	47
Table 5.1: Descriptive Statistics results.....	62
Table 5.2: Correlation analysis.....	63
Table 5.3: Unit root test using ADF test results.....	64
Table 5.4: Unit root test using PP test results.....	65
Table 5.5: lag length selection.....	66
Table 5.6: Bounds test results.....	67
Table 5.7: ARDL long-run results.....	67
Table 5.8: Error correction model.....	69
Table 5.9: Pairwise Granger Causality results.....	70
Table 5.10: Serial correlation test results.....	72
Table 5.11: Heteroskedasticity test results.....	72
Table 5.12: Variance Decomposition.....	76

CHAPTER 1

ORIENTATION OF THE STUDY

1.1 INTRODUCTION AND BACKGROUND

Economic growth serves as a critical catalyst for national development, allowing countries to enhance living standards and promote stability (Mohamed, Lui & Nie, 2022). According to Ambya and Hamzah (2022), coal is recognized as a significant energy source, a mineral commodity traded among nations. As a developing nation, South Africa is among the countries with an abundance of coal and is heavily reliant on it as an input for electricity generation (Makgetla & Patel, 2021). Theoretically, natural resources such as coal should boost economic development by broadening the production capabilities of the economy. However, extensive reports in recent years, as highlighted by Ramez, Hooi, and Clark (2017), consistently demonstrate an adverse association between economic growth and the abundance of natural resources. The phenomenon is referred to as the Resource curse, particularly evident in developing economies. Despite having an abundance of coal, a key input for producing electricity, South Africa's poor economic performance is consistent with the resource curse theory. Nonetheless, South Africa as one of the largest coal exporters globally, has significantly gained revenue through the exportation of coal by substantially contributing to the nation's trade balance (DMRE, 2023). A positive trade balance led to foreign exchange accumulation, providing stability to the country's currency and enabling investments in infrastructure, further supporting long-term economic growth and hence, export-led growth.

As asserted by Twerefou, Iddrisu, and Twum (2018), economic growth is significantly influenced by growth in electricity consumption. In turn, higher electricity consumption usually corresponds with broader economic growth. Growing industries, increased urbanization, and rising standards of living contribute to a greater need for electricity and hence consumption. According to Inglesi-Lotz and Pouris (2010) and Bowman (2020), electricity demand in South Africa increased drastically after 1994 when the economic sanctions of the apartheid era were dropped, and rapid industrialization occurred in the country. In 1998, the South African state developed a comprehensive white paper on

energy policy. This initiative aimed to enhance energy access and affordability, serving as a crucial step toward ensuring that all citizens can benefit from reliable and cost-effective energy solutions (Department of Minerals and Energy Resources, 1998; Mukonza & Nhamo, 2018). This resulted in a rise in electricity demand and usage. In 2001, the free basic energy policy was implemented where disadvantaged households were given 50KWh per month without charge. Kwakwa and Adusah-Poku (2019) state that electricity demand increased even more upon the free basic energy policy implementation.

According to Akinbami, Oke and Bodunrin (2021), the energy crisis in the country officially began in 2007. This crisis arose due to a significant imbalance in the energy sector, where the growing demand for energy started to surpass the available supply. Consequently, the country encountered growing difficulties in fulfilling the energy demands of its population and industries. This led Eskom, the national utility of electricity supply, to implement a measure to balance electricity demand with the available supply by means of electricity rationing/load-shedding (Pretorius, Piketh, Burger & Neomagus, 2015; Mbomvu, Hlongwane, Nxazonke, Qayi & Bruwer, 2021). According to Inglesi-Lotz and Ajmi (2021), South Africa experienced the most significant and longest blackouts (electricity rationing) in 2014 and 2019. A recent report from Eskom shows that 2023 is the year the country experienced the most load-shedding hours, up to almost 6000 in 280 days (Eskom, 2023). These frequent power interruptions generate significant operational disruptions for many businesses. GDP-contributing industries such as manufacturing and mining which rely heavily on energy supply become susceptible to production delays. Furthermore, businesses incurred additional costs associated with alternative power sources, such as generators, thereby exacerbating financial pressures. Such unpredictability in the energy supply deterred potential investment, as investors may perceive unreliable infrastructure as a substantial risk.

According to Tankentsi, Sibanda, and Hosu (2021), energy prices are a vital element in facilitating economic growth. However, rising energy prices can contribute to an energy crisis in the economy, a situation that is currently evident in South Africa. On the other hand, falling energy prices can also have adverse effects. When energy prices are low, it can lead to greater inefficiency and waste in energy consumption thereby compromising

economic development and growth. South Africa's electricity tariffs are overseen by the National Energy Regulator of South Africa (NERSA) in compliance with the National Energy Regulatory Act of 2004 and the Electricity Regulation Act of 2006 (DMRE, 2023). NERSA aims to foster energy efficiency and security by promoting accessible and affordable energy and increasing competition within the energy sector.

Early in 2023, ESKOM was granted an average tariff increase of 18.65% by NERSA (NERSA, 2023). In December 2023, NERSA approved a further tariff increase of 12.74% for the year 2024/2025. For the past 17 years (2007-2024) since load shedding started in the country, electricity tariffs have risen by an astonishing 937%, while inflation, the general price increase in the country, has only increased by 155%. In essence, electricity tariffs have grown six times faster than inflation, burdening households and businesses considerably (ESKOM, 2024). This significant increase in electricity tariffs has markedly lowered productivity levels across various sectors, as the escalating cost of energy burdens businesses with higher operational expenses. Consequently, many businesses have had to divert funds away from investment in innovation and workforce development to cover soaring energy costs. This strain on resources not only has the potential to hinder economic growth but also limits competitiveness in both domestic and international markets. As businesses grapple with these financial pressures, the overall economic landscape suffers, further impacting job creation and economic stability.

As a country rich in coal resources, South Africa has relied heavily on coal for electricity generation, significantly influencing its economic trajectory. However, the ongoing energy crisis, characterized by persistent load-shedding and rising electricity costs, raises critical questions about the sustainability of this reliance and its implications for economic performance. South Africa is currently making efforts to transition from the traditional use of coal to generate electricity to greener energy mix. This shift is projected to have an unfavorable effect on the nation's GDP, particularly looking at how the downfall of the coal industry will result in a rise in unemployment and a drop in income. Therefore, this study explores the connection between electricity consumption, electricity price, coal exports, and their collective impact on economic growth.

1.2 PROBLEM STATEMENT

According to the report by the Organization for Economic Cooperation and Development (2022), South Africa's economic growth underperformed significantly for the past decade, as evidenced by the fact that GDP per capita in 2019 was lower than in 2008. In 2022, GDP decelerated to 1.9%, down from the 4.9% recorded in 2021, which was much lower than the global and African averages of between 3.4 percent and 3.8 percent (African Development Bank, 2023). This lackluster economic performance led to various adverse effects, including increased unemployment rates and challenges in funding public services such as healthcare and education. Additionally, it obstructed innovation and investor confidence (National Treasury, 2023).

South Africa has abundant coal reserves, which have historically been relied upon as a source of electricity. Despite this, the country has experienced electricity shortages that have affected both businesses and the population. Load shedding in the country started in the year 2007 and has intensified exponentially (Inglesi-Lotz, 2023). This was evident in 2022 when the country experienced nearly 9 hours of power cuts per day, resulting in a total of 11,759 Gigawatt hours (GWh) of load shedding. The severe electricity rationing across the country disrupted economic sectors including the mining, agricultural, and manufacturing sectors, and led to an increase in operating costs for businesses whilst also harming the consumers. In a somewhat impulsive turn of events, South Africa has emerged as one of the top 10 coal exporters. While this surge in coal exports may have bolstered the economy, it has simultaneously drained domestic coal reserves, exacerbating the electricity generation crisis. Consequently, businesses faced reduced productivity, leading to challenges in affording labor and other factors of production.

According to Eskom (2024), electricity prices increased six times faster than inflation since 2007. In 2024, NERSA granted Eskom an average electricity tariff increase of 12.74%, following an 18.65% increase in 2023. (NERSA, 2024). These price hikes have placed significant pressure on households and businesses by reducing disposable income and increasing production costs, thereby impacting economic growth. The export of coal contributes significantly to South Africa's economic revenue, providing income through international trade and foreign exchange earnings. However, the export of coal

reduces the amount of available coal reserves and hence may lower the production of electricity and, subsequently, consumption in the economy. Therefore, it became imperious to examine the significance of electricity consumption, price, as well as coal exports on economic growth in South Africa.

1.3 RESEARCH AIM AND OBJECTIVES

1.3.1 Aim of the study

The aim of the study is to investigate the impact of electricity consumption, electricity price and coal exports on economic growth of South Africa for the period 2016 to 2023.

1.3.2 Objectives of the study

- To determine the impact of electricity consumption and price on economic growth.
- To examine the effect of coal exports on economic growth.
- To determine any existing causality among electricity consumption and price, coal exports, and economic growth.
- To test the sensitivity of economic growth emanating from shocks in electricity consumption, price and coal exports.

1.4 RESEARCH QUESTIONS

- Does electricity consumption and price influence South Africa's economic growth?
- Do coal exports have an impact on economic growth of South Africa?
- Does causality exist among the variables in question?
- Does economic growth exhibit sensitivity to shocks in electricity consumption, price and coal exports?

1.5 SIGNIFICANCE OF THE STUDY

The Solow growth model is an exogeneous model which focuses on long-term economic growth. According to Cicea, Ciocoiu, and Marinescu (2021), economic growth is fundamentally driven by energy and conversely, energy shortages can hinder economic growth. This aligns with the Heckscher-Ohlin theory, which suggests that coal, being a cheap and abundant resource in South Africa, should be produced and exported in large

quantities. This approach would enhance the country's economic outlook and promote export-led growth. A growing concern is whether the country is producing enough to sustain the economy and meet export demands. As it stands, coal contributes over 90% of electricity generation in the country (Mirzania, Gordon, Balta-Ozkan, Sayan and Marais, 2023). However, the country currently seeks to transition from the traditional use of coal to cleaner energy and as a result, coal industries are expected to collapse and significantly have an adverse impact on employment, standard of living, and overall economic outlook.

This study explores the energy-growth relationship considering the inclusion of the crucial factors that may be the cornerstone of the relationship; that is, coal exports and electricity prices. Hence, a multivariate model incorporating energy variables. South Africa's status as a major global exporter of coal, an abundant resource, underscores the importance of examining the link. This is in line with the dilemma of resource export-led growth. In South Africa, most of the energy-growth literature covers the timeframe from the late 1900s and early 2000s (Molele & Ncanywa, 2018; Menyah & Wolde-Rufael, 2010; Boquiang, Presley & Wesseh, 2014; Gasealahwe, 2020; Odhiambo, 2023). In this study, the focus was on the period from 2016 to 2023 only. This is an important modeling path looking at how the country has advanced and lacked in some areas over the years. Particularly looking at how the current government is struggling to take control of high electricity prices and electricity rationing and how the situation has worsened in between the time frame of 2016-2023 than the early 2000s. The export of coal accelerated in between the time frame of the study even though power supply is still a concern. Thus, this study aims to provide a solid policy perspective given the energy path the country is seeking to take.

1.6 DEFINITION OF KEY CONCEPTS

- **Electricity consumption:** According to Sama and Tah (2016) electricity consumption refers to the total amount of electrical energy used over a period of time by businesses and households, measured in kilowatt hours (KWh).
- **Electricity price:** refers to the cost associated with the consumption of electrical energy, typically measured in kilowatt hours (ESKOM, 2023).

- **Coal exports:** refers to the international trade of coal, where coal-producing countries sell coal to other nations for consumption or industrial use (Susanto & Admi, 2021).
- **Economic growth:** refers to an increase in the overall value of all finished goods produced in an economy over a specific period (Mohr, 2015).

1.7 ETHICAL CONSIDERATIONS

The study employed quantitative statistical analysis by making use of secondary data gathered from authoritative sources. The data is freely available, and the student applied for TREC permission. In addition, the data was analyzed transparently, without falsification, and securely stored to uphold ethical research standards. To sustain academic standards, the study was carried out while considering the university's postgrad manual, thereby avoiding plagiarism issues.

1.8 STRUCTURE OF THE STUDY

There are six chapters in this dissertation, and they are structured as follows: Chapter one is the orientation of the study which provides the introduction and background of the study, the problem statement, research aim and objectives, research questions, the definition of concepts, ethical consideration, and significance of the study. Chapter two provides an overview of the variables, revealing the trends of these variables for the past years.

Chapter three unpacks the literature, including both theoretical and empirical literature relevant to the interlink between the variables of contention. Chapter four is the research methodology which reports the source of data, how the model is specified, and a detailed explanation of estimation techniques. Chapter five is the presentation of the results and discussion of various tests conducted using EViews 12. Chapter six includes the summary, conclusion and recommendation, contributions, and the limitations of the study. All journal articles, books, and other sources used in this study appear on the list of references. Appendices include data collected from Quantec and all results obtained from EViews 12.

CHAPTER 2

OVERVIEW OF ECONOMIC GROWTH, ELECTRICITY CONSUMPTION, PRICE AND COAL EXPORTS

2.1 INTRODUCTION

South Africa's economic structure is deeply linked with its energy sector, where coal remains a critical source of electricity generation. Electricity consumption drives productivity across vital sectors such as mining and manufacturing, directly influencing the Gross Domestic Product (GDP) of the nation. However, persistent challenges, including frequent load shedding and rising electricity prices have constrained economic growth and industrial output. This chapter centers on the overview of the variables; economic growth, electricity consumption, price and coal exports, exploring how these variables shape economic stability or instability in South Africa.

2.2 AN OVERVIEW OF ECONOMIC GROWTH

This subsection analyzes the trend in GDP percentage growth for South Africa in comparison to Botswana, Sub-Saharan Africa, and the world over the years. The comparative analysis of Botswana and South Africa is particularly significant, as both countries are located within the Sub-Saharan African region and share the status of developing countries. Additionally, South Africa exports a portion of its electricity to Botswana (Bamboleka, Belaid, Muzenda & Nhubu, 2022). The inclusion of Sub-Saharan Africa and the world's growth rates will provide insight into how these countries perform relative to the rest of the world. This subsection will also provide and analyze the descriptive statistics on GDP growth for South Africa, Botswana, Sub-Saharan Africa, and the world, allowing for a comprehensive comparison of GDP growth rates across the four regions. Finally, this subsection will examine the impact of electricity rationing, also referred to as load shedding or power outage, on the economic growth of South Africa.

2.2.1 Comparative GDP Growth Trends

According to the National Treasury (2024), South Africa has experienced weak GDP growth for over 10 years. It was reported that GDP growth has only averaged 0.8% since

2012. This lackluster economic growth has entrenched high unemployment rates and poor standards of living. Annual GDP growth rates of South Africa relative to Botswana, Sub-Saharan Africa, and the world from 2000 to 2023 are illustrated in Figure 2.1 below.

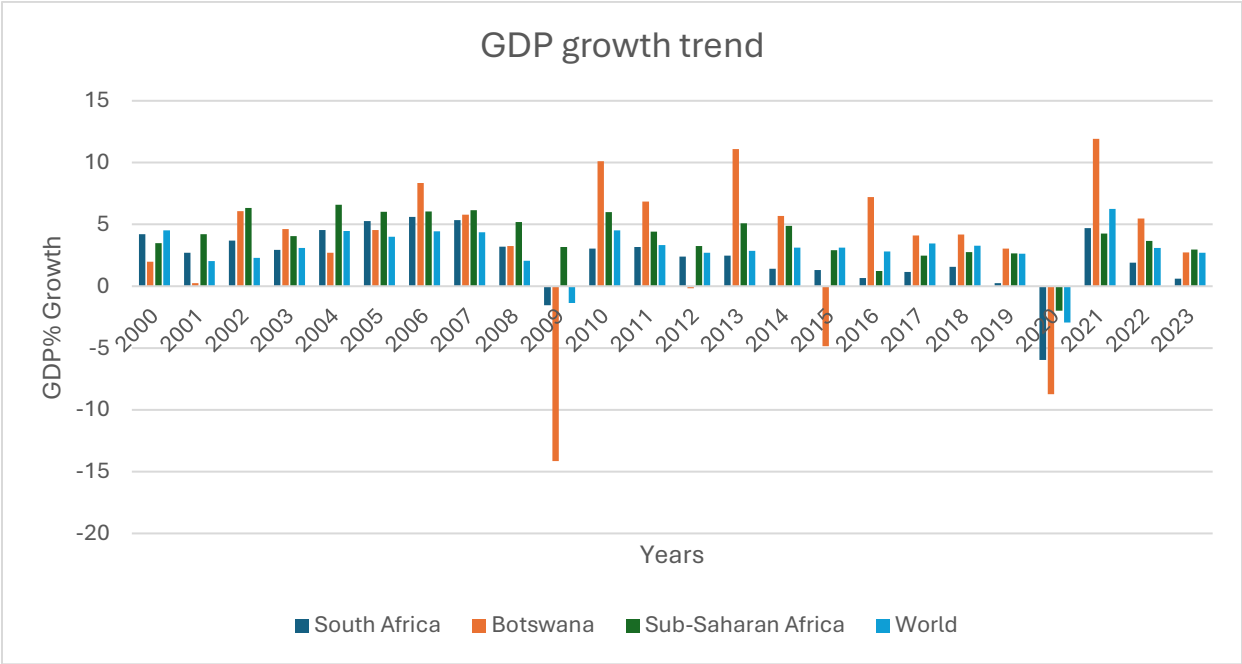


Figure 2.1: Comparative GDP growth trends

Source: Author’s compilation using data from the World Bank

As observed, South Africa's economy grew at a moderate pace, with growth rates of between 2.7% and 5% from 2001 to 2005 which surpassed global averages of between 2% and 4.5%. In contrast, Botswana experienced lower growth rates than South Africa during 2000 and 2001. However, between 2002 and 2003, Botswana's growth reached over 5%, surpassing both global and South Africa's growth, largely due to strong diamond exports (Mbayi, 2016). The years 2006 and 2007 marked South Africa’s growth peak, with an average increase of 5.6% and 5.3%, respectively. However, by 2009, the global financial crisis had begun to affect South Africa, resulting in a 1.5% drop in economic growth (Felipe & Estrada, 2020). Botswana also experienced solid growth during 2006 and 2007, although it too faced adverse impacts of the global financial crisis by 2009, which caused a decline of economic growth of about 14% while global averages only declined by 1.3%. In counterpoint, Sub-Saharan African countries experienced positive growth, with rates reaching 3%. Although the financial crisis took a toll on Botswana’s

growth, it rebounded more effectively, stabilizing around 10% growth in 2010 due to robust policy measures, doing better than all other three regions. South Africa's growth remained sluggish with around 3% growth from 2010 to 2011.

From 2016 to 2019, South Africa's economic growth further declined, failing to exceed 1% due to ongoing domestic structural issues that hindered expansion, possibly influenced by load shedding. On the other hand, Botswana experienced more robust growth, ranging from 4% to 7%, supported by consistent government investments. Concurrently, the growth rates for Sub-Saharan Africa and the global economy were approximately 2% and 3%, respectively. According to Gagnon, Kamin and Kearns (2023), the COVID-19 pandemic in 2020 caused a sharp contraction globally since the Great Depression, with the world's growth declining by 3%, South Africa's GDP dropping by 6%, Botswana's by 9% and Sub-Saharan African countries' growth rates declining by 2%. The lockdowns and global recession severely impacted many economies. The post-pandemic years from 2021 to 2023 witnessed a recovery in GDP growth rates across all regions. However, Botswana's rebound was more pronounced, with a growth rate of 11.9% in 2021. In contrast, South Africa experienced a slower recovery, achieving a growth rate of 4.7% in 2021, which still surpassed the Sub-Saharan Africa average of 4.2%. Meanwhile, the global growth rate stood at 6.2%. In essence, Botswana's GDP growth has been generally more resilient and consistent compared to South Africa, Sub-Saharan Africa and global growth averages, with faster recoveries following global shocks.

2.2.2 Descriptive GDP growth analysis.

Table 2.1 gives a summary of the GDP growth statistics for South Africa, Botswana and the world. The descriptive statistics give a clearer indication of how these regions have been performing in terms of GDP growth from 2000 to 2023, summing 24 observations.

Table 2.1: Descriptive statistics of GDP growth.

	South Africa	Botswana	Sub-Saharan Africa	World
Mean	2.2797	3.4226	3.9946	2.9579
Median	2.5927	4.3723	4.1242	3.1140
Maximum	5.6038	11.9206	6.6019	6.2598
Minimum	-5.9633	-14.1442	-1.9668	-2.9320
Std.Dev	2.5088	5.9095	1.9283	1.8912
Skewness	-1.4208	-1.3397	-1.0801	-1.5966
Kurtosis	5.9981	4.9760	4.8804	6.4193
Jarque-Bera	17.0642	11.0844	8.2031	21.8882
Probability	0.000197	0.003918	0.0165	0.000018
Sum	54.7149	82.1444	95.8712	70.9919
Sum of Std Dev	144.7694	803.2308	85.5305	79.6749
Observations	24	24	24	24

Source: Author's compilation using World Bank data and Eviews 12

According to the statistics, the average GDP growth rates are 2.27% for South Africa, 3.42% for Botswana, 3.99% for Sub-Saharan Africa and 2.95% for the world. This indicates that Sub-Saharan African countries outperform the world, Botswana and South Africa in terms of GDP growth, with South Africa having the lowest rate. Additionally, the maximum GDP growth for South Africa, Botswana, Sub-Saharan African countries and the world are 5.6%, 11.9%, 6.6% and 6.9% respectively. This suggests that Botswana had the highest GDP growth rate, surpassing the three regions by over 5%. Nonetheless, Botswana still experienced the lowest GDP growth of -14.14%, followed by South Africa at -5.96%. Sub-Saharan Africa and the world's growth rates were moderately low at -1.96% and -2.93% respectively.

Furthermore, the statistics reveal that Botswana has the highest standard deviation in GDP growth at 5.90, indicating that its GDP growth is more volatile compared to that of South Africa, Sub-Saharan Africa and the world. A high standard deviation indicates that the growth rates vary widely from the average, which could be attributed to factors such

as external shocks. South Africa follows Botswana with a standard deviation of 2.50. In contrast, the low standard deviation in GDP growth of Sub-Saharan Africa and the world's growth rates suggests a more stable economic growth trajectory, with standard deviations of 1.92 and 1.89 respectively.

2.2.3 The Impact of Electricity Rationing on South Africa's Economic Growth

According to StatsSA (2022), electricity rationing, also known as load shedding, has significantly impacted the economic growth of South Africa, with this effect being most noticeable from the start of the energy crisis in 2007. As the country grapples with frequent power cuts, the effects extend beyond mere inconvenience to serious economic repercussions (Wiese & Van der Westhuizen, 2024; Inglesi-Lotz, 2023). Evidently, load shedding has led to substantial financial losses, reduced economic productivity, and hence a slower GDP. Figure 2.2 gives an overview of load shedding for the last five years, 2019 to 2023.

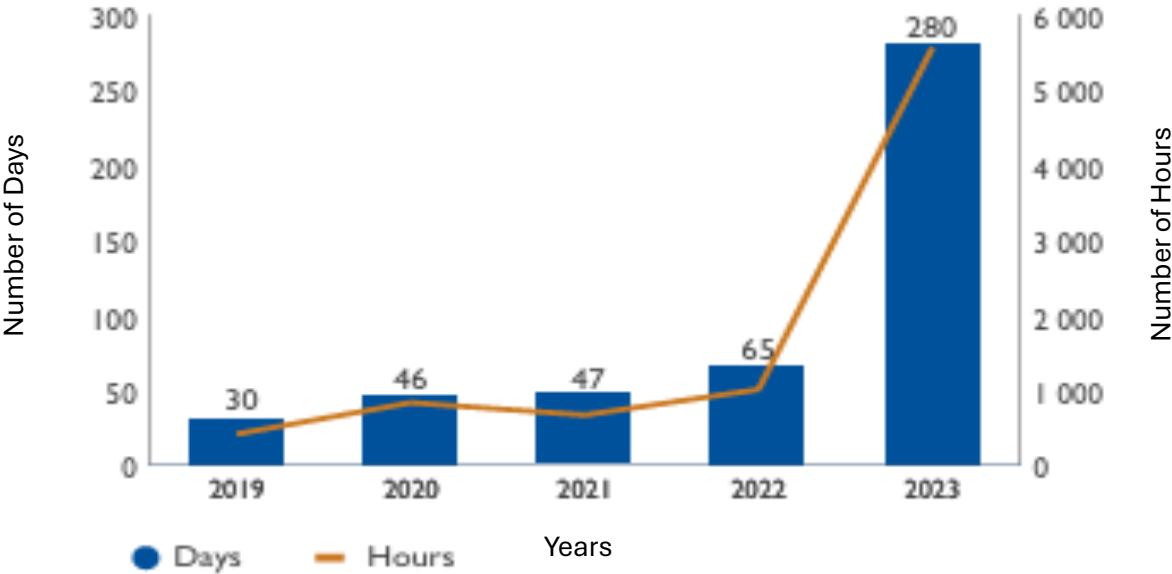


Figure 2.2: Load-shedding over the past 5 years, 2019-2023

Source: Eskom integrated report, 2023

According to Inglesi-Lotz (2023), South Africa has been experiencing an ongoing energy crisis since 2007. This crisis has led to frequent power cuts, known as load-shedding, throughout the country. This can be attributed to the rising demand for energy that has

exceeded the available supply. The figure above demonstrates the number of days and hours of load-shedding in the country from 2019 until 2023. As observed, load shedding increased exponentially, with 2023 being the year with the most load-shedding hours, up to almost 6000 hours in 280 days.

According to Walsh, Theron, and Reeders (2021), the estimated financial burden of load shedding on the South African economy exceeded R35 billion between 2007 and 2018. Furthermore, the Council for Scientific and Industrial Research (CSIR) (2020) reports that load shedding resulted in a substantial economic loss of approximately R120 billion during the year 2019 alone. This adverse effect can be attributed to blackouts that accumulated to a total of 1,352 GWh, equating to roughly 530 hours of electricity outages in 2019. In estimation, the cumulative economic impact of load shedding in South Africa is anticipated to have surpassed over R338 billion in the past decade. According to StatsSA (2022), the country's economic growth declined by 0.7% in the second quarter of 2022 due to persistent blackouts. Furthermore, the Monetary Policy Committee (MPC) projected GDP growth for 2023 to be 0.3% due to load-shedding, which is nearly accurate as the actual GDP growth is 0.6% for 2023 (SARB, 2023).

Inglesi-Lotz (2023) poses that load-shedding is not a crisis but a way to mitigate it. However, this exponential increase in load-shedding has far-reaching implications for both the economy and daily life within the country. The continuous disruption in power supply has severely impacted the economy, resulting in industry shutdowns, leading to an increase in the unemployment rate, and adverse education and healthcare impacts (Naidoo, 2023). Load-shedding significantly impacts key industries, especially those that depend heavily on electricity, such as manufacturing, mining, agriculture, and services (Erero, 2023). Manufacturing, for example, contributes significantly to South Africa's GDP and requires a consistent power supply to function effectively. Frequent power interruptions lead to reduced operational hours, increased costs for backup power solutions, and the risk of wasting raw materials in processes that depend on precise timing. As a result, jobs are lost, household incomes decline, and consumer spending shrinks, all of which negatively affects economic growth.

Schoeman and Saunders (2018), argue that a significant majority of businesses, specifically 90.7%, consider electricity to be essential for their day-to-day operation. This reliance on a steady power supply is particularly critical for small businesses, as 38.9% of small, medium, and micro-enterprises (SMMEs) reported that power outages directly result in fewer customers. Such reductions in customer interaction led to severe repercussions for small enterprises. Many of which operate on thin profit margins and depend heavily on consistent customer engagement to sustain their operations. Schoeman and Saunders (2018) further revealed that 37% of businesses have suffered damage to their equipment due to power outages, underscoring the tangible risks associated with unreliable electricity supply. The implications of these findings are profound, given that SMMEs constitute approximately 40% of all businesses in South Africa. These enterprises are essential to the national economy, contributing approximately 36% of the country's overall economic output (Global Entrepreneurship Monitor, 2017). As the backbone of job creation and innovation, any disruption faced by SMMEs translates into larger socio-economic challenges thus having unfavorable effects on economic growth.

According to Erero (2023), prospective foreign investors tend to view a stable energy supply as a prerequisite for investment decisions. Persistent and widespread power outages serve to deter Foreign Direct Investment (FDI), as investors often seek reliable environments for capital allocation. Thus, investors tend to become doubtful about investing in the country due to the current load-shedding. This avoidance can be attributed to concerns over the cost implications of energy instability, coupled with the fear of prolonged operational disruptions. Therefore, the reduced inflow of FDI limits the opportunities for technological advancement and infrastructure development, thereby stunting long-term economic growth.

2.3 OVERVIEW OF ELECTRICITY SECTOR IN SOUTH AFRICA

The purpose of this subsection is to provide an evaluation of South Africa's electricity sector. It commences with exploring governance structures that regulate the electricity sector, followed by an analysis of the prevailing trends in electricity production and consumption over the years.

2.3.1 Electricity Sector Governance

South Africa's electricity sector is regulated by various entities, each with a unique role in overseeing policy, regulation, and operations. Eskom, the state-owned utility, is at the center of the structure, generating around 90% of South Africa's electricity (ESKOM integrated report, 2023). Additionally, it is responsible for supplying around 40% of the electricity consumed across Africa (DMRE energy price report, 2018). Eskom's operations are complemented by various regulatory bodies and government departments, which set the legal and operational boundaries within which Eskom and other stakeholders operate.

The Department of Mineral Resources and Energy (DMRE) serves as the principal entity responsible for formulating policies that shape the national energy strategy. This includes determining the types of energy sources to be utilized, establishing pricing frameworks, and defining long-term objectives for energy security and sustainability. The Department of Energy (DoE) works in conjunction with DMRE to oversee the energy sector, including electricity, in accordance with the Electricity Regulation Act 4 of 2006 (DMRE, 2023). According to Goga (2023), the National Energy Regulator of South Africa (NERSA) is responsible for regulating electricity tariffs, licensing providers, and ensuring compliance with government standards for service and pricing. NERSA plays a vital role in tariff regulation, particularly as Eskom faces the challenge of balancing affordability with revenue needs amid financial difficulties.

Additionally, the Department of Public Enterprises (DPE) oversees Eskom's governance and performance as the main shareholder of the utility. The DPE monitors Eskom's financial health, management practices, and project execution, holding it accountable to both national objectives and its public mandate (ESKOM integrated report, 2023). However, Eskom's financial difficulties and management challenges have exposed limitations in this oversight, often leading to friction between governmental departments and the utility, especially regarding issues of transparency and financial sustainability.

Independent power producers (IPPs) play a crucial role in South Africa's electricity sector, according to DMRE (2023). One of the main initiatives aimed at diversifying energy sources and reducing the country's dependence on coal is the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) launched by the

government. Although Eskom retains control over the national grid, IPPs now contribute a growing share of renewable energy, adding complexity to the governance landscape as these producers interact with both Eskom and regulatory bodies like NERSA.

2.3.2 Electricity Production and Consumption Trends

Figure 2.3 below shows changes in electricity production in South Africa from the year 2000 to 2020.

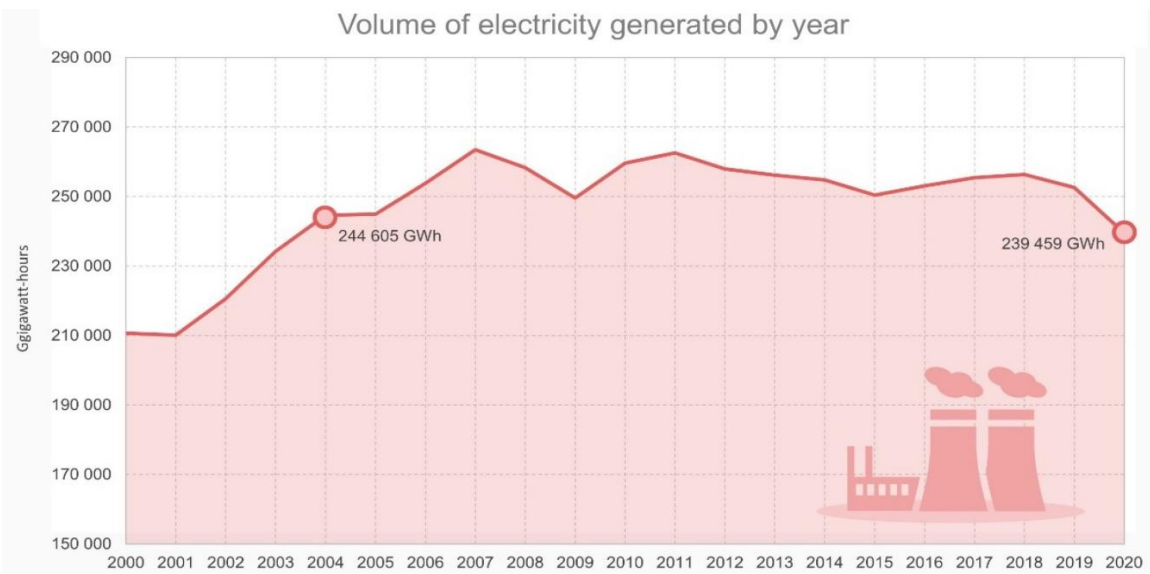


Figure 2.3: Volume of electricity produced from 2000-2020

Source: StatsSA (2021)

The graph above reveals an upward trajectory in electricity generation from 2000 to 2007, which corresponds with the period of industrialization and increased demand for energy in the economy. However, when the energy crisis started in 2007, the volume of electricity produced declined significantly. This downturn was particularly detrimental for various sectors, including businesses and households, as the implementation of load-shedding measures became necessary to manage the dwindling supply.

In 2009, the situation was exacerbated by the onset of the global financial crisis, which severely impacted the nation and contributed to a further reduction in electricity generation, dropping to approximately 250,000 GWh. This decline can be attributed to decreased industrial activity and investment in energy infrastructure during this critical period. Following 2009, there was a slight recovery in electricity production; however, the

growth trend began to taper off around 2011. A report from StatsSA (2021) postulates that the electricity sector produced less electricity in 2019 than it did in 2010. Again, the electricity produced in 2020 is less than the electricity produced in 2004 by 5,152 GWh. Table 2.2 shows the percentage change in electricity production in South Africa from 2016 to 2020. Hence, this is a year-on-year analysis.

Table 2.2: Percentage change in volume of electricity produced in South Africa

Month	2016	2017	2018	2019	2020
Jan	-2.0	0.9	2.3	-2.0	-2.5
Feb	3.1	-3.9	1.8	-1.9	1.0
March	-3.9	2.6	1.2	-2.9	-4.0
Apr	0.9	0.7	-0.5	1.8	-22.8
May	1.3	4.6	-0.8	-0.6	-13.2
Jun	0.5	1.6	0.3	0.1	-5.8
Jul	2.8	-1.8	2.2	-0.6	-4.5
Aug	3.9	0.9	-0.5	-2.4	-2.4
Sep	1.2	1.0	-0.8	-0.4	-3.1
Oct	2.2	1.4	0.8	-1.9	-2.8
Nov	2.2	1.6	-0.1	-2.8	-2.4
Dec	0.9	1.4	-1.6	-4.0	1.1
Total	1.1	0.9	0.4	-1.5	-5.3

Note: 2015 is used as a base year, meaning percentage change in electricity generated in 2015 = 100

Source: StatsSA (2021)

Electricity production experienced a modest increase of 1.1% in 2016. In the following year, 2017, electricity generation rose by 0.9%, reflecting a minor decline of 0.2% relative to the preceding year. This slight downtrend in growth highlights the instability in South Africa's energy production, pointing to underlying factors that may have influenced production rates, such as maintenance issues, shifts in demand, or policy impacts.

The year 2018 saw a further reduction in growth, with a mere increase of 0.4%. This diminishing percentage suggests a concerning trend within the electricity manufacturing sector, potentially indicative of broader economic challenges or infrastructural inefficiencies that were beginning to manifest at that time. The situation worsened drastically in 2019, as electricity production saw a decline of 1.5%. This marked the first

negative growth in the period analyzed, which could be attributed to a combination of aging infrastructure, and increased load-shedding initiatives. The decrease in electricity generation contributed to broader economic impacts, affecting various sectors reliant on consistent energy supply. The decline continued into 2020, with a significant drop of 5.3%. This sharp decrease can be linked to the COVID-19 pandemic, which severely disrupted economic activities and energy consumption patterns. Additionally, the ongoing challenges in the energy sector, such as reliance on coal power and inadequate investment in renewable alternatives, compounded the difficulties faced during this period. Figure 2.4 depicts the electricity consumption trend for South Africa from 2016 quarter 1 to 2023 quarter 3, which is the period for this study.

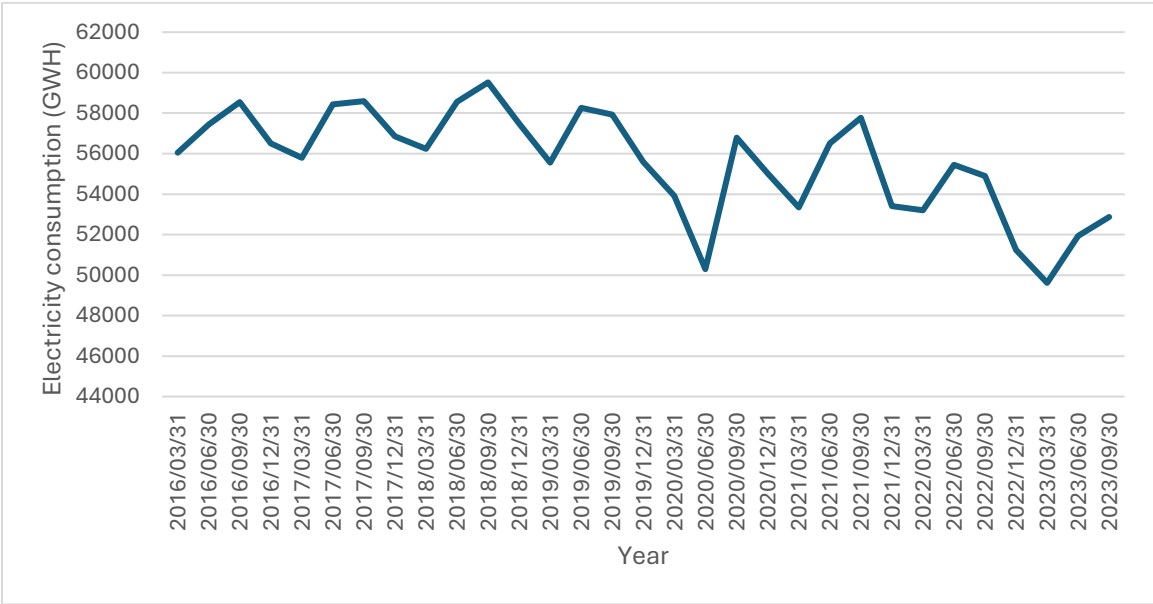


Figure 2.4: Historical trends of electricity consumption (2016 to 2023)

Source: Author’s compilation using Excel

As shown in the graph, electricity consumption in South Africa has had serious fluctuations over the years; most significantly it reveals a decline in electricity consumption. The graph indicates that electricity consumption peaked in the third quarter of 2018. According to Stungwa, Hlongwane, and Daw (2022), the increase in electricity consumption in this period was due to an expansion of households in the country.

Following this peak, electricity consumption generally declined on account of demand exceeding supply thus resulting in load shedding. However, electricity consumption began to recover in the first quarter of 2019. As reported by Ritchie, Burger, Naidoo, and Booyesen (2022), the occurrence of the COVID-19 outbreak in 2019 instigated a significant economic downturn, resulting in lower electricity consumption as many businesses closed or reduced their operation. This decline is reflected in the graph, which shows a sharp drop in consumption from 2019 quarter two up to 2020 quarter two. After the pandemic, recovery efforts led to a gradual increase in electricity demand and consumption, although ongoing supply constraints and load shedding often hindered growth. Load shedding intensified in recent years, especially 2021-2023, significantly disrupting business operations and household consumption patterns. Table 2.3 below illustrates the percentage change in electricity consumption in South Africa from 2017 to 2020.

Table 2.3: Percentage change in electricity consumption in South Africa.

Month	2017	2018	2019	2020
Jan	-0.5	1.5	0.1	-3.6
Feb	-3.6	0.7	-1.0	0.0
Mar	2.7	0.1	-2.8	-5.0
Apr	0.1	-0.7	1.6	-23.2
May	3.4	0.2	-1.3	-13.5
Jun	1.6	1.0	-1.6	-4.8
Jul	-1.5	3.1	-1.9	-3.4
Aug	1.6	0.9	-4.7	-0.4
Sep	0.1	0.7	-1.2	-2.1
Oct	0.0	2.2	-2.1	-2.5
Nov	0.8	1.0	-3.1	-2.1
Dec	1.0	0.1	-4.9	1.7
Total	0.5	0.9	-1.9	-5.0

Source: StatsSA (2021)

In 2017, electricity consumption in the country increased by 0.5%, followed by a 0.9% rise in 2018. This increase underscores the rising demand for electricity from 2017 to 2018. The COVID-19 pandemic, which began in 2019, represented a significant turning point that profoundly impacted various industries, particularly the energy sector. As observed

on the table, electricity consumption declined by 1.9%. This contraction is the result of elements such as lockdowns and reduced economic activity. Many businesses, particularly within the manufacturing and services sectors, either reduced their operational capacity or temporarily suspended activities, resulting in a substantial decrease in energy consumption.

As the pandemic continued into 2020, the situation further deteriorated, with electricity consumption dropping by 5%. According to Tembe and Hlengwa (2022), the decline in electricity consumption in the country is not only due to the COVID-19 outbreak but can also be attributed to the challenges faced by the state-owned power utility, Eskom, including load shedding and infrastructure shortcomings. This resulted in a contraction of economic growth as businesses faced increased operational disruptions and uncertainty.

2.4 AN OVERVIEW OF ELECTRICITY PRICE IN SOUTH AFRICA

This subsection provides an overview of electricity prices in South Africa by first explaining how these prices are determined or modeled in the country. Additionally, it will analyze electricity price trends from 2016 to 2023. A further analysis will be conducted on Eskom's electricity price increases relative to the consumer price index (CPI).

2.4.1 Electricity Price Model

Electricity pricing in South Africa is primarily governed by the Multi-Year Price Determination (MYPD) methodology, a regulatory framework established by the National Energy Regulator of South Africa (NERSA) in terms of the National Energy Regulatory Act, 2004 and the Electricity Regulation Act, 2006 (DMRE, 2023). The MYPD was first introduced in 2006 and serves as a central mechanism for determining electricity tariffs, balancing Eskom's revenue needs with consumer affordability, and addressing infrastructure and operational costs (NERSA, 2018).

The MYPD framework typically operates over a three-year cycle. Within each cycle, NERSA sets tariffs that Eskom can charge, based on projected costs and revenues for that period. This multi-year approach helps smooth out price changes, avoiding sudden or extreme tariff adjustments. On each MYPD period, Eskom applies to NERSA, detailing projected costs for generation, transmission, and distribution and other expenditures like

debt servicing. NERSA reviews the application, often soliciting public input, before approving a final tariff structure. The following formula is used for submitting a tariff application under the MYPD methodology:

$$AR = (RAB \times WACC) + E + PE + D + TNC + R\&D + IDM \pm SQI + L\&T \pm RCA$$

AR = Allowance Revenue

RAB = Regulated Asset Base

WACC = Weighted Average Cost of Capital

E = Expenses

PE = Primary Energy Costs

D = Depreciation

TNC = Transmission and Network Costs

R&D = Research and Development

IDM = Integrated Demand Management Costs

SQI = Costs related to Service Quality incentives

L&T = Levies and Taxes

RCA = Balance in the Regulatory Clearing Account

According to DMRE (Energy Price Report, 2021), NERSA is designated to set Eskom's allowable revenue (AR) by estimating costs and a fair rate of return (RoR) on a multi-year basis. This implies that the revenue generated by Eskom should match the efficient cost of supplying electricity to the nation, along with a fair rate of return. If actual costs differ from these estimates, the changes are recorded in the Regulatory Clearing Account (RCA). This account tracks discrepancies, allowing for adjustments in future tariffs to recover lost revenue. According to Ismail and Wood (2023), NERSA also evaluates factors like consumer affordability, support among customer groups, and the impact of negotiated pricing when reviewing Eskom's tariff requests.

2.4.2 Electricity Price Trends

Figure 2.5 below shows the trend of electricity prices from 2016Q1 to 2023Q3 in South Africa.

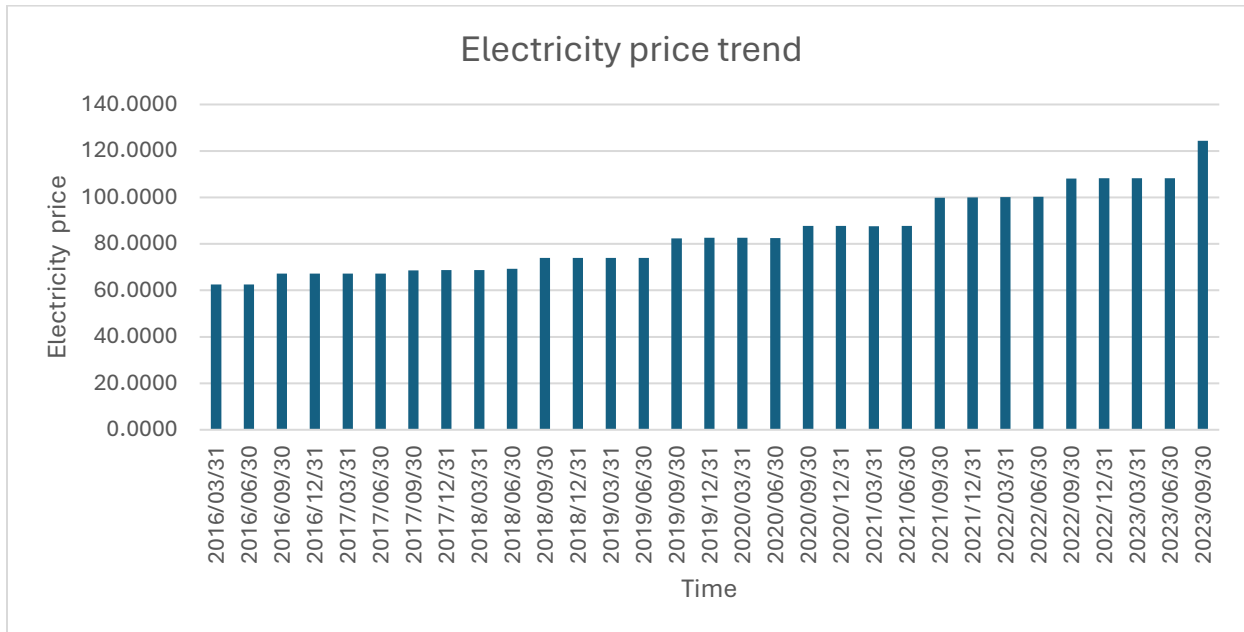


Figure 2.5: Historical trend of electricity price from 2016 to 2023

Source: Author's compilation using Excel

According to Gonese, Hompashe, and Sibanda (2019), historically electricity prices were relatively low in South Africa, supported by abundant coal resources. However, increasing demand, aging infrastructure, and financial challenges have pressured Eskom leading to escalating prices after 2008. Figure 2.5 reveals a clear upward trajectory in electricity prices from 2016 quarter one until 2023 quarter three. Load shedding intensified between 2014 and 2019 in the country prompting price hikes (Inglesi-Lotz & Ajmi, 2021). From 2019 to 2020, prices continued to rise sharply, driven by the need for more investment in renewable energy to meet new government sustainability policies. These environmental considerations led to a reevaluation of energy generation, resulting in higher costs being passed on to consumers.

From 2021 to 2023, the effect of the COVID-19 outbreak on the economy became evident. While there was a temporary dip in demand, subsequent recovery saw surges in inflation

and operating costs for Eskom. As energy prices across the globe increased, so too did the price of electricity in South Africa. The average annual increase was seen to be over 10%, reflecting the global energy crisis and domestic economic challenges. Figure 2.6 below shows Eskom tariffs relative to inflation, to further highlight the stark contrast between electricity price increases and consumer price index in South Africa.

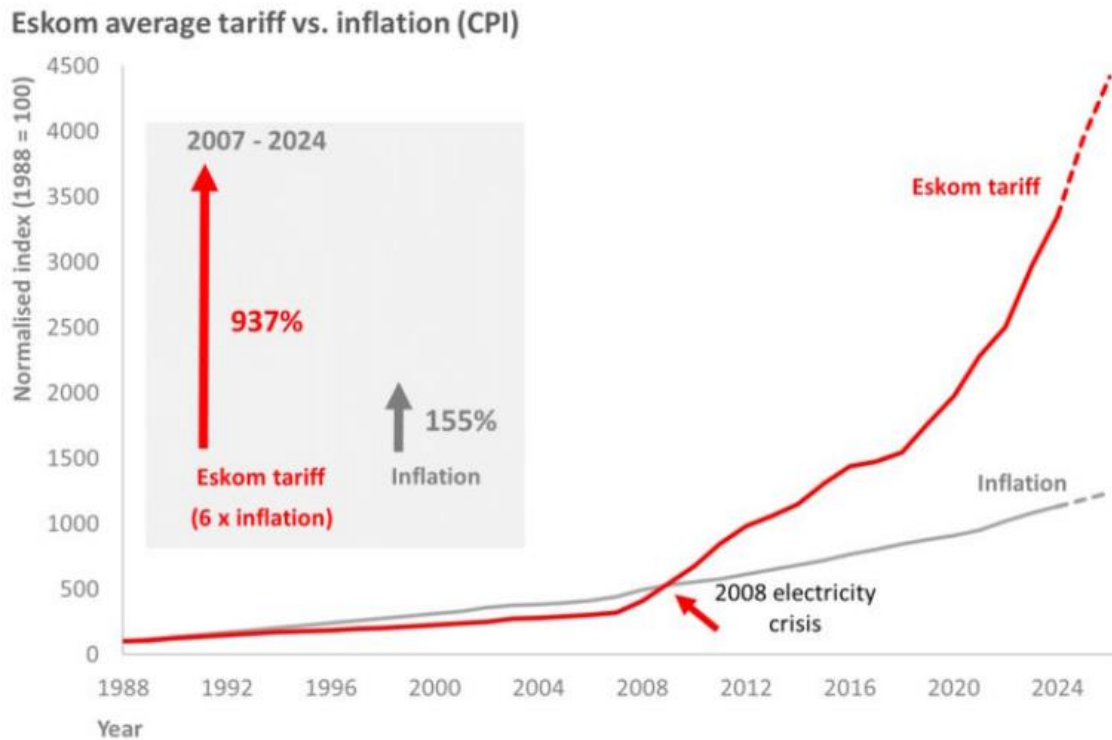


Figure 2.6: Eskom average tariff vs inflation from 1988 to 2024

Source: Eskom Tariff Book, 2024

Figure 2.6 above shows the average electricity price increases by Eskom compared to inflation from 1988 to 2024. The red line represents the tariff trend, while the grey line indicates inflation as shown on the graph. Additionally, the dotted lines project trends for the years 2025 to 2026.

As seen in the graph above, from 1988 until the 2008 electricity crisis, South Africa's electricity tariffs saw only modest increases, failing to keep pace with inflation. Over two decades (1988-2008), while inflation grew by 335%, electricity tariffs rose by just 223% (Eskom Tariff Book, 2024). This gap stemmed from two main factors: government policy

aimed at keeping electricity affordable for poorer households and Eskom's surplus energy supply in the 1990s, which reduced the need for further investment in new capacity (Nkosi & Govender, 2022). However, this approach to keeping prices low came with hidden costs. Eskom's focus on affordability and surplus led to underinvestment in new infrastructure, leaving South Africa with aging power plants and insufficient capacity to meet future demand.

In 2008, South Africa experienced a significant turning point characterized by an electricity crisis that had far-reaching implications. ESKOM, the state-owned electricity supplier, struggled to sustain the escalating demand for electricity, which gave rise to severe supply shortages. This inability to provide adequate power led to frequent and widespread outages, effectively signaling the onset of the country's energy crisis. This crisis forced Eskom to accelerate infrastructure upgrades, which required significant capital, and the only way to cover these costs was through steep tariff hikes. From 2007 to 2024, electricity tariffs rose by an astonishing 937%, while inflation grew by only 155%, as shown in the figure above. In effect, electricity tariffs increased six times faster than inflation, making the cost of electricity a considerable burden on households and businesses.

In December 2023, NERSA approved a 12.74% tariff increment for the fiscal year 2024/2025 following the 18.65% increase in tariff in 2023 (Eskom tariff book, 2024). Furthermore, looking at the graph, electricity prices are projected to go higher for the coming years, 2025 and 2026, as indicated by the dotted lines. To substantiate the projection, ESKOM is seeking total revenues of R446 billion for the fiscal year 2026, R495 billion for 2027, and R537 billion for 2028. This request will result in average electricity price hikes for Eskom's direct customers of 36.15% from the 1st of April 2025 to the 31st of March 2026, 11.81% from the 1st of April 2026 to the 31st of March 2027, and 9.10% from 1st of April 2027 to the 31st of March 2028 (ESKOM, 2024).

These rising costs have made electricity an increasingly unaffordable expense for ordinary South Africans. Households, especially in lower-income brackets, struggle with higher monthly bills, often forced to choose between basic necessities and keeping the lights on. Small businesses, which rely on affordable energy to remain competitive, also

feel the strain, as do energy-intensive industries like mining and manufacturing. These price hikes have not only impacted affordability but have also hindered economic growth, as companies scale back operations or even consider relocating to countries with cheaper energy.

Eskom's challenges illustrate the difficulty of balancing energy affordability, supply, and infrastructure investment. Continued tariff increases may ensure Eskom's financial stability, but they risk alienating vulnerable communities and placing further strain on an already fragile economy. Conversely, maintaining low prices without investing in reliable infrastructure could lead to further crises, with devastating impacts on economic growth and everyday lives of South Africans

2.5 OVERVIEW OF COAL EXPORTS

This subsection explores the evolving dynamics of coal exports in South Africa, analyzing the volume of coal exports from 2009 to 2022. Furthermore, this analysis investigates the pricing trends associated with coal exports. According to DMRE (2023), coal remains the dominant primary energy source globally, comprising approximately 36% of total fuel use for the generation of electricity. Coal is even more significant in South Africa, constituting approximately 57% of the country's primary energy supply. Notably, around 37% of the country's coal is exported. Around 74% of the total coal available for domestic use is dedicated to electricity generation while 26% is for the production of petroleum products.

SARS (2021) reports that, among other nations, South Africa exports significant amounts of coal, primarily bituminous coal, to India. In 2020, India accounted for 51% of all coal exports, making it the most major market for South African coal. Pakistan came in second at 16%, with Vietnam following at 10%. The other nations contributed smaller portions to the overall exports (DMRE, 2023). Figure 2.7 below illustrates the various types of coal exported from South Africa between 2009 and 2022: anthracite, bituminous, and other coal. Bituminous coal is the most exported type due to its abundance in the country according to DMRE (2023).

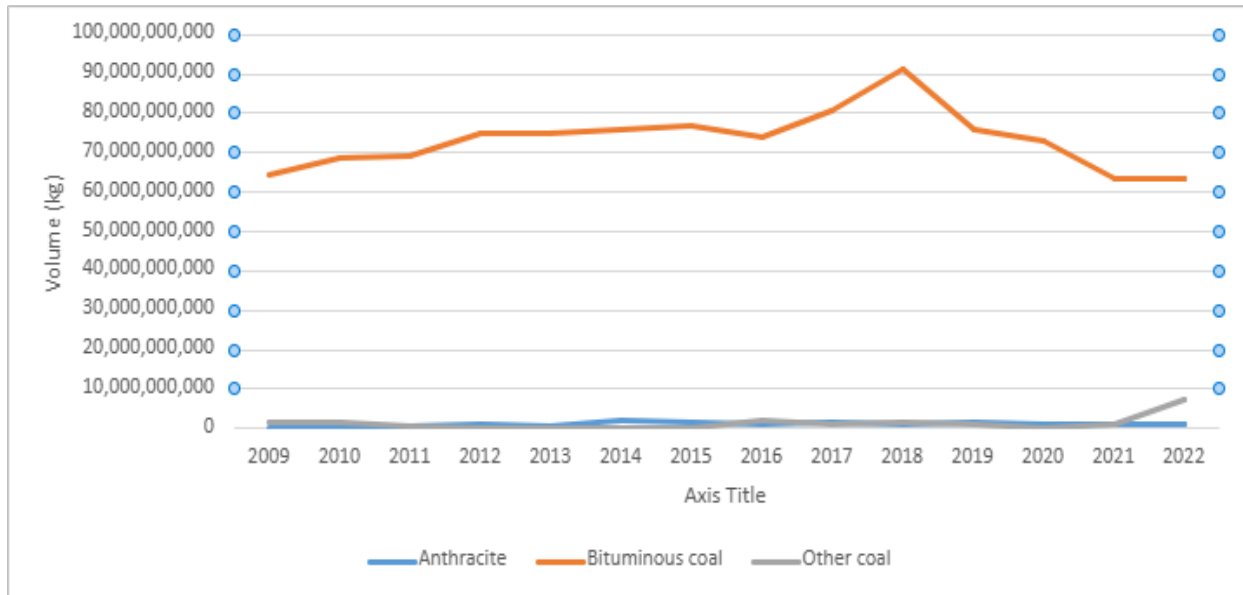


Figure 2.7: Coal exports in South Africa from 2009 to 2022

Source: South African Revenue Service (SARS)

As shown in the graph, exports of bituminous coal have been steadily increasing since 2009, although there was a slight decline in 2016. According to DMRE (Energy Price Report, 2017), South Africa experienced a decline in coal production by 0.6% in 2016. This is associated with the modest decline in coal exports in 2016. In 2018, coal exports reached an unprecedented peak, driven by strong international demand and favorable market conditions. However, beginning in 2019, there was a significant fall in coal exports, which can be ascribed to events such as the COVID-19 pandemic. The mining sector was badly disrupted by the outbreak, leading to operational challenges such as workforce shortages, supply chain disruptions, and stringent health and safety regulations. Figure 2.8 illustrates the evolution in coal export prices from 2006 to 2015.



Figure 2.8: Prices of exported coal from 2006 to 2015

Source: DMRE (2016)

South Africa's coal export prices saw consistent growth in the latter half of 2007, largely fueled by a surge in international demand for coal. These prices escalated dramatically, peaking in July 2008 at an all-time high of about 170 dollars equivalent to R1,279 per ton. This remarkable increase was primarily driven by robust demand in global markets. However, by June 2009, the situation changed drastically; coal export prices dropped to R484 per ton as the global financial crisis dampened demand for coal. In the latter half of 2009, coal prices began to recover. This resurgence was largely attributed to increased demand for coal from Asia. By the end of the first quarter of 2011, prices had once again reached impressive heights, indicating a rebound in the industry. Despite this upturn, coal prices have experienced a downward trend in the years following that peak. By the end of 2015, prices had declined significantly, settling at approximately R749.22 per ton (DMRE, 2016).

The persistent fluctuations in coal prices underscore the volatility of the global energy market and highlight the significant influence of broader economic conditions on commodity pricing (Nene, Mashau & Mpanza, 2023). This volatility poses a considerable challenge to investors, who may approach long-term projects in South Africa with caution due to the perceived risks associated with an unstable coal market. Such uncertainty has

the potential to deter both domestic and foreign investments, which are crucial for fostering economic growth in the country. Furthermore, coal exports represent a vital component of South Africa's trade balance (DMRE, 2023). When coal prices rise, this can boost the trade balance, thereby strengthening the South African rand and creating a more conducive environment for economic advancement. Conversely, declining coal prices can negatively impact the trade balance, resulting in currency depreciation and triggering inflationary pressures, therefore hindering economic growth and creating a challenging landscape for businesses and policymakers.

2.6 GOVERNMENT AND POLICY INTERVENTION

This section examines government and policy interventions aimed at reducing load-shedding and increasing electricity production in the country. Furthermore, unpack the government's intervention and policies in managing natural resources exploration, particularly in the case of coal.

2.6.1 Measures to Curb Load Shedding

Load-shedding, a controlled process of temporarily reducing the demand for electricity when supply is insufficient, has been a significant challenge in South Africa (Mogodi, Howells & Chipangura, 2024). South Africa is currently having a power shortfall of approximately 6,000 MW, which is the reason Eskom is implementing load shedding. So, each additional 1,000 MW of capacity added to the national grid reduces load shedding by one stage (SONA, 2023). Recognizing the detrimental effects load-shedding has on the economy and individuals' daily lives, the government has taken initiatives to alleviate the problem. In 2022, South Africa's Presidency formed the National Energy Crisis Committee (NECOM). The main mandate of the committee is to carry out the Energy Action Plan (EAP). This plan was aimed at reducing load-shedding and achieving national energy security (SONA, 2023). The Energy Action Plan focuses on addressing issues at ESKOM and increasing generation capacity through the following five key interventions:

- Fix ESKOM and improve the availability of existing supply.

Eskom's financial difficulties have been a major barrier to its effective functioning. With a debt burden of approximately R400 billion in recent years, the utility has struggled to finance critical maintenance, infrastructure upgrades, and new power generation projects. In accordance with the SONA (2024), the National Treasury allocated a significant debt relief package of R254 billion inclusive of R168 billion in capital and R86 billion in interest to Eskom as part of a broader strategy to stabilize the utility and address the country's persistent energy crisis. This intervention, announced in the 2023 budget, aims to enable Eskom to focus on maintaining and expanding its infrastructure, improving energy availability, and transitioning toward a more sustainable energy model.

- Allow and speed up private investment in power generation capacity

In 2021, the president announced an increase in the licensing threshold for new generation projects to 100 megawatts (MW), thereby exempting private investors from the requirement of obtaining a license for the construction of generation facilities within this capacity limit. However, a new legislative measure enacted in January 2023 has removed the 100 MW cap on electricity generation without a license (Naidoo, 2023). This adjustment was meant to alleviate the operational pressures faced by Eskom, while simultaneously augmenting the overall availability of electrical supply.

- Fast-track the procurement of new generation capacity from renewables, gas and battery storage

A significant expansion of renewable energy presents the most promising opportunity to eliminate load shedding swiftly (The Presidency, 2023). The government has made a significant step forward by approving the purchase of approximately 14,000 MW of renewable energy capacity from wind, solar, and battery storage sources. This initiative not only supports a greener energy future but also enhances energy security. Furthermore, the successful integration of the Battery Energy Storage System (BESS) initiative into the power grid, which provides 100 MWh of storage capacity, marks an exciting development in our transition to sustainable energy solutions. In addition, Eskom is focusing on increasing power imports from neighboring countries, including Botswana, Mozambique, and Zambia. Currently, an additional 400 MW of electricity is being imported from the Cahora Bassa facility in Mozambique (SONA, 2024).

- Encourage both businesses and households to make investments in rooftop solar

In addition to a redesigned bounce-back credit program intended to assist small businesses in their transition to solar power, the government also established tax incentives targeted at families and businesses who invest in solar energy. As a result, South Africa's installed rooftop solar capacity has exceeded 4,000 MW, significantly mitigating the challenges of load shedding during the winter months. Within a year of the President's unveiling of the Energy Action Plan, rooftop solar installations by households and companies have more than doubled. These new tax incentives and financial support are catalyzing a substantial increase in rooftop solar deployment, thereby contributing to an alleviation of the impact of load-shedding in the country. Furthermore, it fosters economic growth through the increment of production levels in businesses.

- Restructuring the electricity sector to succeed in long-term energy security

The National Transmission Company of South Africa (NTCSA), an autonomous organization tasked with overseeing the country's electrical system, was founded in order to revolutionize the electrical sector. The NTCSA promotes transparency and greater competition within the electricity sector, encouraging increased private-sector involvement and expanding generation capacity. Additionally, to promote a competitive electricity market, the Electricity Regulation Amendment Bill was introduced in Parliament in 2023. This new legislation aims to empower consumers to choose their electricity suppliers, fostering competition and improving efficiency among various electricity generators (SONA, 2024).

2.6.2 Government Intervention in Natural Resources Exploration

Many countries' economic prosperity depends heavily on their natural resources, especially resource-rich economies such as South Africa. According to DMRE (2022), South Africa's economic growth is largely driven by the endowment in natural resources, including platinum group metals (PMGs), gold, diamonds, coal, and iron among others. Coal, as one of the country's most significant natural resources, has been a cornerstone of South Africa's energy sector. Coal generates around 80% of South Africa's electricity

and makes a substantial contribution to export earnings, according to CSIR (2023). To regulate the exploration of natural resources, the government has initiated policies with the objective of fostering responsible extraction of natural resources while sustaining economic priorities with environmental conservation and social equity.

South Africa's primary environmental legislation, known as the National Environmental Management Act (NEMA, Act 107 of 1998), was enacted in 1998 to uphold the environmental rights enshrined in the Constitution (Republic of South Africa, 1998). The NEMA primarily outlines key principles aimed at fostering the responsible management of environmental resources and promoting sustainable development throughout the country. The Act also specifies various activities that must obtain environmental authorization from the relevant authorities prior to commencement. Through NEMA, the government conducts an Environmental Impact Assessment (EIA) to assess and mitigate the environmental risks associated with coal exploration. The EIA process is intended to advance sustainable development by encouraging the mitigation of negative environmental impacts, or by rejecting projects that would be harmful to the environment (Ashukem, 2024).

In South Africa, mineral resources are governed by the DMRE in compliance with the Mineral and Petroleum Resources Development Act (MPRDA), as stated by Mothudi (2023). The MPRDA, which was signed into law in 2002, gives the government custodianship over all mineral and petroleum resources, hence facilitating the exploration and exploitation of these resources. This ensures that their extraction is conducted in a way that promotes equitable access, socio-economic development, and environmental sustainability. The Act requires the companies involved in mining to request licenses and permits from DMRE. The functions of the DMRE, acting upon the MPRDA, include granting, refusing, controlling, administering, and managing specified permissions, rights, and permits (Schmidt, 2023). As a condition for obtaining mining rights, the Act compels companies to conduct Environmental Impact Assessments (EIAs) and further mandates that mining companies prepare Social and Labour Plans (SLPs). Thus, coal mining companies are compelled to contribute to the socio-economic development of mining-

affected communities, addressing issues such as housing, education, and employment (Heyns, 2019). This is intended to assist in reducing the harmful effects of resource exploitation on communities and the environment.

2.7 CHALLENGES AND IMPEDIMENTS TO POLICY IMPLEMENTATION

Policies are fundamental to effective governance, serving as the strategic framework through which the government addresses social needs and promotes economic development and growth. Seopetsa (2020) posits that failure to implement policy hinders economic development, particularly in developing countries. For more than 15 years, South Africa has faced persistent challenges in achieving stability and reliability within its electricity sector although the government has made concerted efforts to formulate policies aimed at ensuring the sector's long-term sustainability. These are some of the challenges:

- Corruption

One of the key challenges in relation to policy implementation in South Africa is corruption (Ntoyanto, 2019). According to Mahlala, Juta, Chigova, and Zweni (2023), corruption is not only an impediment to policy implementation but also a significant factor in undermining the country's economic growth and development. South Africa's state-owned electricity utility has faced persistent corruption issues that have significantly undermined its effectiveness and hindered the implementation of energy policies. Around 2018, for example, Eskom was found to have misappropriated over R140 billion annually, with much of this linked to Gupta-affiliated businesses and subsidiaries. These funds were diverted through the manipulation of procurement procedures, as highlighted by Mathebula and Masiya (2022). This ongoing corruption continues to undermine Eskom's ability to meet South Africa's energy needs and obstructs successful policy implementation in the sector.

- Resources limitation

Brynard (2021) asserts that financial constraints encountered by government departments and state-owned entities such as limited budgets, misallocation of funds, and inefficient financial management significantly hinder their capacity to implement

policies effectively. These challenges not only restrict operational flexibility but also undermine the overall objectives of governance and public service. Furthermore, resource limitations can lead to prioritizing short-term solutions over sustainable, long-term strategies.

- Skills shortage

According to Marume, Mutongi and Madziyire (2016), human resource quality poses another significant challenge. Skills shortages, poor training, and inadequate capacity within the public sector hinder the ability to implement policies effectively. This is particularly evident in local government, where many municipalities lack qualified personnel to execute national policies, resulting in inefficiency and delays. Furthermore, the study by Seopetsa (2020) revealed that challenges such as the government's inability to involve the public in the policy process, the public's failure to follow public policies, and setting unrealistic goals contribute to the failure of policy implementation in South Africa. Thus, the government needs to enforce measures such as training and education and ensure that participants are committed to transparency and accountability in order to augment successful policy implementation.

2.8 SUMMARY

This chapter provided an overview of economic growth, electricity consumption, electricity prices, and coal exports in South Africa. The economic growth of Botswana, Sub-Saharan Africa, and the global economy were contrasted with that of South Africa. Compared to the three other regions, Botswana's GDP growth has clearly shown greater resilience and consistency, recovering more quickly from global economic shocks like the COVID-19 epidemic and the global financial crisis. This was followed by an analysis of how load shedding or electricity rationing affected South Africa's economic growth. Additionally, the chapter revealed the governmental and regulatory bodies governing the electricity sector in South Africa. These include the Department of Mineral Resources and Energy, Department of Energy, Department of Public Enterprise, National Energy Regulator of South Africa, and the Independent Power Producers. With Eskom occupying a key role in power production and supply, these bodies coordinate their efforts to ensure the nation's electricity generation, regulation, and distribution.

This chapter also explored trends in electricity consumption and production over the years. According to the data, the country saw a downward trend in electricity production. At the same time, electricity consumption has been impacted by economic slowdowns, rising electricity costs, and load shedding. The chapter proceeded to discuss how electricity prices are modeled in the country. The National Energy Regulator of South Africa models electricity tariffs or prices through the Multi-Year Price Determination (MYPD) methodology which operates over a three-year cycle. NERSA sets tariffs that Eskom can charge based on the projected costs and revenues for that period. Furthermore, price fluctuations of electricity and also in comparison with inflation were analyzed in this chapter. Historically, electricity prices have been relatively low in the country. However, recent data indicated a significant upward trend in electricity prices over the past years. Over and above, since 2007 electricity prices have risen six times faster than the general price of goods and services, inflation. Both individuals and businesses suffered as a result of this exponential rise in electricity costs, which hampered economic expansion. An overview of coal exports and their price trends over time were presented and discussed. The South African economy is greatly abundant in coal as a natural source of energy. Thus, making the economy a key player in coal exports globally, with India as a major market. However, the coal industry has experienced notable fluctuations in export volumes and prices in the past years.

The discussion further included government policies and intervention, particularly looking at the ways to mitigate load shedding in the country and preserve coal as a natural resource. Loadshedding has posed a major challenge in the economy. In response, the government established the National Energy Crisis Committee to oversee the execution of the Energy Action Plan. This plan aimed to tackle issues within Eskom and expand the country's electricity generation capacity, thereby reducing load shedding. In South Africa, the exploration of natural resources is regulated through the National Environmental Management Act (NEMA), Act 107 of 1998. The primary aim of NEMA is to foster responsible management of environmental resources such as coal. Additionally, the Mineral and Petroleum Resources Development Act (MPRDA) was enacted in 2002 under the Department of Mineral Resources and Energy (DMRE) for the regulation of exploration and exploitation of mineral resources. Lastly, this chapter outlined the

challenges and impediments to effective policy execution. Some of the key challenges addressed include corruption, resource limitation, and skill shortages. These challenges significantly delayed progress and undermined policy outcomes. The subsequent chapter will be centered on the theoretical and empirical literature pertinent to this study.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

A comprehensive analysis will be undertaken in this section of the study to integrate both theoretical and empirical perspectives in exploring the intricate relationship between electricity consumption, pricing, and coal exports, and their collective impact economic growth of South Africa.

3.2 THEORETICAL FRAMEWORK

Three theoretical perspectives, namely the Solow growth model, export-led growth hypothesis, and resource curse theory were utilized to comprehend the role of electricity consumption, price, and coal exports on South Africa's economic growth. The theories are explained below.

3.2.1 The Solow growth model

According to Dykas, Tokarski, and Wisla (2023), the Solow growth model, also known as the neoclassical economic growth model, serves as the starting point for analyzing the economy. This study employed the Solow growth model to comprehend the influence of electricity consumption and price on economic growth. The Nobel winner Robert M. Solow first proposed the Solow growth model in his seminal paper "A Contribution to the Theory of Economic Growth" (1956). The Solow model is an important framework for understanding long-term economic growth as it emphasizes the significance of capital accumulation, labor, and technological progress. The fundamental equation of the Solow model is the production function, which can be depicted as:

$$Y = AF(K, L) \tag{3.1}$$

$$A = \text{electricity consumption} \tag{3.2}$$

Where: Y represents the level of output, K denotes the stock of physical capital, L signifies the size of the labour force, and A represents total factor productivity (TFP).

In the model, A or TFP captures technology, efficiency improvements, research and development and other factors that enhance productivity. In this case it represents electricity consumption as an essential element in production. Wherein, Haider and Bhat (2020), indeed affirms TFP as can be closely linked to energy consumption. While the Solow model does not explicitly include electricity as a separate factor in production, electricity consumption acts as a critical enabler of capital and labor productivity. As firms and economies transition to more energy-intensive technologies, electricity consumption becomes more closely aligned with TFP growth.

Studies confirm the positive relationship between electricity consumption and productivity. Wang, Zhu, Wang, Ntim and Liu (2023) found that higher electricity consumption in Belt and Road (B&R) countries, including South Africa, was closely correlated with TFP growth over period 2000 to 2021. This implies that increased access to reliable electricity positively impacted TFP, as sectors dependent on electricity could operate more efficiently. In return, productivity gains spurred further electricity demand, particularly as industries scaled up and required more consistent power to operate efficiently. This loop reflects the dual role of electricity as both an input to and a product of economic growth, where higher TFP indirectly increases electricity consumption through expanded economic activities.

Furthermore, the Solow Growth model emphasizes capital accumulation as a key driver of economic growth. According to Ateba, Prinsloo, and Gawlik (2019), electricity is essential for the operation of capital-intensive industries and the production of goods and services. Thus, rising electricity prices increase operational costs, reducing profitability and discouraging investment in new machinery, equipment, and infrastructure. This effect is particularly pronounced in energy-intensive sectors such as mining, manufacturing, and agriculture, which are critical to South Africa's economy (Kohler, 2006). Conversely, affordable electricity promotes capital investment by lowering input costs. Businesses can allocate more resources to expansion and innovation, contributing to sustainable economic growth. Therefore, electricity prices influence not only the level of capital accumulation but also the rate at which an economy can converge toward its steady-state growth path.

3.2.2 The export-led growth hypothesis

According to the theory of export-led growth (ELG), countries can increase their production capacity, increase employment, and accumulate foreign exchange reserves by increasing their exports (Krueger, 1997; Feder, 1982). Richards (2001) and Awukuse (2003) allude to this hypothesis by saying countries can accomplish economic growth not only by growing labor and capital, but also by increasing exports. Coal, as one of South Africa's major export commodities, plays a significant role in the economy, through exemplifying ELG principles by contributing to GDP growth and the nation's balance of payments. ELG builds on classical trade theories, such as comparative advantage (Ricardo, 1817) and the factor endowment model (Heckscher & Ohlin, 1933), which suggest that countries benefit by specializing in goods they can produce efficiently. South Africa possesses extensive coal reserves, granting it a natural comparative advantage in coal production that allows for effective competition in the international market.

StatsSA (2019) highlights the substantial contribution of coal to South Africa's GDP and trade balance, with coal accounting for a significant share of total exports and foreign exchange earnings. These export revenues support infrastructure, government spending, and capital investments that facilitate broader economic development and growth. The coal industry is also a critical source of employment, particularly in coal-producing regions such as Mpumalanga Province, where it generates jobs and stimulates local economic activity (Bohlmann, Horridge, Inglesi-Lotz, Roos & Staner, 2019). This aligns with ELG's premise that exports can create domestic employment and contribute to economic development.

On the other hand, Dreger and Herzer (2013) posit that the positive productivity effects expected from the export-led growth hypothesis may not always be present in developing countries, especially those rich in natural resources. While exports of natural resources can promote economic growth, they also make the economy vulnerable to risks like price volatility and demand shocks (Sachs and Warner, 1995; Guan, Zhang, Ahmad & Naqvi, 2021). This is especially relevant for South Africa, whose economy is sensitive to fluctuations in coal demand and prices. ELG models generally assume a sustainable path to growth, but South Africa's dependence on coal, a non-renewable resource, raises

sustainability concerns. Studies argue that without diversification into cleaner energy or other export sectors, South Africa may face significant economic disruptions as global markets shift away from coal.

3.2.3 Resource Curse Theory

Auty Richard first proposed the resource curse theory in his 1993 book *Sustaining Development in Mineral Economies* (Auty, 1993). The theory simply says that economies abundant in resources, particularly minerals and fuels, may face economic challenges that may prevent them from benefiting significantly from their resource wealth. Over the past four decades, economists have amassed extensive data demonstrating an adverse connection between the abundance of natural resources and economic growth (Yasmeen, Zameer & Shahbaz, 2021; Aslan & Altinoz, 2021; Sharma & Mishra, 2022). This phenomenon, also explored by Badeeb, Lean, and Clark (2017), suggests that regions rich in natural resources may not experience the expected economic benefits associated with such wealth. Instead, these resources can sometimes lead to adverse economic outcomes, including resource mismanagement, reliance on a narrow range of industries, and socio-political instability. As such, the relationship between natural resource endowments and sustainable economic progress deserves careful examination, particularly in the context of policy implications for resource-rich nations.

The resource curse theory is relevant to this study because of South Africa's high reliance on coal for the production of electricity. The country has large coal reserves, which have made it a leader in energy production (Nel, Marais & Mqotjana, 2023). However, this dependence on coal has caused many problems that fit the "resource curse" idea proposed by Auty. The resource curse describes the situation where countries rich in natural resources have slower economic growth, more authoritarian governments, and developmental challenges compared to countries with fewer resources. In South Africa's case, while coal has supported industrial growth and provided electricity to households and firms, it has also led to serious environmental damage and public health issues (Wang, 2023).

According to Nel, Marais, and Mqotjana (2023), relying on just one resource has made the economy vulnerable to changes in global markets, regulations, and shifts toward

renewable energy. For years, coal exports have helped the economy and provided vital electricity for industries. Nevertheless, this dependence also renders South Africa susceptible to fluctuations in the world's coal prices and the adverse environmental consequences of coal emissions. This issue harms economic stability and productivity. Rising electricity prices have increased these economic pressures, showing ongoing supply problems and higher operational costs (Maphuto, 2023). Hence, this study utilizes the resource curse hypothesis to comprehend the role of coal exports on the economic growth of South Africa.

3.3 EMPIRICAL LITERATURE

This study reviewed some of the studies that set foot on the energy-growth nexus inclusive of electricity price and coal exports. Many studies that dealt with the energy-growth relationship applied different time frames and employed different methodologies including the Autoregressive Distributed lag model (ARDL), Vector Error Correction Model (VECM), and Vector Autoregression (VAR) model. Thus, this section unpacks the empirical findings of the relevant studies and will consist of 4 subsections; the impact of electricity consumption and price on economic growth, secondly, the influence of coal exports on economic growth, thirdly investigate the causality among the variables and lastly assess the shock effects of electricity consumption, price and coal exports on economic growth.

3.3.1 The impact of electricity consumption and price on economic growth

A variety of research has explored the intricate interplay between energy consumption and economic growth; nevertheless, the findings of these investigations frequently present divergent conclusions. For instance, the study by Molele and Ncanywa (2018), titled "Resolving the Energy-Growth Nexus in South Africa," applied the VECM approach making use of annual data from 1980 to 2012. According to their findings, there is an adverse relationship between economic growth and electricity consumption, meaning that a rise in the consumption of electricity is linked to slower economic growth. Raheem and Yusuf (2015), who studied the energy-growth relationship across 15 chosen African nations from 1980 to 2010, corroborate the findings of Molele and Ncanywa (2018). The ordinary least squares method was used in the study to capture the results of the linear

and nonlinear regression. As per the findings of the study, most African nations, including South Africa, have negative correlations between energy consumption and economic growth.

Hlongwane and Daw (2023) carried out a comparative analysis of Zimbabwe and South Africa using the ARDL methodology and data from 1990 to 2019. The study focused on the connection between economic growth and energy consumption. The study concluded that electricity consumption had a statistically significant detrimental effect on economic growth in the two countries in the short term. In addition, the relationship between electricity consumption and economic growth remained negative in South Africa over the long term. Nonetheless, in Zimbabwe, economic growth was positively impacted by the consumption of electricity, although the relationship was statistically not significant. Using data ranging from 1970 to 2016, Chirwa and Odhiambo (2020) applied the Panel ARDL to investigate the electricity-growth relationship in 12 advanced, emerging, and developing nations including South Africa. The study concluded that electricity consumption and economic growth had a substantial and beneficial long-run association.

Badamasi (2023) used the ARDL methodology to find that, in Nigeria, a developing nation like South Africa, there is a positive link between electricity use and economic growth over the short and long term, from 1986 to 2015. Another study in Nigeria by Okoye, Omankhanlen, Okoh, Adeleye, Ezeji, Ezu and Ehikioya (2021) adopted the ARDL methodology to analyze the impact of energy consumption and economic growth nexus. Data span from 1981 to 2017 was used and the results indicated a positive impact of energy consumption on economic growth. Zhang, Zhou, Yang, and Shao (2017) applied the VAR and VECM approaches to study the connection between China's economic growth and its electricity consumption. The analysis covered data from 1978 to 2016. Their findings demonstrated that economic growth and electricity usage had a positive relationship, suggesting that a surge in economic output drives greater electricity usage, and vice versa.

The study of Churchill and Ivanovski (2020) evaluated the short and long-run connection between electricity consumption and economic growth across Australian states and territories from 1990 to 2015. They used panel data to assess the association between

the variables through the application of the fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and ARDL methodologies. The findings revealed that in the long and short run, economic growth is augmented by an upsurge in the consumption of electricity. A study in Bangladesh explored the link between electricity consumption and GDP. They used the ARDL model to evaluate this relationship, drawing on time series data spanning 1971 to 2014. The research outcomes indicate that a positive association exists between economic growth and electricity consumption over the long and short run (Dey & Tareque, 2019). Ha and Ngoc (2021) investigated the connection between Vietnam's GDP growth and energy consumption. The annual time series data gathered between 1971 and 2017 is the foundation of their study. They investigated the relationship between these variables using an asymmetric autoregressive distributed lag model. The findings convey that the adverse effects of electricity consumption on economic growth outweigh the favorable effects, in the short and long run. Due to the diverse methodologies, timelines, and types of data employed, the majority of studies examining the relationship between economic growth and electricity consumption yield inconsistent results.

According to Alshehry and Belloumi (2015) and Dagoumas, Polemis and Soursou (2020), energy prices are a vital element in facilitating economic growth. Therefore, it became imperative to incorporate electricity price into the economic growth model. Berk and Yetkiner (2014) demonstrated a significant inverse relationship between energy prices and GDP, using the ARDL methodology from 1978 to 2011. Berk and Yetkiner's (2014) findings are corroborated by Khobai, Mugano, and Le Roux (2017), who conducted a study in South Africa on the impact of energy prices on economic growth between 1985 and 2014. According to the ARDL's long-run findings, South Africa's economic growth is adversely affected by electricity prices. Another study was carried out in South Africa by Gonese, Hompashe, and Sibanda (2019) using data from 1994 to 2015. According to the report, sectoral output was adversely impacted by electricity prices. Using ARDL methodology, Takentsi, Sibanda, and Hosu (2022) assessed the connection between energy prices (electricity and oil prices) and economic performance in the economy of South Africa from 1994 to 2019. They reported that electricity prices have a significant and adverse relationship with economic growth in the short and long run.

3.3.2 The effect of coal exports on economic growth

Coal is an important element of South Africa's energy landscape, accounting for over 90% of the country's electricity generation (Beidari, Lin, & Lewis, 2017). This heavy reliance on coal highlights the importance of this fossil fuel in meeting the nation's energy demands and fostering economic growth while also raising questions about sustainability and environmental impact moving forward. Insufficient attention has been paid to how coal exports affect economic growth around the world, more especially in South Africa. Hence, literature pertaining to coal exports-growth nexus is lacking. Bohlmann, Horridge, Inglesi-Lotz, Roos, and Staner (2019) employed a newly developed regional CGE model to analyze the long-term economic effects of changing South Africa's electricity generation mix. The findings indicate that minimizing the negative impacts of reducing coal reliance depends not only on the nation's energy profile and economic structure but also on global market reactions, especially regarding coal exports. If coal exports remain stable or increase, employment and GDP growth in coal mining provinces, especially Mpumalanga, will be constrained.

Some studies have explored the effect of exports in general on economic growth. For instance, Sunde (2017) employed the ARDL approach to investigate the relationship between foreign direct investment, exports, and economic growth in South Africa. The findings were that exports and economic growth are positively correlated. The findings are in contradiction with the study of Ratombo (2019) who investigated the effects of international trade on the economic growth of South Africa for the period 2000 to 2017. The results were that exports harm economic growth, which led to the conclusion that a rise in exports does not lead to the expansion of economic growth in the country in the short and long run. Thus, the conclusions on the relationship between exports and economic growth are contradictory.

3.3.3 Causality effect among the variables

The third objective of this study is to determine if there is a causal relationship between electricity consumption, price, coal exports, and economic growth. Causality has four directions: unidirectional causality running from X to Y, unidirectional causality running from Y to X, bidirectional causality, and no causality. Different directions of causality were

thus found in numerous research that investigated the relationship between energy and growth. This includes the study of Faisal, Tursoy, and Ercantan (2017) who conducted a study in Belgium and employed the T-Y approach to investigate the causal relationship between energy consumption and economic growth from 1960 to 2012. The study revealed a unidirectional relationship running from GDP to energy consumption. The results were corroborated by Khobai, Abel and Le Roux (2021) who employed the pairwise Granger causality technique to assess the causal relationship between energy consumption and economic growth in BRICS countries from 1990 to 2018.

Zhang, Zhang, Zhao, and Yuan (2021) carried out an investigation on electricity consumption and economic growth across 45 “Belt and Road Initiative” (BRI) countries that were classified into 4 categories; all, low-medium, high-income, and “Organization of Petroleum Exporting Countries” (OPEC) for the period 1990 to 2015 found the same results where economic growth granger cause electricity consumption in the short-run and long-run in all-countries, low and medium-income and high-income countries. However, a bidirectional causal relationship between electricity consumption and economic growth existed in the short run for the OPEC nations. Mughal, Arif, Jain, Chupradit, Shabbir, Ramos-Meza and Zhanbayev (2022) also found a bidirectional causality between energy use and economic growth in South Asian countries. Through the EKC framework, they utilized the data from 1990 to 2019.

Bekun, Emir and Sarkodie (2019) examined how energy consumption, carbon emissions, and economic growth are interconnected in South Africa. The research utilized annual time series data spanning from 1960 to 2016. To assess the direction of the causality among the variables, they applied a Granger causality test. Their findings showed a unidirectional causality from electricity use or consumption to economic growth. The study conducted in China by Kapila, Seneviratna and Long (2018) examined the causal relationship between energy consumption and economic growth from 1980 to 2013. The results revealed that energy consumption and economic growth have a bi-directional Granger causality in the long run, implying that energy consumption and economic growth can help predict or forecast one another. However, Phiri and Nyoni (2016) who used

quarterly data ranging from 1994 quarter 1 to 2014 quarter revealed no causality between electricity consumption and economic growth.

A study by Belaid and Youssef (2017) explored the interplay between Algeria's economic growth, renewable and non-renewable electricity consumption, and environmental degradation. The Granger causality test was used in the study to investigate the relationships of causality between the variables using annual time series data from 1980 to 2012. The empirical results indicated a unidirectional long-run causality from Gross Domestic Product (GDP) to non-renewable electricity consumption. Sunde (2017) used the VECM Granger causality, and the findings indicated that exports and economic growth are causally related in both directions. In other words, there is a bidirectional causality among them.

3.3.4 The economic growth forecast from shock effects of electricity consumption and prices, and coal exports

A study in Benin employed the asymmetric approach over the period 1971 to 2014 and demonstrated that negative shock effects from electricity consumption cause negative shocks on real GDP (Dakpogan & Smit, 2018). The study of Antonakakis, Chatziantoniou, and Filis (2017) used the Impulse response function and found that a positive change in energy consumption has a stronger relative impact on economic growth over the period 1971 to 2011. Alexeev and Chih (2021) analyzed the shock effects of energy price on economic growth in the United States (US) from 1975 to 2018. Their research utilized ordinary least squares FE and spatial dependence models, finding that energy prices generally have small, yet statistically significant, positive effects on economic growth.

Wang, Su, Li, and Ponce (2019) adopted the impulse response function to assess the shock effects of energy prices, urbanization, and economic growth on energy consumption in 186 nations for the period 1980 to 2015. The nations were classified into 3 groups: lower-middle income, high-income, and upper-middle income groups. According to the results of the Impulse Response Function (IRF), fluctuations in energy prices have a detrimental effect on energy consumption in both high-income and lower-middle-income countries. Specifically, as energy prices rise in these regions, consumers tend to reduce their energy usage, likely due to the increased costs. However, the analysis

revealed that in upper-middle-income countries, higher energy prices can lead to an upsurge in energy consumption. This suggests that in these nations, consumers may either have a greater ability to absorb costs or may increase consumption due to rising demand or other economic factors that prompt the usage of more energy despite higher prices.

3.4 SUMMARY

This chapter discussed the theoretical and empirical literature underlying the research. Three theories namely, the Solow growth model, the export-led growth theory, and the resource curse theory, were utilized to comprehend the relationship between electricity consumption, price, and coal exports on economic growth. This study concluded with empirical literature which outlined the findings of previous studies. The empirical literature was divided into four sections following the objectives outlined in Chapter 1.

Firstly, this chapter discussed the impact of electricity consumption and price on economic growth. The studies reviewed reveal contradictory findings and there's no consensus on the relationship thereof. Secondly, the effect of coal exports on economic growth was reviewed, however, there is little literature based on that. Thus, deeming the importance of this study to contribute to the literature by examining the relationship between coal exports and economic growth. Thirdly, the study looked into available literature on the causality among variables and lastly, the shock effects of the variables on economic growth were analyzed as per previous studies.

Most literature has focused on the period from the post-apartheid era to the early 2000s. In contrast, this study examines the critical timeframe from 2016 to 2023, a period marked by significant electricity rationing in South Africa. This narrower focus is particularly significant, as it allows for a more in-depth analysis of the relationship between electricity consumption, price, coal exports and economic growth during a time when energy supply constraints were most pronounced.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

Using quantitative research methodology, this study examines the implications of electricity consumption, price, and coal exports on South Africa's economic growth from 2016 to 2023. Thus, to achieve the aim and objectives stated in Chapter 1, this chapter provides a thorough overview of the research techniques employed. This chapter of the study thus includes the data source, model specification, and estimation techniques used for the economic growth model.

4.2 DATA

This research utilizes secondary quarterly data collected from 2016Q1 until 2023Q3, summing up 31 observations. All the data for the variables examined in this research are collected from Quantec, a reliable economic data source. The description and measurement of the variables examined are outlined in Table 4.1 below.

Table 4.1: Data Description

Variable	Description	Measurement/ Unit	Source of data
GDP	Real Gross Domestic Product	R' Millions	Quantec EasyData
EC	Electricity consumption	Gigawatt hours (GWH)	Quantec EasyData
Elec_Price	Consumer price index for electricity	Index Dec 2021=100	Quantec EasyData
Coal_Exp	Coal Exports	Index Dec 2020=100	Quantec EasyData

Source: Author's compilation

4.3 MODEL SPECIFICATION

Empirically, electricity consumption and price can be linked to economic growth (Abbasi, Abbas & Tufail, 2021). On the other hand, Bohlmann, Horridge, Inglesi-Lotz, Roos, and Staner (2019) suggest that there is a link between coal exports and South Africa's economic growth. Thus, the functional model for economic growth can be written as:

$$GDP_t = f(EC_t, Elec_Price_t, CoalExp_t) \quad (4.1)$$

Then, the econometric equation can be presented as follows:

$$LGDP_t = \beta_0 + \beta_1 LEC_t + \beta_2 Elec_Price_t + \beta_3 CoalExp_t + \varepsilon_t \quad (4.2)$$

L represents the natural logarithm of the variables, β_0 is a constant parameter, the residual ε_t represents the disturbance or an error term and is assumed to be normally distributed and white noise. Symbols $\beta_1\beta_2\beta_3$ are the coefficients of the estimated model. Only GDP and electricity consumption are quantified in the logarithms in order to standardize the computation of the coefficients. The apriori expectations are as follows:

$$\beta_1 > 0; \beta_2 < 0; \beta_3 < 0$$

Electricity consumption is projected to be positively related to economic growth (Chirwa & Odhiambo, 2020). An increase in electricity consumption can lead to job creation in various sectors, from energy production to service delivery. According to the majority of empirical studies in South Africa, electricity prices harm economic growth. Therefore, it is anticipated that price will hinder economic growth (Berk & Yetkiner, 2014; Khobai, Mugano & Le Roux, 2017). High and unstable energy prices can decrease consumer spending power, hampering economic growth. Finally, coal exports are projected to be inversely associated with economic growth.

4.4 ESTIMATION TECHNIQUES

The process of estimating data involves several methodologies. These include descriptive statistics and correlation analysis, followed by unit root/stationarity test, lag length criteria, cointegration test, and the use of various econometric models such as Autoregressive Distributed Lag (ARDL). Additionally, the data collection will undergo further causality, diagnostic, and stability tests, as well as impulse response function and variance decomposition analysis.

4.4.1 Descriptive statistics

Descriptive statistics are an important first step in research according to Kaur, Stoltzfus, and Yellapu (2018). It involves numerical and graphical methods utilized to arrange, present, and analyze a data set (Fisher & Marshall, 2009). It is a valuable tool that summarizes and describes data. Descriptive statistics enable researchers to comprehend

the central tendencies; mean, mode, median, variability, and distribution of the data, providing crucial insights into the relationships between different variables within a sample or population.

4.4.2 Correlation analysis

The significance of correlation analysis lies in its ability to reveal relationships and quantify the degree of association between variables, aiding in understanding patterns and trends with the sampled data set (Gogtay & Thatte, 2017). Essentially, the correlation coefficient will range between -1 and +1 to reveal the strength and the direction of the correlation (Senthilnathan, 2019).

According to Franzese and Luliano (2018), the correlation coefficient serves as an indicator of the relationship between variables. A coefficient greater than zero signifies a positive relationship, while a coefficient less than zero points to a negative relationship. A coefficient of zero, on the other hand, means there is no correlation between the variables. Ratner (2009) elaborates further, stating that values ranging from 0 to 0.3 indicate a weak linear correlation, values between 0.3 and 0.7 suggest a moderate linear correlation, and values from 0.7 to 1 denote a strong linear correlation.

4.4.3 Unit root/ stationarity test

Persaran, Shin, and Smith (2001) highlighted the importance of testing the variables for stationarity before determining their relationship in the long run. Either I (1) or I (0) must be the order in which the variables are integrated. When a variable is integrated at order I (0), it indicates that the variable is stationary at level form. For variables integrating at order I (1), this means that the variable is non-stationary at level but becomes stationary after taking the first difference. The study employs the Augmented Dickey-Fuller test to determine whether the data set is stationary (ADF, 1981). The outcomes of the ADF test will be corroborated using the Phillips-Perron test (PP, 1988). Granger and Newbold (1974) assert that the stationarity tests will assist us in preventing erroneous causality results.

4.4.3.1 Augmented Dickey-Fuller test

The Augmented Dickey-Fuller (ADF) test was originally proposed in 1979 by Dickey and Fuller (Dickey & Fuller, 1979). According to Ajewole, Adejuwon & Jemilohun, 2020, the purpose of the ADF test is to assess the stationarity of time series. Mushtaq (2011) defines stationary time series as those that meet the following conditions. First, the series' mean must be consistent across time, indicating that there are no long-term trends influencing the average value. Second, the variance of the series should be time-invariant, suggesting that the degree of fluctuation in the data does not change across different time periods. Finally, the covariance between different time points must remain constant, implying that the relationship between observations does not evolve over time.

The formula for the ADF test is:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^p \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (4.3)$$

The null hypothesis (H_0) of the ADF test is that the series has a unit root, meaning that it is non-stationary. The alternative hypothesis (H_1) is that the series is stationary (Dickey & Fuller, 1979; 1981). The mathematical representations of the null hypothesis and the alternative hypothesis are as follows: $H_0 : \gamma = 0$ and $H_1 : \gamma < 0$

That is, the coefficient of the lagged series must be equal to zero for the series to be non-stationary and less than zero for the series to be rendered stationary. Similarly, an ADF test will be conducted for lagged LGDP in this study, and the null hypothesis and alternative hypothesis will be as follows.

$$H_0 : \mu = 0 \text{ and } H_1 : \mu < 0.$$

The ADF test on LGDP will run on the following formulated equation:

$$\Delta LGDP_t = \tau + \mu LGDP_{t-1} + \sum_{i=1}^p \kappa_i \Delta LGDP_{t-i} + \varepsilon_t \quad (4.4)$$

In the same manner, the ADF test will be carried out for the lagged LEC.

$$H_0 : \varphi = 0 \text{ and } H_1 : \varphi < 0.$$

The ADF test for LEC will be executed using the formulated equation.

$$\Delta LEC_t = \omega + \varphi LEC_{t-1} + \sum_{i=1}^p \lambda_i \Delta LEC_{t-i} + \varepsilon_t \quad (4.5)$$

An ADF test will be performed for lagged ELEC_PRICE.

$$H_0 : \beta = 0 \text{ and } H_1 : \beta < 0.$$

The ADF test on ELEC_PRICE will be conducted using the formulated equation:

$$\Delta ELEC_PRICE_t = \gamma + \beta ELEC_PRICE_{t-1} + \sum_{i=1}^p \delta_i \Delta ELEC_PRICE_{t-i} + \varepsilon_t \quad (4.6)$$

Lastly, an ADF test will be conducted for lagged COAL_EXP.

$$H_0 : \delta = 0 \text{ and } H_1 : \delta < 0.$$

The ADF test on COAL_EXP will run on the following formulated equation:

$$\Delta COAL_EXP_t = \sigma + \delta COAL_EXP_{t-1} + \sum_{i=1}^p \rho_i \Delta COAL_EXP_{t-i} + \varepsilon_t \quad (4.7)$$

4.4.3.2 Phillips Perron test

An alternative method for assessing the stationarity of a variable is the Phillips-Perron (PP) test introduced in 1988 (Phillips & Perron, 1988). This test serves to authenticate the results obtained from the ADF test by confirming the order of integration of the time series under investigation. The PP test modifies the ADF test by not relying on assumptions to take into consideration the serial correlation and heteroscedasticity in the disturbance terms (Phillips & Perron, 1989). As a result, unlike the ADF test, it does not require the inclusion of the dependent variable's lagged difference terms.

The regression model used in the PP test is as follows:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \varepsilon_t \quad (4.8)$$

The null hypothesis of the PP test depicts that the time series is non-stationary. The calculated PP test statistic is compared against the critical values from the Phillips-Perron distribution. If the PP statistic is less than the critical value at all levels of significance (1%, 5%, and 10%), the null hypothesis is rejected, meaning that the time series is stationary.

4.4.4 Lag length criteria

According to Liew (2004), it is vital to estimate optimal lag lengths in an autoregressive (AR) model. Various lag length selection criteria are used, including the Akaike information Criterion (Akaike, 1973), Bayesian information criterion (Akaike, 1979), Hannan-Quinn criterion (Hannan and Quinn, 1979), Schwarz information criterion (Schwarz, 1978), and the final prediction error (Akaike, 1969). This procedure is carried out before establishing whether there are long-term relationships among the variables. The use of few lags in a model may result in specification errors whereas too many lags may result in multicollinearity of variables, statistically insignificant coefficients, and loose degree of freedom. Hence, choosing the optimal lag length is important. This study employs Econometric Views 12 to automatically choose the appropriate lag lengths for the economic growth model.

4.4.5 Cointegration test (Bounds Test)

Nkoro and Uko (2016) describe cointegration as an econometric concept that signifies the existence of a long-term equilibrium between variables. Testing for cointegration is essential for determining whether a model empirically demonstrates significant long-term relationships. According to Kasem and Al-Gasaymeh (2022), when variables have a long-term relationship, they move together throughout time, making it possible to adjust for short-term deviations from long-term deviations. Since both series are thought to be cointegrated, they share a root stochastic trend. According to Zainal, Hitam, Zin, Vijayarajoo, and Senturk (2023), several cointegration tests can be used to determine the long-run relationship between variables including the ARDL bounds test, Johansen and Juselius (1990) test and Engel-Granger (1987) two-step method cointegration test. The Engel-Granger two-step method and Johansen and Juselius cointegration tests are suitable only for large datasets. In situations where the dataset is limited, the Autoregressive Distributed Lag (ARDL) model is more appropriate. Since the dataset for this study is limited, the ARDL bounds test to cointegration methodology was used to determine the long-run relationship between the variables.

4.4.5.1 Autoregressive Distributed Lag Model (ARDL)

The bounds test for cointegration, which is frequently applied within the framework of the ARDL model, was originally introduced by Pesaran and Shin in 1999. This methodology was subsequently refined and expanded upon by Pesaran, Shin, and Smith in 2001. The significance of the bounds test is to determine the presence of a long-run relationship between dependent variables and the regressors (Kakar, Kakar & Khan, 2010). Therefore, this study employs the Bounds test to determine the long-run cointegration between economic growth, electricity consumption, price, and coal exports. The ARDL bounds test for cointegration is often favored over the traditional method introduced by Johansen and Juselius (1990) for several reasons. According to Nkoro and Uko (2016), the ARDL cointegration technique is particularly advantageous when analyzing variables that are integrated of different orders, including I(0), I(1), or a combination of both. In contrast, Johansen's procedure requires that the variables should be integrated in the same order, either I(0) or I(1). Additionally, the ARDL bounds test approach is robust in identifying long-term relationships among the variables, even when applied to small sample sizes.

The bounds test involves estimating the following unrestricted error correction model:

$$\Delta Y_t = \alpha + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + \sum_{j=0}^q \gamma_j \Delta X_{t-j} + \lambda_1 Y_t + \lambda_2 X_{t-1} + \varepsilon_t \quad (4.9)$$

Where:

ΔY_t and ΔX_{t-j} are the first differences of the series at time (t), α is a constant, β_i and γ_j are coefficients for the lagged differences of Y and X, respectively, λ_1 and λ_2 are the coefficients for the lagged levels of Y and X, respectively and ε_t is the error term

The null hypothesis of no cointegration is tested by checking if the coefficients (λ_1 and λ_2) are summing to zero when combined (Pesaran, Shin & Smith, 2001). This is done using an F-statistic. When the F-statistic is greater than the lower and higher bound, it means there is cointegration among the variables. In other words, there is a long-run relationship between the variables (Nayam & Smyth, 2005).

According to Sari, Ewing, and Soytas (2008), following the confirmation of cointegration among the variables, the next step involves estimating the long-term relationship between these variables. Accordingly, the ARDL model, as proposed by Pesaran, Shin, and Smith (2001), will be employed as the methodological framework for analyzing the long-run relationship among economic growth, electricity consumption, price, and coal exports. The long-run coefficients obtained reflect the impact of independent variables on economic growth. This methodology therefore answers the first two study objectives.

According to Pesaran, Shin, and Smith (2001), the process of determining the long-run relationship among the variables involves specifying an ARDL (p, q) model, where p and q represent the lag length of the dependent and independent variables, respectively. Through this specification, the ARDL model incorporated lagged values of the variables, allowing it to capture delayed responses that often characterize economic data. In order to select the optimal lag, model selection criteria such as the Akaike information criteria, Schwartz information criteria, and Hannan-Quin information criteria can be used (Boluk & Mert, 2015). Ozturk and Acaravci (2010) further allude that the ARDL method allows the series to have different optimal lags. Regardless of the endogeneity of some regressors, Nkoro and Uko (2016) argue that the ARDL approach yields unbiased estimates and reliable t-statistics.

Angeliki and Menegaki (2019) assert that the ARDL methodology is versatile in its applicability, accommodating time series data with a mixed order of integration, specifically $I(0)$ and $I(1)$. This flexibility is a significant advantage over Vector Error Correction Models (VECM), which are only appropriate for time series classified as $I(1)$. Moreover, as noted by Ahmed, Zhang, and Cary (2021), the ARDL approach not only generates simultaneous short-run and long-run estimates but also produces the error correction term (ECT). The ECT is crucial as it indicates the speed of adjustment of the model, revealing how long it takes for the model to return to long-run equilibrium after a shock. In comparison to VAR models, ARDL further distinguishes itself by requiring a smaller sample size for reliable estimations, making it advantageous for empirical research where data availability may be limited. Additionally, while VAR necessitates that all included variables are stationary, ARDL accommodates non-stationary data more

seamlessly. Furthermore, econometric problems such as misspecification and autocorrelation, according to Ghouse, Khan and Rehman (2018), can be accounted for using the ARDL methodology. Thus, this study employs the ARDL methodology for the economic growth model.

The ARDL equation can be expressed as:

$$\begin{aligned} \Delta LGDP_t = & \beta + \beta_1 LGDP + \beta_2 LEC_{t-1} + \beta_3 ELEC_PRICE_{t-1} + \beta_4 COAL_EXP_{t-1} + \\ & \sum_{i=1}^n \beta_5 i \Delta LGDP_{t-i} + \sum_{i=1}^n \beta_6 i \Delta LEC_{1t-i} + \sum_{i=1}^n \beta_7 ELEC_PRICE_{t-1} + \\ & + \sum_{i=1}^n \beta_8 i \Delta COAL_EXP_{t-1} + \varepsilon_t \end{aligned} \quad (4.10)$$

4.4.5.2 Error Correction Model

This study employed the Error correction model (ECM) to estimate the short-run coefficients and the speed of adjustment which indicates the convergence of variables in the dataset towards long-run equilibrium. Pinshi (2020) specifies that the error correction coefficient must be negative and significant to guarantee the convergence of the long-run equilibrium dynamics, otherwise, the ECM specification cannot be accepted. The primary advantage of the ECM is that it avoids serial correlation in the residuals, and its regression coefficients provide good economic interpretation. According to Gujarati and Porter (2010), the size of the coefficient of the speed of adjustment can be analyzed as follows:

- Small values approaching -1 suggest that economic forces remove a significant percentage of disequilibrium each time. Thus, the correction occurs in one period.
- Extremely small values between -1 and -2 indicate that the correction will be larger and will return to long-run equilibrium after some time.
- Large values, tending to 0, indicate that the adjustment is slow.
- The value of zero indicates no change towards equilibrium and is considered insignificant.

The ECM for Economic growth model is mathematically expressed as:

$$\begin{aligned} &\Delta LGDP_t + \beta + \sum_{i=1}^n \beta_{0i} \Delta LGDP_{t-i} + \\ &\sum_{i=1}^n \beta_{1i} \Delta LEC_{t-i} + \sum_{i=1}^n \beta_{2i} \Delta ELEC_PRICE_{t-i} + \sum_{i=1}^n \beta_{3i} \Delta COAL_EXP_{t-i} + \delta ECM_{t-1} + \varepsilon_t \end{aligned} \quad (4.11)$$

Where ECM_{t-1} is the lagged error correction term and δ indicate the speed of adjustment wherein the variables will converge towards the long-run equilibrium.

4.4.6 Pairwise Granger causality test

According to Menegaki (2019), Granger Causality refers to a situation where the past can be used to predict the future. Therefore, if past values of variable X significantly contribute to forecasting future values of variable Y, then X is said to Granger cause the Y and vice versa. In accordance with Ibrahiem (2015), after confirming the long-term relationship between electricity consumption, price, coal exports, and economic growth using the ARDL bounds test technique, the pairwise Granger Causality test is applied to assess the directional influence among the variables.

The Granger Causality test involves estimating the following regression models for Y and X:

$$Y_t = \alpha_0 + \sum_{i=1}^p \alpha_i Y_{t-i} + \sum_{j=1}^q \beta_j X_{t-j} + \varepsilon_t \quad (4.12)$$

$$X_t = \gamma_0 + \sum_{i=1}^p \gamma_i X_{t-i} + \sum_{j=1}^q \delta_j Y_{t-j} + \varepsilon_t \quad (4.13)$$

Where:

Y_t and X_t are the time series at time (t), α_0 and γ_0 are constants, α_i and γ_i are coefficients for the lagged values of Y and X, respectively, β_j and δ_j are coefficients for the lagged values of X and Y, respectively and ε_t represents error term

The null hypothesis for Granger Causality test is that the coefficients of the lagged values of X in the first model are zero, ($\beta_j = 0$) for all j values. This means that X does not granger-cause Y. Similarly, the null hypothesis for the second model is that the coefficients of the lagged values of Y are zero, ($\delta_j = 0$) for all j values. Therefore, Y does not granger-cause X.

There are four possible directions of causality:

- Unidirectional causality from variable X to variable Y
- Unidirectional causality from variable Y to variable X
- Bidirectional causality between variable X and variable Y
- No existence of causality among the variables.

4.4.7 Diagnostic tests

The reliability and robustness of the model will be validated through the use of various diagnostic tests, including the Normality test, Serial Correlation test and the Heteroskedasticity tests. These tests will be carried out using EViews version 12.

4.4.7.1 Normality test

The Jarque-Bera test, developed by Jarque and Bera (1980), is a statistical test that examines the skewness and kurtosis of a given data set to determine if it deviates from a normal distribution. It is based on a Lagrange multiplier approach and is commonly used in econometrics and finance to assess the normality of data.

The following illustrates the equation of the Jarque Bera test.

$$JB = \frac{N}{6} \left[S^2 + \frac{(K-3)}{4} \right]$$

Where: N is the number of observations, S represents skewness and K represents the kurtosis.

According to Brys, Hubert, and Struyt (2004), skewness indicates the degree of asymmetry in a distribution. A distribution is symmetric when it has zero skewness, positively skewed when it has a longer tail to the right, and negatively skewed when it has a longer tail to the left. In essence, normal distribution exhibits perfect symmetry around the mean, with a skew of zero and a kurtosis of three. According to Jarque-Bera (1987), kurtosis essentially tells how peaked the distribution of the data is. If the data is not normally distributed, it may affect the validity of the statistical analyses and conclusions drawn from the data. According to the normality tests' null hypothesis, the residuals have a normal distribution. The residuals are considered normally distributed only if the probability value exceeds 0.05. Hence, the acceptance of the null hypothesis.

4.4.7.2 Serial Correlation Test

Gujarati and Porter (2010) affirm that serial correlation pertains to the correlation that exists among the error terms of a time series model. This phenomenon suggests that the residuals derived from a statistical model exhibit a lack of independence among themselves, indicating that the value of an error term at a specific time point is correlated with the values of error terms at preceding time points. This correlation violates the assumption of independence of error terms in a regression model. Possible reasons for serial correlation in the model include the tendency of the variable to remain unchanged over time, the omission of important variables from regression, and the prediction of current values based on past values. The presence of serial correlation can lead to inaccurate estimations of parameters and biased hypothesis testing.

To test for serial correlation, various statistical tests can be employed, such as the Durbin-Watson test, the Breusch-Godfrey test, or the Ljung-Box test. These tests help in determining whether the error terms are serially correlated and to what extent. If serial correlation is detected, adjustments to the model may be necessary to account for this correlation and ensure the reliability of the model's results. This study will employ the Breusch-pagan Godfrey LM test to check for serial correlation in the model. The LM test is chosen for this study because it can effectively detect higher-order ARMA errors and is applicable regardless of the presence of lagged dependent variables, making it a versatile and robust option for assessing model accuracy (Breusch & Godfrey, 2015).

The null hypothesis of the Breusch-pagan Godfrey LM test states that there is no serial correlation. The null hypothesis is tested against the probability value. If the probability value is greater than the probability value, the null hypothesis will be accepted. Therefore, the model will not suffer from heteroskedasticity (Rois, Basak, Rahman & Majumber, 2012).

4.4.7.3 Heteroskedasticity test

Raza, Ahmed, Razzaque, and Hina (2023) define heteroskedasticity as the variability, or variance, of errors in a regression model that is not constant. E-Views offers various heteroskedasticity tests, each of which involves conducting auxiliary regression using the residuals from the original equation to detect potential variance instability. This study

employs the Breusch-pagan Godfrey and Harvey to check for heteroskedasticity in the economic growth model. The null hypothesis of the Breusch-pagan Godfrey and Harvey tests states that there is no heteroskedasticity (homoskedasticity). The null hypothesis is tested against the probability value. The acceptance of the null hypothesis will occur if the probability value exceeds the probability value. Therefore, the model does not suffer from heteroskedasticity. In other words, the residuals are homoscedastic (Breusch & Pagan, 1979; Harvey, 1979).

4.4.8 Stability tests

Given the potential for instability, this study used the Cumulative Sum (CUSUM) and Cumulative Sum of squares (CUSUM of squares) to verify the model's stability (Brown, Durbin & Evans, 1975). This helps detect any structural breaks in the model and hence, leads to accurate forecasting. The CUSUM as well as the CUSUM of squares are tested through visual inspection. For the model to be considered stable over time, the CUSUM line must vary within the 5% line of significance.

4.4.9 Impulse response function

The behavior of the explained variable is revealed by the impulse response function (IRF), which takes into account both the regressors' standard deviation shock and the dependent variable's own shock. The behavior of economic growth subject to the shock influences of coal exports, electricity price, and consumption was evaluated in this study using the impulse response function. According to Alam and Ahmed (2010), the impulse response function can also be defined as the moving average of the vector autoregressive equation. Thus, a shock to a VAR system is referred to as an impulse response function and enables the representation of how variables react over time to the shocks.

4.4.10 Variance Decomposition

According to Pesaran and Shin (1995), variance decomposition estimates each innovation's contribution to the dependent variable's one-step forecast error variance. They also highlight how this approach aids in comprehending the importance of innovations in explaining the changes in the dependent variable of the model. According to Alam and Ahmed (2010), the impulse response function involves a graphical

representation of determining whether the economic shocks have a negative or positive impact, while variance decomposition indicates the magnitude of the impact.

The ordering of the variables on the stage of estimation significantly influences the resulting output (Basse and Reddemann, 2010; Jakada, Mahmood, Ahmad, Garba Muhammad, Aliyu Danmaraya and Sani Yahaya, 2022). Thus, the ordering of variables in the impulse response function and variance decomposition in this study is grounded in the Solow growth theory. Economic growth is placed first because it is the explained variable as per this study and the Solow growth model. According to Twerefou, Iddrisu, and Twum (2018), economic growth drives electricity consumption. In turn, an increase in electricity consumption imply an expansion in economic growth. Therefore, electricity consumption is placed second. The third variable is the electricity price. Changes in electricity consumption and overall demand can directly influence prices. Higher demand for electricity due to economic growth and increased consumption can lead to price adjustments in the market. Finally, coal exports are placed last. Changes in the consumption of electricity and prices can significantly impact the volume of coal exports. The IRF and Variance decomposition are estimated from the VAR system.

4.5 SUMMARY

This chapter described the research methods used to examine the implications of electricity consumption, price, and coal exports on South Africa's economic growth. It includes the source of data used in this analysis. The economic growth model was specified based on the theoretical and empirical literature studied in Chapter 3. This study further explained the econometric techniques appropriate for time series. The estimation of the economic growth model followed the ARDL model. Therefore, to ensure cointegration among the variables, the study adopted the Bounds test. The ECM is developed based on the ARDL to determine the cointegration equation, which indicates how quickly the variables will converge to equilibrium in the long run. The subsequent chapter will apply all techniques explained in this chapter, including descriptive statistics, correlation analysis, unit root test, causality, diagnostic, stability tests, impulse response function, and variance decomposition analysis.

CHAPTER 5

DISCUSSION/ PRESENTATION/ INTERPRETATION OF FINDINGS

5.1 INTRODUCTION

Several studies have looked into the relationship between the consumption of energy and economic growth. Different methodologies were applied in these studies, leading to contradictory findings regarding the energy-growth relationship. Therefore, the purpose of this chapter is to present the results of each econometric technique tested using EViews 12, including the descriptive statistics, correlation analysis, stationarity tests, Autoregressive distributive lag (ARDL) model, error correction model (ECM), diagnostic tests, Pairwise Granger causality test, stability tests, impulse response functions (IRF) and Variance decomposition. In-depth analysis and discussion of the outcomes from various econometric techniques are provided to report the empirical results.

5.2. EMPIRICAL TEST RESULTS

This section is intended to provide a comprehensive presentation and report on the econometric results obtained from EViews 12, following the same order as they were presented in Chapter 3.

5.2.1 Descriptive statistics results

Descriptive analysis as a technique to summarize the main features of the dataset is presented in Table 5.1. It includes the sample, measure of central tendency (mean, median, and mode), measure of variability (standard deviation), and measures of distribution (skewness, kurtosis, and the Jarque Bera).

Table 5.1: Descriptive analysis

	LGDP	LEC	ELEC PRICE	COAL EXP
Mean	6.6544	4.7446	83.9946	118.0419
Median	6.6579	4.7485	82.5666	109.6000
Maximum	6.6667	4.7746	124.3667	222.8333
Minimum	6.5824	4.6956	62.6000	81.1000
Std. Dev	0.0149	0.0206	16.7785	30.0714
Skewness	-3.7508	-0.7320	0.5964	1.8434
Kurtosis	18.6938	2.7261	2.3033	6.7711
Jarque Bera	390.8234	2.8655	2.4650	35.9283
Probability	0.0000	0.2386	0.2915	0.0000
Sum	206.2887	147.0827	2603.833	3659.300
Sum Sq Dev	0.0066	0.0127	8445.562	27128.79
Observations	31	31	31	31

Source: Author's computation using EViews 12

The descriptive statistics as indicated by Table 5.1 show statistical summaries for four variables: LGDP, LEC, Elec Price, and Coal Exp. The first row indicates the mean values of the variables, which represent the averages. According to the table, the average values of economic growth, electricity consumption, price, and coal exports are 6.6544, 4.7446, 83.9946, and 118.0419, respectively. Row 5 illustrates the standard deviation values per variable. It is drawn from the results that coal exports and electricity price have the highest standard deviation values. This means that coal exports and electricity price are more volatile. However economic growth and electricity consumption depict low standard deviation values of 0,0149 and 0,0206, respectively. This means that the data points for electricity consumption and economic growth are closer to the mean or average.

A normal distribution has a skewness of zero according to Brys, Hubert and Struyt (2004). Therefore, the skewness coefficients in Table 5.1 show that economic growth and electricity consumption are negatively skewed while electricity price and coal exports are positively skewed. Jarque-Bera (1879) alluded that a series must have a kurtosis of 3 for the series to be normally distributed. Looking at the Jarque Bera results in Table 5.1, it is shown that the null hypothesis for economic growth (LGDP) and coal exports cannot be

accepted since the probability value is less than 0.5. This implies that economic growth and coal exports are non-normally distributed. However, the null hypothesis for electricity consumption and price is accepted because the probability value is greater than 0.5. The Jarque Bera coefficients for electricity consumption and price are 2.8655 and 2.4650, respectively, which are closer to the value of 3. This concludes that electricity consumption and price are normally distributed. The number of observations is 31 in this study.

5.2.2 Correlation analysis

For the purpose of assessing the degree and direction of the association among the variables, the study relied on correlation analysis. Table 5.2 below showcases the findings.

Table 5.2: Correlation analysis

	LGDP	LEC	ELEC_PRICE	COAL_EXP
LGDP	1			
LEC	0.1852	1		
ELEC_PRICE	0.2303	-0.6666	1	
COAL_EXP	0.3542	-0.1573	0.5286	1

Source: Author's computation using EViews 12

According to the results, there is a weak positive relationship between electricity consumption and GDP. Electricity price also exhibit a weak positive relationship with GDP. The findings indicate that high electricity consumption and price will boost economic growth. However, the study of Takentsi, Sibanda, and Hosu (2022) revealed a weak negative relationship between electricity prices and economic growth. The results further reveal a moderate positive relationship between coal exports and economic growth, implying that as coal exports increase so does economic growth. Additionally, the findings show a moderate negative relationship between electricity price and electricity consumption and a weak negative relationship between coal exports and electricity consumption. Lastly, a moderate positive correlation exists between coal exports and electricity price. Hence, multicollinearity is not a concern.

5.2.3 Unit root/ stationarity test results

To verify the unit root or stationarity of the variables, the study employed the Augmented Dickey-Fuller (ADF) test. The Phillips Perron (PP) test was used to corroborate the findings. The findings of the unit root tests using ADF test and PP test are shown in Table 5.3 and Table 5.4, respectively.

Table 5.3: Unit root results using ADF test

Variables	Model specification	At level	1 st difference	Decision
LGDP	Intercept	-4.1177***	-7.9399***	Stationary at I(0)
	Trend and intercept	-4.1628**	-7.7940***	Stationary at I(0)
	None	0.2403	-8.0728***	Stationary at I(1)
LEC	Intercept	-2.6185	-7.7855***	Stationary at I(1)
	Trend and intercept	-4.6824***	-7.7085***	Stationary at I(0)
	None	-1.0673	-7.6925***	Stationary at I(1)
Elec_Price	Intercept	5.1884	-0.3275	Non-stationary
	Trend and intercept	-0.1235	-1.8307	Non-stationary
	None	1.85	1.9994***	Stationary at I(1)
Coal_Exp	Intercept	-2.3149	-4.8758***	Stationary at I(1)
	Trend and intercept	-2.4598	-4.8181***	Stationary at I(1)
	None	-0.2434	-4.9472***	Stationary at I(1)

Note: The variables are statistically significant at (*), (**), (***) represent 10%, 5%, 1% respectively.

Source: Author's computations using EViews 12

According to the results in Table 5.3, the Augmented Dickey-Fuller (ADF) test reveals that LGDP is stationary when there is intercept and, trend and intercept at level form. Therefore, the null hypothesis of non-stationarity is then rejected. Even after differencing, LGDP became stationary at all model specifications. The ADF test further reports that electricity consumption (LEC), electricity price (Elec_Price), and coal exports (Coal_Exp) are non-stationary at level, however, they became stationary after the first difference. Thus, the null hypothesis of non-stationarity is accepted. In summary, the results of ADF

conclude that LGDP integrates at order I(0), LEC integrates at order I(1), Elec_Price integrates at order I(1), and Coal Exp integrates at order I(1).

Table 5.4: unit root results using PP test.

Variables	Model specification	At level	1 st difference	Decision
LGDP	Intercept	-4.1177***	-19.335***	Stationery at I(0)
	Trend and intercept	-4.1628***	-19.6762***	Stationery at I(0)
	None	0.6027	-17.0425***	Stationery at I(1)
LEC	Intercept	-2.6185	-11.7151***	Stationery at I(1)
	Trend and intercept	-4.2994	-12.8055***	Stationery at I(1)
	None	-0.7456	-9.3368***	Stationery at I(1)
Elec_Price	Intercept	4.1354	-5.1338***	Stationery at I(1)
	Trend and intercept	-1.4924	-7.1268***	Stationery at I(1)
	None	5.1593	-3.8901***	Stationery at I(1)
Coal_Exp	Intercept	-2.3529	-4.9644***	Stationery at I(1)
	Trend and intercept	-2.6007	-4.9423***	Stationery at I(1)
	None	-0.0602	-5.0387***	Stationery at I(1)

Note: The variables are statistically significant at (*), (**), (***) represent 10%, 5%, 1% respectively.

Source: Author's computations using EViews 12.

Table 5.4 shows the outcomes of the PP test at level and first difference. The PP test confirmed the results obtained from the ADF test on LGDP, LEC, Elec Price, and Coal Exp. LGDP was shown to be stationary at level, and hence, the null hypothesis of non-stationarity is rejected. Furthermore, LEC, Elec Price, and Coal Exp became stationary only after the first difference, and therefore, the null hypothesis of non-stationarity is accepted. This implies that LGDP integrates at order I(0) while LEC, Elec Price, and Coal Exp integrate at order I (1). Therefore, since the model consists of a mixed order of integration I (0) and I (1), ARDL is the right model to check for cointegration among the variables.

5.2.4 Lag Length Selection Criteria

Selecting the proper lag length becomes essential in time series analysis since it helps in accurately specifying models such as ARDL. In this study, the right lag length for the model was evaluated using EViews 12. Table 5.5 below displays the outcomes of the selection criteria.

Table 5.5: Lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-90.5615	NA	0.0079	6.5214	6.7100	6.5805
1	-25.9028	107.0214	0.0002	3.1657	4.1086	3.4610
2	9.4799	48.8031*	7.96e-05*	1.8289*	3.5263*	2.3605*

Note: *Indicates lag order selected by the criterion; LR: Sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Source: Author's computation using EViews 12

According to Table 5.5, all lag criteria (LR, FPE, AIC, SC and HQ) suggest a lag order of two. Thus, the model's lag is two in this study, as indicated by the asterisks. The Akaike Information Criterion (AIC) is the preferred selection criterion because of its robustness in handling small sample sizes (Hurvich & Tsai, 1989). Therefore, this study will use the AIC for model specification, given that the number of observations in this model is small.

5.2.5 Cointegration test results

The study applied the ARDL bounds test to establish whether the variables had a relationship in the long run. The findings are presented in Table 5.6.

Table 5.6: Bounds test results

Test Statistic	Value	K
F-statistic	9.779121	3
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	3.47	4.45
5%	4.01	5.07
2.5%	4.52	5.62
1%	5.17	6.36

Source: Author's computations using EViews 12

According to the findings of the Bounds test, the calculated f-statistic of 9.7791 is beyond the upper bound and the lower bound critical values at all significance levels. As a result, we have sufficient evidence to confirm cointegration among the variables since the null hypothesis of no cointegration cannot be accepted. Therefore, the cointegration of the variables allows for the long-run estimation of the coefficients and subsequently, the error correction model (ECM) of the economic growth model.

5.2.6 Autoregressive Distributive Lag (ARDL) results

The following Table 5.7 displays the ARDL estimates for the economic growth model in the long run.

Table 5.7: Long-run results

Variable	Coefficient	Std. Error	T-stat	Prob
LEC	2.277678	0.4366	5.2156	0.0000
ELEC_PRICE	0.004961	0.0010	4.6103	0.0002
COAL_EXP	-0.000314	0.0001	-2.7525	0.0127

Source: Author's computation using EViews 12

$$LGDP = 2.2776LEC + 0.0049ElecPrice - 0.0003CoalExp \quad (5.1)$$

According to the findings, LEC and LGDP have a positive long-term relationship that is significant at 1%. So, the gross domestic product of South Africa will rise by 2.2776% for every 1% increase in electricity consumption, ceteris paribus. The findings are in line with the Solow growth model wherein electricity consumption, through the total factor productivity (TFP), influences economic growth. According to Chirwa and Odhiambo

(2020), electricity consumption promotes the production of goods and services thus leading to economic expansion or growth. The findings support the study of Opeyemi and Paul-Francois (2019) confirming the observations. South Africa faces challenges such as electricity supply shortages and frequent load-shedding. These issues hinder economic growth by reducing productivity, increasing operating costs and discouraging investment. Thus, increased and reliable electricity consumption is crucial for South Africa's economic growth as it drives industrial activity, fosters innovation and supports the expansion of infrastructure. Addressing the current energy challenges is key to unlocking the full potential of economic growth in the country.

The findings further illustrate a positive long-term relationship between electricity price and LGDP. The relationship is statistically significant at a 1% level. Thus, a 1% rise in the price of electricity would cause a 0.0049% boost in economic growth, *ceteris paribus*. The findings contradict the Solow growth model, which suggests that an increase in electricity prices adversely affects capital accumulation, a key factor for driving economic growth. Additionally, these findings contradict those of Khobai, Mugano, and Le Roux (2017) and Takentsi, Sibanda, and Hosu (2022), who indicated that prices of electricity have a detrimental long-term influence on economic growth. Nonetheless, the coefficient is rather small, signifying the almost zero elasticity of GDP response. While lower prices are beneficial, South Africa has endured high electricity prices due to factors like inefficiencies in the state-owned utility ESKOM and reliance on aging coal plants. Thus, affordable and stable electricity prices will allow South African companies, particularly in sectors like mining and manufacturing, to produce goods at lower costs.

At a 5% significance level, it was discovered that coal exports had an adverse relationship with LGDP in the long run. When coal exports rise by 1%, economic growth will decrease by 0.0003%, *ceteris paribus*. The findings contravene the export-led growth theory as the expansion of coal exports has not led to significant benefits for the nation. The results support the resource curse hypothesis introduced in 1993 by Auty Richard. Despite South Africa's abundant coal reserves, the country is still experiencing severe electricity rationing and high electricity prices. Export of coal reduces the tons of coal available for electricity generation thus leading to a contraction in economic growth. Therefore,

stakeholders are advised to reduce the exportation of coal to increase electricity generation and consumption. Excess supply of coal reserves has the potential to reduce electricity rationing and escalating electricity prices that the country is facing. This strategy will benefit the economic prognosis of South Africa.

5.2.7 Error correction model

After obtaining the long-run estimates using ARDL, the speed of adjustment and the relationship among the variables in the short run were ascertained by employing the ECM. Table 5.8 depicts the ECM findings.

Table 5.8: ECM and short-run results

Unrestricted constant and unrestricted trend				
Variable	Coefficient	Std. Error	t-stat	Prob
C	-4.4719	0.6641	-6.7334	0.0000
@TREND	-0.0037	0.0058	-6.4106	0.0000
D(LEC)	1.2117	0.1312	9.2321	0.0000
D(LEC (-1))	-0.4497	0.1325	-3.3945	0.0030
D(ELEC_PRICE)	-0.0004	0.0006	-0.8172	0.4239
D(ELEC_PRICE (-1))	-0.00032	0.0012	-2.6327	0.0164
CointEq (-1)*	-1.0022	0.1489	-6.7299	0.0000

Source: Author's computation using EViews 12

In the short run electricity consumption maintained a positive relationship with LGDP at a 1% significance level. This means that a 1% increase in electricity consumption translates to a 1.2117% improvement in economic growth, *ceteris paribus*. The results are in tune with the findings of Badamasi (2023), who found that electricity consumption positively impacts economic growth in the short and long run. Furthermore, the results indicate a negative, yet insignificant relationship between electricity price and LGDP in the short run. An increase of 1% in electricity prices is associated with a decline of 0.0004 in the rate of economic expansion. Although the relationship is insignificant, the coefficient is too small implying a zero elasticity of electricity price to LGDP. On the other hand, coal exports did not exhibit any short-run estimation. Perhaps given the set model estimation coal is not fundamentally producing estimates worth noting. The coefficient of the cointegration equation (-1.0022) is negative as required and statistically significant at all levels. The

cointegration vector shows that a short-term deviation from the long-term equilibrium is corrected by 100.22% quarterly. The ECT results align with those of Golder, Sultana, Hossain, Hossen, and Hossain (2022), who studied the nexus between finance and growth in Bangladesh using the ARDL model. The cointegration equation above -1 indicates that the GDP model returns to long-run equilibrium relatively quickly.

5.2.8 Pairwise Granger Causality Results

In order to determine the causal relationships among the variables, the study conducted the Granger causality test. This analysis facilitates the prediction of one variable based on the behavior of another. The results of the Granger causality test are presented in Table 5.9.

Table 5.9: Pairwise Granger causality

Null Hypothesis	Obs	F-statistic	Prob
LEC does not Granger cause LGDP LGDP does not Granger cause LEC	29	0.07623 3.92187	0.9268 0.0336*
ELEC PRICE does not Granger cause LGDP LGDP does not Granger cause ELEC PRICE	29	0.35158 0.25827	0.7071 0.7745
COAL EXP does not Granger cause LGDP LGDP does not Granger cause COAL EXP	29	0.59281 0.12821	0.5607 0.8803
ELEC PRICE does not Granger cause LEC LEC does not Granger cause ELEC PRICE	29	12.3507 7.51216	0.0002*** 0.0029***
COAL EXP does not Granger cause LEC LEC does not Granger cause COAL EXP	29	2.17748 1.03346	0.1352 0.3711
COAL EXP does not Granger cause ELEC PRICE ELEC PRICE does not Granger cause COAL EXP	29	0.89351 1.15503	0.4224 0.3320

Note: *, ** and *** represent significance at 1%, 5% and 10% levels.

Source: Author's computation with E-Views 12

The results obtained reveal a unidirectional causality running from GDP to electricity consumption. This implies GDP can be used to predict electricity consumption. The results are congruent with those reported by Yusuf (2018) and Khabai (2017). As such, a high rate of economic growth would be accompanied by increased consumption of electricity. Typically, as the production of businesses increases due to economic growth,

more energy will be required to sustain growth and thus the consumption of electricity will increase. Additionally, the Granger Causality outcomes demonstrated a bidirectional causality involving electricity price and electricity consumption. So, electricity consumption does not only influence electricity price, but electricity price also affects electricity consumption. When electricity consumption increases, demand for electricity then may exceed the supply capacity, which leads to higher electricity prices. Conversely, when electricity prices are high, consumers and businesses may reduce their electricity consumption to lower their energy bills thus lowering the productivity rate. Granger Causality results further report the absence of a causal relationship concerning coal exports and GDP. This means that changes in coal exports do not predict changes in the economic growth of South Africa.

5.2.9 Diagnostic test results

This study conducted the normality (Jarque-Bera) test, heteroskedasticity tests, and the serial correlation test to validate the model's reliability and robustness. The diagnostic tests are presented below.

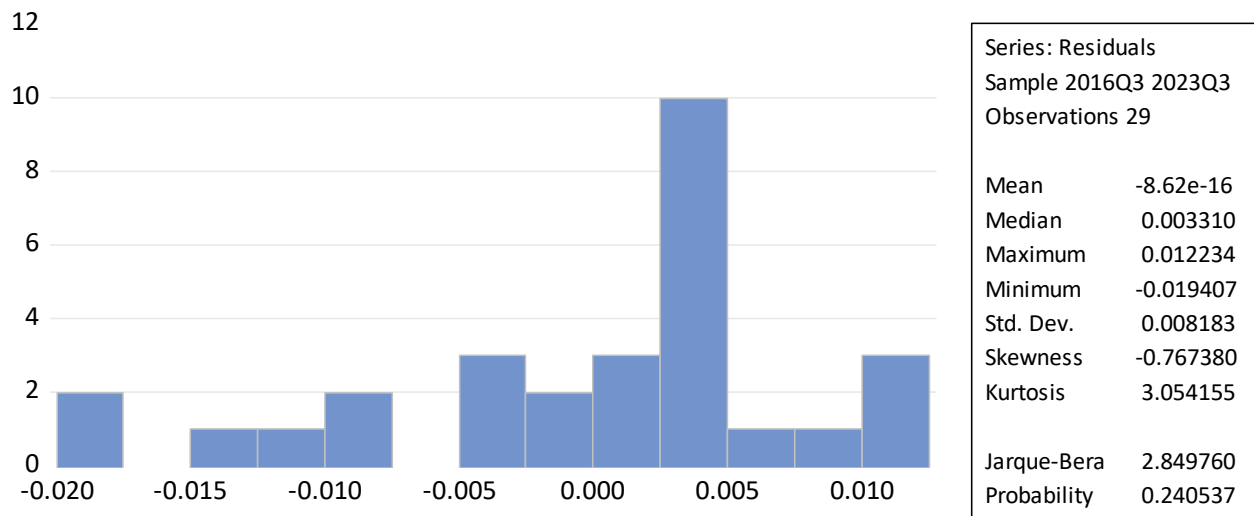


Figure 5.1 Normality test

Source: Author's computation using EViews 12

According to the Normality test, the residuals of the model are normally distributed. In light of the probability value of 0.2405 being higher than 0.05 implies that the null hypothesis, according to which the residuals are normally distributed, cannot be rejected. The skewness of the model which suggests the degree of asymmetry in the distribution of the data illustrates that the residuals are skewed to the left since it is negative (-0.7673). The left-skew of the residuals is because the median is greater than the mean value of the model. Furthermore, the kurtosis of 3.05 is mesokurtic which suggests a normal distribution of the residuals.

Table 5.10: Serial correlation test

Item	Applied test	Null Hypothesis	F-stat	p-value	Decision
Serial correlation	Breusch-Godfrey	No autoregressive serial correlation	0.07009	0.8882	Do not reject H_0 , there is no serial correlation among variables.

Source: Author's computation using EViews 12

This study relied on the Breusch-Pagan Godfrey test in order to diagnose the model for serial correlation. The computed probability value of 0.8882 exceeds the 0.05 significance level. Therefore, the null hypothesis of no autoregressive serial correlation among the variables is not rejected. In essence, the Breusch-Godfrey serial correlation test confirms that the model is free from serial correlation.

Table 5.11: Heteroskedasticity tests

Item	Applied test	Null Hypothesis	F-stat	p-value	Decision
Heteroskedasticity	Breusch pagan Godfrey	No heteroskedasticity	1.3574	0.2525	Do not reject H_0 , there is no heteroscedasticity
Heteroskedasticity	Harvey	No heteroskedasticity	0.6653	0.6424	Do not reject H_0 , there is no heteroscedasticity

Source: Author's computation using EViews 12

The Breusch-Pagan Godfrey test and the Harvey test were used in this study to test for heteroskedasticity in the model. According to the tests, the model is devoid of heteroskedasticity given the estimated probability values of 0.2525 and 0.6424,

respectively. The null hypothesis in both tests of no heteroskedasticity is therefore accepted since the p-values exceed the 5% significance level.

5.2.10 Stability test results

To verify the model's stability, the study incorporated the CUSUM and CUSUM of squares. Figures 5.2 and 5.3 depict the CUSUM and CUSUM of squares tests, respectively.

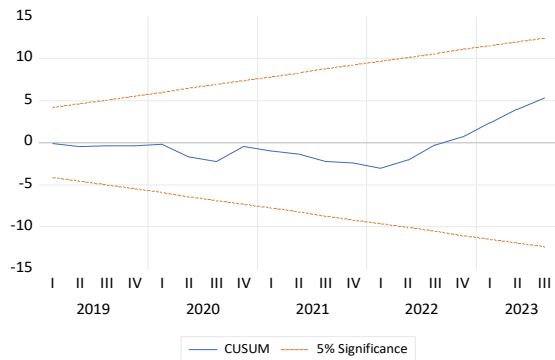


Figure 5.2: CUSUM test

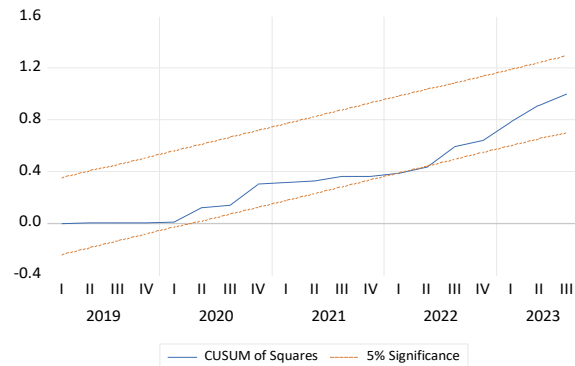


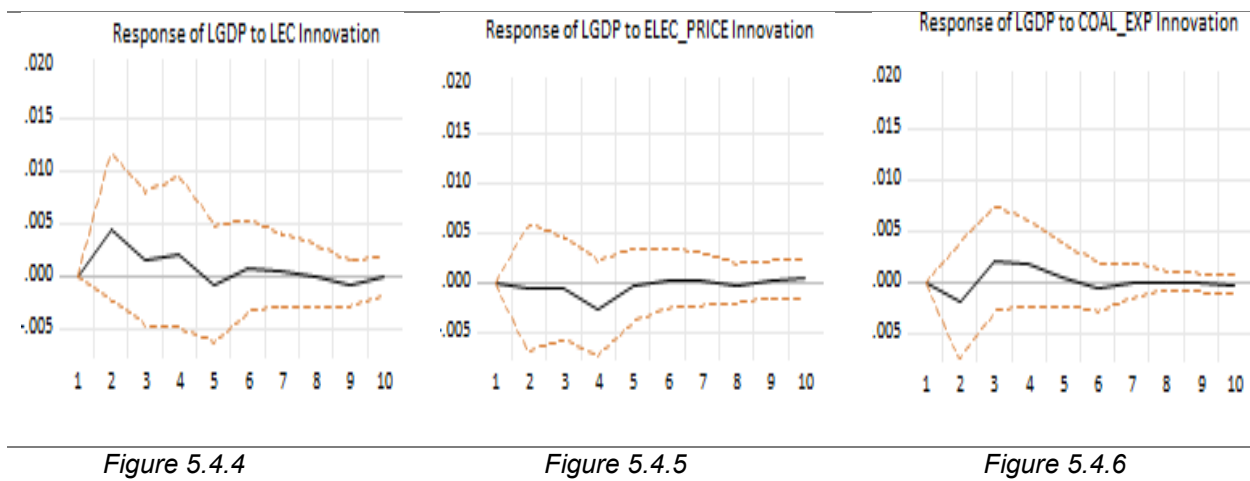
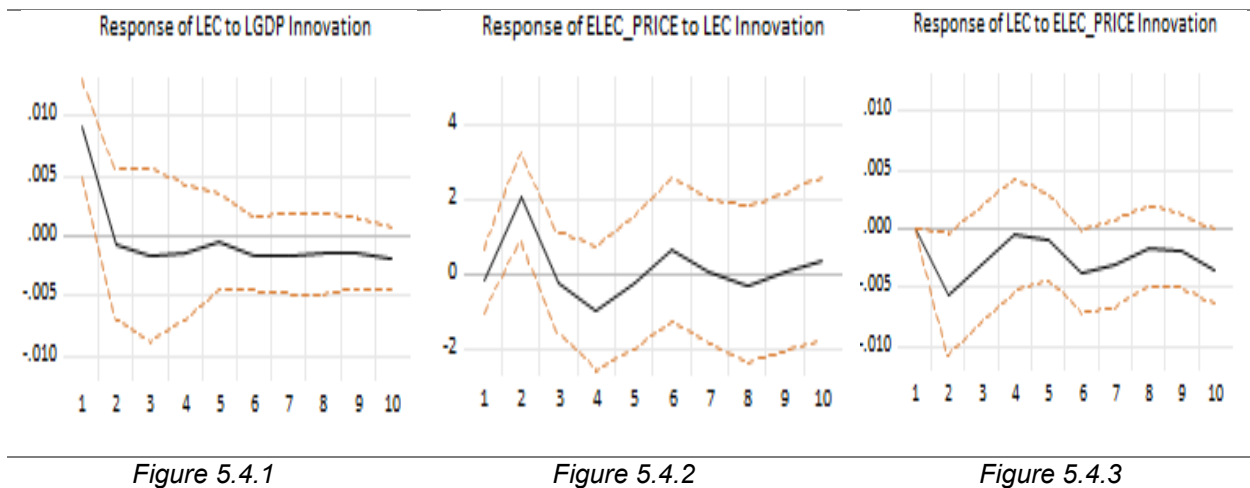
Figure 5.3: CUSUM of squares test

Source: Author's computations using EViews 12

Based on the CUSUM test in Figure 1, the model appears to be stable as the CUSUM line fluctuates within the 5% significance line for the given period. The CUSUM of squares test in Figure 2 similarly appears to be stable, with the CUSUM line fluctuating inside the 5% significance line. Although the CUSUM line touched the 5% line in 2022 quarter 1 to 3, it did not exceed it.

5.2.11 Impulse Response Function

The dynamic effects of a shock to a variable in a system are examined using the impulse response function (IRF). The IRF showcases how the system responds over time to a sudden change or shock in one of the variables. The figures 5.4.1 to 5.4.6 below present the impulse response function.



Source: Author's computations using EViews 12

The dotted lines indicate a one standard deviation range around the point estimate, used to assess the statistical significance of the impulse response function. Figure 5.4.1 shows that the response of electricity consumption to a one-period shock to GDP results in a marginal negative change from the 2nd period till the 10th period. Figure 5.4.2 shows that a one-period standard deviation shock to electricity consumption marginally raises electricity prices, although the impact on average diminishes. Furthermore, a shock to electricity prices reduces the amount of electricity consumption, which is illustrated in Figure 5.4.3. Increased electricity prices can contribute to overall inflation, as the cost of goods and services rise leading to a decline in electricity consumption. Subsequently, a decrease in electricity consumption negatively impacts economic growth. With reference

to the positive impact of electricity consumption on economic growth, potential GDP will be negated due to electricity price shocks.

Figure 5.4.4 depicts that the response of GDP to electricity consumption shock is positive in the short run, however, the impact on average is neutral. The results are in line with the study of Antonakakis, Chatziantoniou and Filis (2017), who used the Impulse response function and found that a change in electricity consumption positively impacts economic growth. Figure 5.4.5 reveals that initially, economic growth responds neutrally to electricity price shock, but it is negative in the medium term. However, the impact is ultimately neutral in the long run. Figure 5.4.6 demonstrates that a shock to coal exports initially reduces GDP. Over the medium term, GDP shows a positive response, but in the long run, the response is neutral.

5.2.12 Variance Decomposition

The variance decompositions of LGDP, LEC, Elec Price, and Coal Exp are presented in Table 5.12 below. Table 5.12 illustrates this decomposition by highlighting the contribution of past values of a regressor to its variance, alongside the effects of other variables incorporated within the model. The objective is to observe the effects of shocks to the regressed variable in the short and long run. The third period indicates the short run, while the tenth period indicates the long run as reflected in the table below.

Table 5.12: Variance Decomposition

Variance decomposition of:	Period	S.E	LGDP	LEC	ELEC PRICE	COAL EXP
LGDP	1	0.01633	100.0000	0.0000	0.0000	0.0000
	3	0.01757	89.7877	7.4393	0.2185	2.5543
	10	0.01812	84.7819	9.1692	2.4958	3.5529
LEC	1	0.0128	50.1016	49.8983	0.000	0.000
	3	0.0169	30.0183	53.7988	14.2605	1.9523
	10	0.0194	26.8262	48.1661	22.1897	2.8178
ELEC PRICE	1	2.2623	0.7075	0.6159	98.67	0.00
	3	3.7412	11.6775	31.8346	56.1530	0.3346
	10	8.6069	21.0686	8.2672	65.7491	4.9149
COAL EXP	1	19.6380	3.3859	13.3501	20.4558	62.8080
	3	31.2508	7.6765	37.4381	20.4139	34.4743
	10	31.8184	7.7997	36.9598	21.7421	33.4982

Source: Author's compilation using Eviews 12

The results indicate that the forecast error for LGDP in the first period was 100% due to its own innovations. From the second period, the variability in the forecast error related to LGDP was mainly associated with its own innovations. Notably, this association showed a downward trend in percentages over time. In the short run, specifically during the third period, the contributions to LGDP innovations were as follows: LGDP accounted for a significant 89.78% of the forecast variance. Meanwhile, LEC contributed 7.43%, the Elec price contributed 0.21%, and coal exports accounted for 2.55%. This distribution underscores the dominant influence of LGDP's own innovations within the short-term forecast error.

By the tenth period, the landscape had evolved, with 84.78% of the one-step forecast variance in LGDP still attributable to its own innovations. However, the impact of other

variables began to gain traction: variations in LEC accounted for 9.16%, while the increase in Elec price contributed 2.49%, and coal exports rose to 3.55%. This gradual rise in the influence of external factors suggests that although LGDP remains significantly self-influencing, there is an increasing interaction with other variables impacting LGDP.

The variance decomposition of LEC reveals that in the first period, changes in LEC are explained by 50.10% due to innovations in LGDP and 49.90% due to its own innovations. This aligns with theory, as economic growth generally leads to an increase in electricity consumption. In the short run, LEC accounts for 53% of its own innovations, while LGDP, electricity prices, and coal exports contribute 30.01%, 14.26%, and 1.95%, respectively. In the long run, shocks to LGDP and electricity prices lead to fluctuations in LEC of 26.82% and 22.18%, respectively, while coal exports account for only 2.81% of these fluctuations.

In the initial period, fluctuations in the Elec price are primarily due to its own shocks, which account for 98% of the variation. In both the short run and the long run, a shock to Coal Exp causes minimal impacts, resulting in approximately 0.33% and 4.91% fluctuations in Elec price, respectively. Similarly, a shock to LGDP leads to changes of 11.67% in the short run and 21.06% in the long run. Meanwhile, a shock to LEC accounts for 31.83% fluctuations in Elec price in the short run and 8.26% in the long run. A shock to LGDP, LEC, and Elec price results in approximately 3.38%, 13.35%, and 20.45% changes in Coal Exp in the first period, respectively. In the short run, a shock to LGDP leads to a 7.67% fluctuation in Coal Exp, while in the long run, this fluctuation increases slightly to 7.79%. Conversely, LEC accounts for 37.43% of changes in Coal Exp in the short run and 36.95% in the long run. Elec price contributes to 20.41% of changes in Coal Exp in the short run and 21.74% in the long run.

5.3 SUMMARY

This chapter reported and discussed the empirical findings based on the methodology discussed in Chapter 4. The descriptive analysis was the first step in allowing for a comprehensive understanding of the data. The correlation analysis followed, which revealed the strength and direction of the relationship among the variables. The study proceeded with the unit root tests using the Augmented Dickey-Fuller test and the Phillip

Perron test. The tests revealed that the model consists of different orders of integration, $I(0)$ and $I(1)$. Therefore, ARDL is the rightful model to investigate the long-run relationship of electricity consumption, price, and coal exports with economic growth.

Prior to ARDL long-run estimations, the study determined the appropriate number of lags to be used. The bounds cointegration test was employed and it was found that indeed long-run relationship exists among the variables. Following the ARDL results, the study ran the error correction model to determine the short-run estimates and the speed of adjustment of the model to converge to equilibrium. Subsequently, the direction of causality among electricity consumption, price, coal exports, and economic growth was evaluated through the pairwise Granger causality. Additionally, various diagnostic tests including the normality tests, heteroskedasticity test, and serial correlation tests were employed to validate the reliability and robustness of the model. The model's stability is validated using the CUSUM and the CUSUM of squares tests. The impulse response function and variance decomposition summed up the chapter.

CHAPTER 6

SUMMARY, RECOMMENDATIONS, CONCLUSION

6.1 INTRODUCTION

This research employed quantitative research methodology in order to attain the given set of aim and objectives outlined in Chapter 1. This chapter constitutes a summary of the study and interpretation of findings, conclusion and recommendations, contributions, limitations of the study, and area of research for future researchers on the topic.

6.2 SUMMARY AND INTERPRETATION OF FINDINGS

The primary aim of the study was to investigate the impact of electricity consumption, electricity price, and coal exports on the economic growth of South Africa. The study utilized the latest data from 2016 to 2023 to explore the energy-growth nexus, including price effects and coal exports, due to the notable escalation in electricity rationing and prices in the country during this period. The aim of the study was then accomplished by addressing the research objectives and questions outlined in Chapter 1. The first research question of the study was whether there is a relationship between electricity consumption and price on economic growth. To answer the research question, the study adopted the ARDL methodology to determine the relationship between electricity consumption and price and economic growth by estimating long-run coefficients. Prior, the Bounds cointegration test indeed revealed the existence of a long-term connection among the variables. The ARDL results indicate a positive relationship between electricity consumption and economic growth, observed at a 1% significance level, which persists in the short run and the long run.

In tandem with using the ARDL methodology, the study reviewed different literature to explore the relationship further. The literature includes the study of Molele and Ncanywa (2018), Raheem and Yusuf (2015), and Hlongwane and Daw (2023) who found a negative relationship between electricity consumption and economic growth. However, the results of this study were consistent with Badamasi (2023) and Churchill and Ivanovski (2020), confirming that electricity consumption and economic growth are positively in sync.

Electricity is a critical component in various sectors of the economy, including manufacturing, services, mining, and agriculture. Increased electricity consumption enables businesses to operate more efficiently and enhance their productivity, which can lead to higher output levels and ultimately contribute to economic growth. Consequently, as electricity consumption increases and economies grow, households gain access to better living conditions. Improved quality of life encourages consumer spending, stimulating demand for goods and services and further driving economic growth.

Furthermore, the findings illustrated a positive relationship between electricity price and economic growth in the long run. These results are in contradiction with the study of Berk and Yetkiner (2014), Khobai, Mugano, and Le Roux (2017), and Takentsi, Sibanda, and Hosu (2022), who found a negative relationship between energy/electricity price and economic growth. Nonetheless, the coefficient of electricity price was small, signifying minimal response to GDP. In the short run, electricity price exhibited a negative yet insignificant relationship with economic growth. Economically, when electricity prices rise, the cost of production for businesses also increases. Consumer demand and overall economic growth may be hampered by increased prices for goods and services due to greater production costs. Conversely, when electricity prices are stable, businesses can maintain their operational costs, potentially boosting production and economic growth.

The second research question addressed whether coal exports influence economic growth. The relationship between coal exports and economic growth over the long term was examined using the ARDL methodology, and the findings showed a negative correlation at the 5% level of significance. Literature pertaining to the association between coal exports and economic growth is lacking. However, the findings contradict the export-led growth theory, which holds that an increase in coal exports spurred economic expansion. Furthermore, the results support the resource curse theory, wherein the abundance of coal in South Africa has not led to significant benefits, particularly when looking at the issue of electricity rationing. The increase in coal exports implies a reduction in coal reserves available for electricity generation in the country. This results in decreased electricity consumption by businesses and households, thus hindering

economic growth. Nonetheless, coal exports did not exhibit any short-run estimation in this study. Additionally, the ECM revealed that the economic growth model returns to equilibrium at a speed of adjustment of 100.2%.

The third research question examined whether there was a causal relationship between the variables. The Granger causality test was employed to determine if one variable may be used to predict another. The results indicated a unidirectional causality from GDP to electricity consumption. These results were consistent with the findings of Yusuf (2018) and Khabai (2017), confirming that economic growth spurred electricity consumption, but not vice versa. As the economy expands, electricity consumption increases due to increased industrial activity, greater demand for services, and rising energy needs for both households and businesses. Additionally, the outcomes revealed a bidirectional causality running from electricity price to electricity consumption and vice versa. This is to say that electricity consumption and price have a mutual influence. Increased electricity consumption signals high demand, which therefore leads to higher electricity prices due to supply constraints. Conversely, when electricity prices rise substantially, consumers may reduce their electricity consumption in response to the higher costs. Finally, the Granger causality outcomes revealed the non-existence of a causal association between coal exports and economic growth. Thus, economic growth and coal exports cannot be predicted from one another.

The final research question examined whether economic growth responds to shocks in electricity consumption, prices, and coal exports. This analysis was conducted using impulse response functions and variance decomposition techniques. The impulse response function revealed that a one-period shock to GDP leads to a negative change in electricity consumption. Conversely, a shock to electricity consumption results in a modest increase in electricity prices, although this impact tends to diminish over time. Additionally, a shock to electricity prices leads to a reduction in electricity consumption. In the short run, GDP positively responds to shocks in electricity consumption; however, the average impact is neutral. These findings are consistent with the study of Antonakakis, Chatziantoniou, and Filis (2017). Furthermore, in the short run, economic growth shows

a neutral response to electricity price shocks, but it turns negative in the medium term, eventually becoming neutral again in the long run. Lastly, a shock to coal exports initially causes a decline in GDP. However, GDP exhibits a positive response in the medium term, while in the long run, the response stabilizes at a neutral level. The variance decomposition outcomes reveal that GDP has a large impact on itself and is strongly influenced by its own innovations in the short and long run. GDP has continuously contributed a larger percentage than other variables over the first ten periods.

6.3 CONCLUSION AND RECOMMENDATION

The conclusions and recommendations presented in this study are directly informed by its findings. According to the study, there is a substantial positive correlation between economic growth and electricity consumption over the long and short run. This suggests that a robust and reliable supply of electricity is crucial to promote the efficient output of goods and services, leading to economic expansion. In light of these findings, the study recommends that the government take proactive steps to diversify the country's energy mix. In addition to maintaining the conventional usage of coal for electricity generation, it is critical to promote the advancement of renewable energy projects including solar, wind, and hydroelectric power. By investing in these renewable resources, the government can enhance the overall electricity supply, making it more sustainable and reliable. Furthermore, broadening the energy mix will support international initiatives to minimize greenhouse gas emissions and fight climate change while also reducing reliance on fossil fuels. Implementing a more diverse energy strategy will contribute to the stability of the energy sector and provide long-lasting benefits to the economy and the environment. Ultimately, prioritizing renewable energy sources will help ensure that the country can meet its energy needs while fostering economic growth and sustainability for future generations.

On the other hand, the impulse response function showed that the response of economic growth to electricity price shock is negative over the medium term. Although the findings also reveal a positive relationship between electricity price and economic growth, high electricity prices remain a burden for both consumers and producers. The study therefore recommends implementing smart grid technology to enhance energy management,

reduce transmission losses, and improve the overall efficiency of electricity distribution. This approach can help prevent unnecessary costs from being passed on to consumers through elevated electricity prices. Additionally, strengthening governance and financial management within the electricity sector is essential for stabilizing electricity prices. Addressing issues such as corruption and enhancing financial sustainability within Eskom, while also enforcing transparent procurement processes, can help prevent the cost escalations that are frequently transferred to consumers.

The study further established a negative relationship between coal exports and economic growth in the long run. Additionally, the impulse response function indicated that a shock to coal exports causes a decline in economic growth in the short run. Since in South Africa coal remains a crucial component of electricity production, the study suggests that diverting coal resources from export markets to domestic electricity generation can yield economic benefits. This would ensure a more stable and sufficient supply for power generation, thereby mitigating load shedding across the country. Increased electricity availability would, in turn, stimulate economic activities, attract investment, and support business expansion, leading to long-term economic growth. To implement this strategy effectively, the government should introduce policies that incentivize coal suppliers to prioritize local power plants over export markets. This can be achieved through regulatory measures such as export levies and quotas or negotiated agreements with coal producers.

6.4 CONTRIBUTIONS OF THE STUDY

The study adopted the ARDL methodology to bring about the relationship between electricity consumption, price, coal exports, and economic growth. There is a dearth of research on the energy-growth relationship in South Africa. As such, this research fills a critical gap in the academic framework by contributing both empirical evidence and theoretical insights into the energy-growth relationship by emphasizing the importance of including vital factors, such as electricity pricing and coal exports. Furthermore, most literature has focused on the period from the post-apartheid era to the early 2000s. Contradictorily, this study examines the critical timeframe from 2016 to 2023, a period marked by significant electricity rationing and high prices in the South African economy.

Thus, the empirical findings of this research can be used to inform energy policy decisions, fostering the development of strategies that promote economic growth while ensuring sustainable energy practices.

6.5 LIMITATIONS OF THE STUDY

This study selected only three regressor variables. There is a host of other variables that may significantly impact the energy-growth nexus such as the reliability of renewable energy as a source of electricity, especially since South Africa is seeking to transition from the traditional use of fossil fuel (coal) for electricity production to cleaner energy. Additionally, the role of foreign direct investment (FDI) in energy is also significant, as it reflects investor confidence in South Africa's energy policies and infrastructure. Perhaps to pursue studies in green energy and outlook on economic performance.

6.6 AREA OF FUTURE RESEARCH

For future research on the topic, researchers could focus on the effectiveness of various policy interventions aimed at managing electricity prices and promoting energy efficiency. By conducting a comparative analysis of different policy frameworks and their impacts on electricity pricing, consumption, and economic growth, the study could offer insights into how effective governance can shape energy markets. Potential case studies may include examining the impacts of tariffs, subsidies, and regulatory changes over time. Furthermore, given the global shift towards sustainable energy sources, it would be crucial to also explore the impact of renewable energy adoption. The study could investigate how investments in renewable energy such as solar and wind, affect economic growth, electricity prices, and consumption patterns in South Africa.

This study applied the ARDL model to investigate the energy-growth nexus inclusive of price and coal exports. There are other techniques or models available to investigate relationships such as the VECM and VAR. Additionally, the study relied on a small sample consisting of quarterly data points. To enhance the robustness and reliability of the findings, future researchers should consider expanding the dataset and using annual data.

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APPENDICES

APPENDIX A: DATA

DATE	GDP	EC	Coal Exp	Elec_Price	LGDP	LEC
2016/03/31	4446289	56049	86.6333	62.6000	6.6480	4.7486
2016/06/30	4450567	57442	81.1000	62.6000	6.6484	4.7592
2016/09/30	4450025	58546	88.4000	67.2000	6.6484	4.7675
2016/12/31	4453803	56509	109.7667	67.2000	6.6487	4.7521
2017/03/31	4474831	55800	108.1667	67.2000	6.6508	4.7466
2017/06/30	4499232	58431	105.8000	67.2000	6.6531	4.7666
2017/09/30	4507506	58584	107.2667	68.6000	6.6539	4.7678
2017/12/31	4525237	56854	124.5667	68.7000	6.6556	4.7548
2018/03/31	4549177	56243	104.0667	68.7000	6.6579	4.7501
2018/06/30	4537865	58554	109.6000	69.3000	6.6569	4.7676

2018/09/30	4593672	59518	132.3333	73.9667	6.6622	4.7746
2018/12/31	4606420	57490	125.3667	74.0000	6.6634	4.7596
2019/03/31	4566186	55555	110.6667	73.9000	6.6596	4.7447
2019/06/30	4586834	58263	107.3667	74.0000	6.6615	4.7654
2019/09/30	4591656	57934	101.1667	82.3333	6.6620	4.7629
2019/12/31	4589993	55584	106.4000	82.7000	6.6618	4.7449
2020/03/31	4600822	53911	115.5333	82.7000	6.6628	4.7317
2020/06/30	3823746	50297	94.4000	82.5667	6.5825	4.7015
2020/09/30	4348748	56787	84.9333	87.7000	6.6384	4.7542
2020/12/31	4467991	55015	91.3333	87.7000	6.6501	4.7405
2021/03/31	4496641	53349	115.2000	87.6667	6.6529	4.7271
2021/06/30	4555001	56498	117.4667	87.7000	6.6585	4.7520
2021/09/30	4469583	57771	130.3000	99.8667	6.6503	4.7617
2021/12/31	4530950	53412	157.1333	100.0000	6.6562	4.7276
2022/03/31	4600368	53197	153.5000	100.0667	6.6628	4.7259
2022/06/30	4561874	55444	192.2000	100.2667	6.6591	4.7439
2022/09/30	4642800	54891	222.8333	108.1333	6.6668	4.7395
2022/12/31	4592004	51238	134.8333	108.3000	6.6620	4.7096
2023/03/31	4610676	49618	108.3000	108.3000	6.6638	4.6956
2023/06/30	4631763	51936	108.3000	108.3000	6.6657	4.7155
2023/09/30	4620297	52868	124.3667	124.3667	6.6647	4.7232

APPENDIX B: DESCRIPTIVE STATISTICS

	LGDP	LEC	ELEC PRICE	COAL EXP
Mean	6.654474	4.744603	83.99462	118.0419
Median	6.657933	4.748568	82.56667	109.6000
Maximum	6.666780	4.774648	124.3667	222.8333
Minimum	6.582489	4.695639	62.60000	81.10000
Std. Dev.	0.014937	0.020634	16.77852	30.07147
Skewness	-3.750850	-0.732038	0.596462	1.843482
Kurtosis	18.69387	2.726134	2.303325	6.771177
Jarque-Bera Probability	390.8234 0.000000	2.865593 0.238641	2.465050 0.291556	35.92833 0.000000
Sum	206.2887	147.0827	2603.833	3659.300
Sum Sq. Dev.	0.006693	0.012773	8445.562	27128.79
Observations	31	31	31	31

APPENDIX C: CORRELATION ANALYSIS

	LGDP	LEC	ELEC PRICE	COAL EXP
LGDP	1	0.18528844...	0.23034485...	0.35428351...
LEC	0.18528844...	1	-0.6666928...	-0.1573627...
ELEC...	0.23034485...	-0.6666928...	1	0.52860142...
COAL...	0.35428351...	-0.1573627...	0.52860142...	1

APPENDIX D: UNIT ROOT TESTS RESULTS

APPENDIX D1: AUGMENTED DICKEY FULLER TEST RESULTS

LGDP (Gross domestic product)

AT LEVEL			AT FIRST DIFFERENCED		
1. INTERCEPT			INTERCEPT		
Null Hypothesis: LGDP has a unit root Exogenous: Constant Lag Length: 0 (Automatic - based on SIC, maxlag=7)			Null Hypothesis: D(LGDP) has a unit root Exogenous: Constant Lag Length: 0 (Automatic - based on SIC, maxlag=7)		
	t-Statistic	Prob.*		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.117789	0.0033	Augmented Dickey-Fuller test statistic	-7.939986	0.0000
Test critical values:			Test critical values:		
	1% level	-3.670170		1% level	-3.679322
	5% level	-2.963972		5% level	-2.967767
	10% level	-2.621007		10% level	-2.622989
*MacKinnon (1996) one-sided p-values.			*MacKinnon (1996) one-sided p-values.		

<p align="center">2. TREND AND INTERCEPT</p> <p>Null Hypothesis: LGDP has a unit root Exogenous: Constant, Linear Trend Lag Length: 0 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th align="center">t-Statistic</th> <th align="center">Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td align="center">-4.162835</td> <td align="center">0.0136</td> </tr> <tr> <td>Test critical values:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">1% level</td> <td align="center">-4.296729</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">5% level</td> <td align="center">-3.568379</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">10% level</td> <td align="center">-3.218382</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-4.162835	0.0136	Test critical values:			1% level	-4.296729		5% level	-3.568379		10% level	-3.218382		<p align="center">TREND AND INTERCEPT</p> <p>Null Hypothesis: D(LGDP) has a unit root Exogenous: Constant, Linear Trend Lag Length: 0 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th align="center">t-Statistic</th> <th align="center">Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td align="center">-7.794034</td> <td align="center">0.0000</td> </tr> <tr> <td>Test critical values:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">1% level</td> <td align="center">-4.309824</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">5% level</td> <td align="center">-3.574244</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">10% level</td> <td align="center">-3.221728</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-7.794034	0.0000	Test critical values:			1% level	-4.309824		5% level	-3.574244		10% level	-3.221728	
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<p align="center">3. NONE</p> <p>Null Hypothesis: LGDP has a unit root Exogenous: None Lag Length: 1 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th align="center">t-Statistic</th> <th align="center">Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td align="center">0.240389</td> <td align="center">0.7489</td> </tr> <tr> <td>Test critical values:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">1% level</td> <td align="center">-2.647120</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">5% level</td> <td align="center">-1.952910</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">10% level</td> <td align="center">-1.610011</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	0.240389	0.7489	Test critical values:			1% level	-2.647120		5% level	-1.952910		10% level	-1.610011		<p align="center">NONE</p> <p>Null Hypothesis: D(LGDP) has a unit root Exogenous: None Lag Length: 0 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th align="center">t-Statistic</th> <th align="center">Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td align="center">-8.072874</td> <td align="center">0.0000</td> </tr> <tr> <td>Test critical values:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">1% level</td> <td align="center">-2.647120</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">5% level</td> <td align="center">-1.952910</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">10% level</td> <td align="center">-1.610011</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-8.072874	0.0000	Test critical values:			1% level	-2.647120		5% level	-1.952910		10% level	-1.610011	
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LEC (electricity consumption)

<p align="center">AT LEVEL</p> <p align="center">1. INTERCEPT</p> <p>Null Hypothesis: LEC has a unit root Exogenous: Constant Lag Length: 0 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th align="center">t-Statistic</th> <th align="center">Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td align="center">-2.618599</td> <td align="center">0.1005</td> </tr> <tr> <td>Test critical values:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">1% level</td> <td align="center">-3.670170</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">5% level</td> <td align="center">-2.963972</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">10% level</td> <td align="center">-2.621007</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-2.618599	0.1005	Test critical values:			1% level	-3.670170		5% level	-2.963972		10% level	-2.621007		<p align="center">AT FIRST DIFFERENCE</p> <p>Null Hypothesis: D(LEC) has a unit root Exogenous: Constant Lag Length: 1 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th align="center">t-Statistic</th> <th align="center">Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td align="center">-7.785512</td> <td align="center">0.0000</td> </tr> <tr> <td>Test critical values:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">1% level</td> <td align="center">-3.689194</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">5% level</td> <td align="center">-2.971853</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">10% level</td> <td align="center">-2.625121</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-7.785512	0.0000	Test critical values:			1% level	-3.689194		5% level	-2.971853		10% level	-2.625121	
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Electricity Price

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2. TREND AND INTERCEPT

Null Hypothesis: ELEC PRICE has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 7 (Automatic - based on SIC, maxlag=7)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.123567	0.9909
Test critical values:		
1% level	-4.416345	
5% level	-3.622033	
10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

TREND AND INTERCEPT

Null Hypothesis: D(ELEC PRICE) has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 7 (Automatic - based on SIC, maxlag=7)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.830718	0.6550
Test critical values:		
1% level	-4.440739	
5% level	-3.632896	
10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

3. NONE

Null Hypothesis: ELEC PRICE has a unit root
 Exogenous: None
 Lag Length: 4 (Automatic - based on SIC, maxlag=7)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	1.850095	0.9817
Test critical values:		
1% level	-2.656915	
5% level	-1.954414	
10% level	-1.609329	

*MacKinnon (1996) one-sided p-values.

NONE

Null Hypothesis: D(ELEC PRICE) has a unit root
 Exogenous: None
 Lag Length: 7 (Automatic - based on SIC, maxlag=7)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	1.999409	0.9860
Test critical values:		
1% level	-2.674290	
5% level	-1.957204	
10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

CE (COAL EXPORTS)

AT LEVEL	AT FIRST DIFFERENCE
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<p>1. INTERCEPT</p> <p>Null Hypothesis: CE has a unit root Exogenous: Constant Lag Length: 0 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1"> <thead> <tr> <th></th> <th>t-Statistic</th> <th>Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td>-2.314904</td> <td>0.1740</td> </tr> <tr> <td>Test critical values: 1% level</td> <td>-3.670170</td> <td></td> </tr> <tr> <td>5% level</td> <td>-2.963972</td> <td></td> </tr> <tr> <td>10% level</td> <td>-2.621007</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-2.314904	0.1740	Test critical values: 1% level	-3.670170		5% level	-2.963972		10% level	-2.621007		<p>INTERCEPT</p> <p>Null Hypothesis: D(CE) has a unit root Exogenous: Constant Lag Length: 0 (Automatic - based on SIC, maxlag=7)</p> <hr/> <table border="1"> <thead> <tr> <th></th> <th>t-Statistic</th> <th>Prob.*</th> </tr> </thead> <tbody> <tr> <td>Augmented Dickey-Fuller test statistic</td> <td>-4.875868</td> <td>0.0005</td> </tr> <tr> <td>Test critical values: 1% level</td> <td>-3.679322</td> <td></td> </tr> <tr> <td>5% level</td> <td>-2.967767</td> <td></td> </tr> <tr> <td>10% level</td> <td>-2.622989</td> <td></td> </tr> </tbody> </table> <hr/> <p>*MacKinnon (1996) one-sided p-values.</p>		t-Statistic	Prob.*	Augmented Dickey-Fuller test statistic	-4.875868	0.0005	Test critical values: 1% level	-3.679322		5% level	-2.967767		10% level	-2.622989	
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APPENDIX D2: PHILLIPS PERRON TEST RESULTS

LGDP

AT LEVEL	AT FIRST DIFFERENCE																																				
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APPENDIX E: LAG LENGTH CRITERION

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-90.56159	NA	0.007987	6.521489	6.710081	6.580554
1	-25.90283	107.0214	0.000282	3.165713	4.108675	3.461037
2	9.479929	48.80381*	7.96e-05*	1.828970*	3.526303*	2.360554*

* indicates lag order selected by the criterion
 LR: sequential modified LR test statistic (each test at 5% level)
 FPE: Final prediction error
 AIC: Akaike information criterion
 SC: Schwarz information criterion
 HQ: Hannan-Quinn information criterion

APPENDIX F: COINTEGRATION TEST (BOUNDS TEST) RESULTS

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	9.779121	10%	3.47	4.45
k	3	5%	4.01	5.07
		2.5%	4.52	5.62
		1%	5.17	6.36
Finite Sample: n=35				
Actual Sample Size	29	10%	3.8	4.888
		5%	4.568	5.795
		1%	6.38	7.73
Finite Sample: n=30				
		10%	3.868	4.965
		5%	4.683	5.98
		1%	6.643	8.313

APPENDIX G: ARDL MODEL

Levels Equation				
Case 5: Unrestricted Constant and Unrestricted Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEC	2.277678	0.436697	5.215693	0.0000
ELEC PRICE	0.004961	0.001076	4.610352	0.0002
COAL EXP	-0.000314	0.000114	-2.752509	0.0127

EC = LGDP - (2.2777*LEC + 0.0050*ELEC PRICE - 0.0003*COAL EXP)

APPENDIX H: ERROR CORRECTION MODEL

ECM Regression				
Case 5: Unrestricted Constant and Unrestricted Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.471918	0.664136	-6.733436	0.0000
@TREND	-0.003754	0.000586	-6.410605	0.0000
D(LEC)	1.211767	0.131256	9.232101	0.0000
D(LEC(-1))	-0.449792	0.132504	-3.394546	0.0030
D(ELEC PRICE)	-0.000497	0.000608	-0.817231	0.4239
D(ELEC PRICE(-1))	-0.003214	0.001221	-2.632763	0.0164
CointEq(-1)*	-1.002280	0.148927	-6.729990	0.0000

APPENDIX I: GRANGER CAUSALITY RESULTS

Pairwise Granger Causality Tests

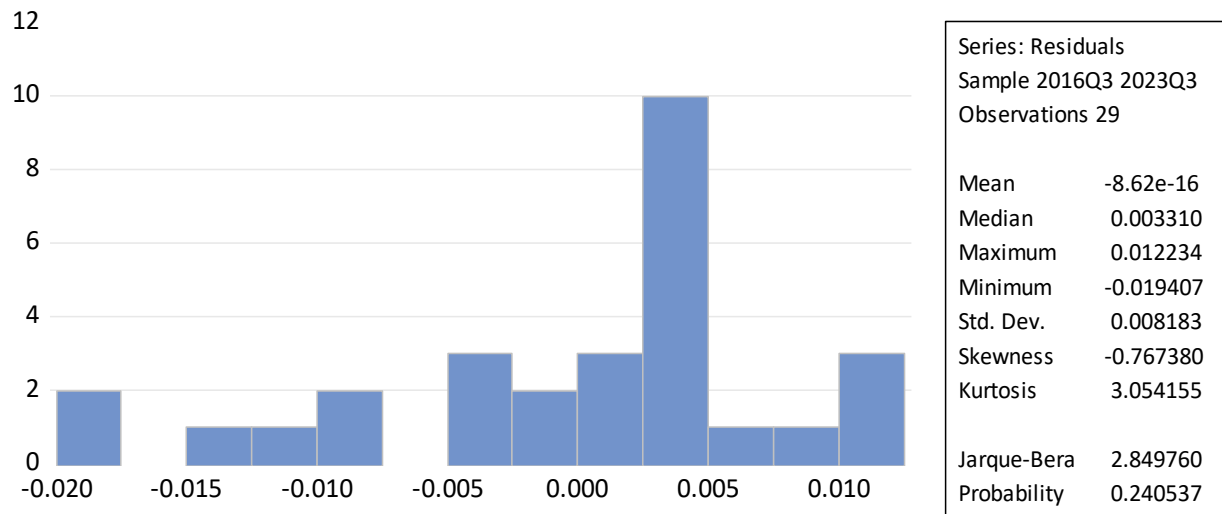
Date: 10/03/24 Time: 00:13

Sample: 2016Q1 2023Q3

Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
LEC does not Granger Cause LGDP	29	0.07623	0.9268
LGDP does not Granger Cause LEC		3.92187	0.0336
ELEC PRICE does not Granger Cause LGDP	29	0.35158	0.7071
LGDP does not Granger Cause ELEC PRICE		0.25827	0.7745
COAL EXP does not Granger Cause LGDP	29	0.59281	0.5607
LGDP does not Granger Cause COAL EXP		0.12821	0.8803
ELEC PRICE does not Granger Cause LEC	29	12.3507	0.0002
LEC does not Granger Cause ELEC PRICE		7.51216	0.0029
COAL EXP does not Granger Cause LEC	29	2.17748	0.1352
LEC does not Granger Cause COAL EXP		1.03346	0.3711
COAL EXP does not Granger Cause ELEC PRICE	29	0.89351	0.4224
ELEC PRICE does not Granger Cause COAL EXP		1.15503	0.3320

APPENDIX J: DIAGNOSTIC TESTS RESULTS



Breusch-Godfrey Serial Correlation LM Test:
 Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.070097	Prob. F(2,17)	0.9326
Obs*R-squared	0.237197	Prob. Chi-Square(2)	0.8882

Test Equation:

Dependent Variable: RESID

Method: ARDL

Date: 10/02/24 Time: 23:12

Sample: 2016Q3 2023Q3

Included observations: 29

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDP(-1)	-0.034967	0.285743	-0.122372	0.9040
LEC	0.010454	0.216057	0.048385	0.9620
LEC(-1)	-0.003519	0.354272	-0.009934	0.9922
LEC(-2)	0.016982	0.176661	0.096130	0.9245
ELEC PRICE	5.38E-05	0.000762	0.070624	0.9445
ELEC PRICE(-1)	-1.59E-05	0.001061	-0.014994	0.9882
ELEC PRICE(-2)	-7.47E-06	0.001516	-0.004925	0.9961
COAL EXP	4.47E-06	0.000128	0.034829	0.9726
C	0.116329	2.077198	0.056003	0.9560
@TREND	-2.24E-05	0.001450	-0.015439	0.9879
RESID(-1)	0.094569	0.425896	0.222046	0.8269
RESID(-2)	-0.070165	0.336585	-0.208460	0.8373

R-squared	0.008179	Mean dependent var	-8.62E-16
Adjusted R-squared	-0.633587	S.D. dependent var	0.008183
S.E. of regression	0.010459	Akaike info criterion	-5.989278
Sum squared resid	0.001860	Schwarz criterion	-5.423500
Log likelihood	98.84453	Hannan-Quinn criter.	-5.812083
F-statistic	0.012745	Durbin-Watson stat	1.909255
Prob(F-statistic)	1.000000		

Heteroskedasticity Test: Breusch-Pagan-Godfrey
 Null hypothesis: Homoskedasticity

F-statistic	1.357442	Prob. F(9,19)	0.2737
Obs*R-squared	11.34935	Prob. Chi-Square(9)	0.2525
Scaled explained SS	5.003632	Prob. Chi-Square(9)	0.8340

Test Equation:
 Dependent Variable: RESID^2
 Method: Least Squares
 Date: 10/02/24 Time: 23:21
 Sample: 2016Q3 2023Q3
 Included observations: 29

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.023942	0.017031	1.405803	0.1759
LGDP(-1)	0.000742	0.001653	0.448963	0.6585
LEC	-0.004719	0.001824	-2.586801	0.0181
LEC(-1)	-0.000402	0.002689	-0.149449	0.8828
LEC(-2)	-0.000773	0.001440	-0.536797	0.5976
ELEC PRICE	6.49E-06	5.94E-06	1.093125	0.2880
ELEC PRICE(-1)	-2.37E-05	8.56E-06	-2.767441	0.0123
ELEC PRICE(-2)	1.96E-06	1.22E-05	0.161121	0.8737
COAL EXP	1.33E-06	1.01E-06	1.309493	0.2060
@TREND	1.52E-05	1.10E-05	1.379206	0.1839

R-squared	0.391357	Mean dependent var	6.46E-05
Adjusted R-squared	0.103052	S.D. dependent var	9.43E-05
S.E. of regression	8.93E-05	Akaike info criterion	-15.54218
Sum squared resid	1.52E-07	Schwarz criterion	-15.07070
Log likelihood	235.3616	Hannan-Quinn criter.	-15.39452
F-statistic	1.357442	Durbin-Watson stat	1.886039
Prob(F-statistic)	0.273740		

Heteroskedasticity Test: Harvey
Null hypothesis: Homoskedasticity

F-statistic	0.665346	Prob. F(9,19)	0.7296
Obs*R-squared	6.949520	Prob. Chi-Square(9)	0.6424
Scaled explained SS	22.18561	Prob. Chi-Square(9)	0.0083

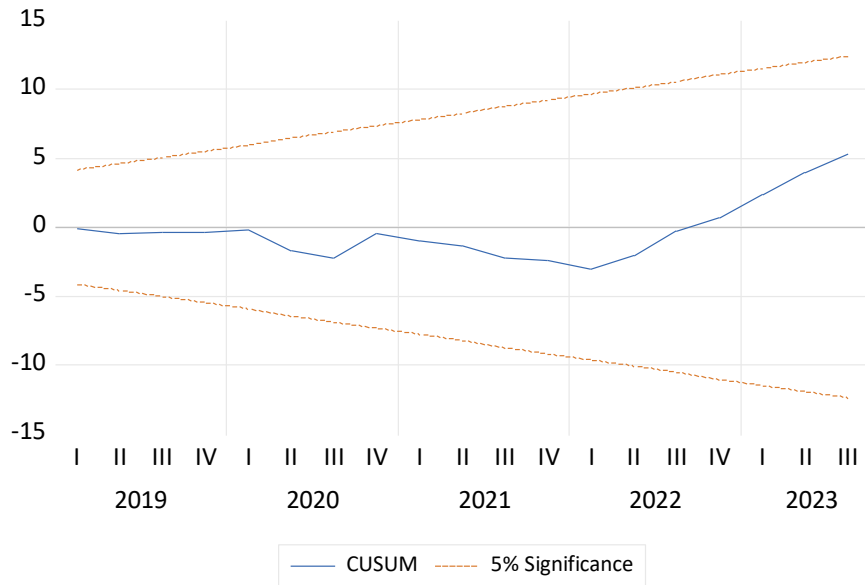
Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 10/02/24 Time: 23:23
Sample: 2016Q3 2023Q3
Included observations: 29

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	589.8813	815.4094	0.723417	0.4782
LGDP(-1)	-0.955008	79.16255	-0.012064	0.9905
LEC	-99.24284	87.33468	-1.136351	0.2699
LEC(-1)	27.68416	128.7611	0.215004	0.8321
LEC(-2)	-54.78512	68.94914	-0.794573	0.4367
ELEC PRICE	0.120593	0.284202	0.424323	0.6761
ELEC PRICE(-1)	-0.467299	0.409604	-1.140855	0.2681
ELEC PRICE(-2)	0.434149	0.582083	0.745854	0.4649
COAL EXP	0.019581	0.048526	0.403514	0.6911
@TREND	-0.292324	0.526274	-0.555461	0.5851

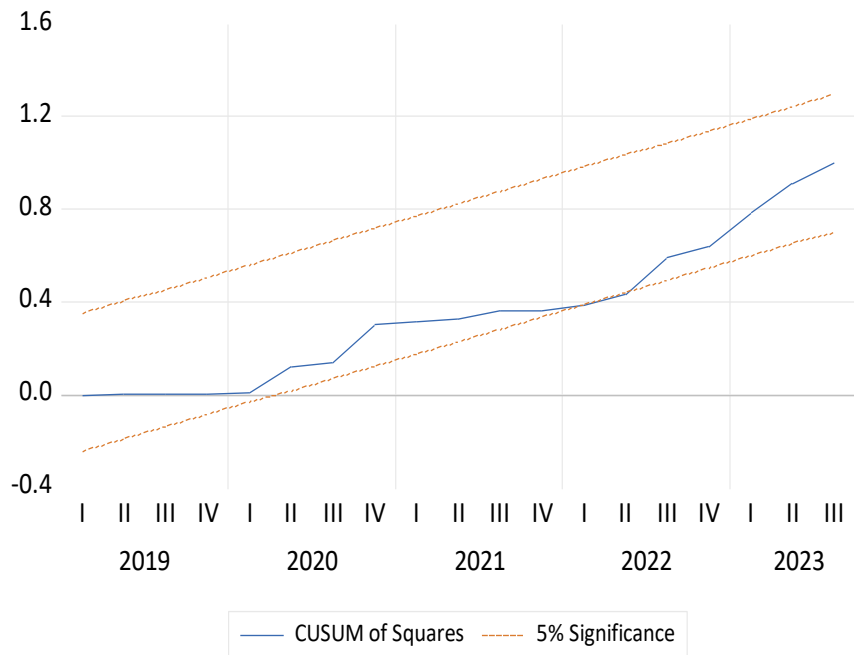
R-squared	0.239639	Mean dependent var	-11.39946
Adjusted R-squared	-0.120533	S.D. dependent var	4.039365
S.E. of regression	4.275878	Akaike info criterion	6.010655
Sum squared resid	347.3796	Schwarz criterion	6.482136
Log likelihood	-77.15449	Hannan-Quinn criter.	6.158317
F-statistic	0.665346	Durbin-Watson stat	2.014893
Prob(F-statistic)	0.729577		

APPENDIX K: STABILITY TEST RESULTS

CUSUM



CUSUM of squares



APPENDIX L: IMPULSE RESPONSE FUNCTION



APPENDIX M: VARIANCE DECOMPOSITION RESULTS

Variance Decomposition of LGDP:					
Period	S.E.	LGDP	LEC	ELEC_PR...	COAL EXP
1	0.016334	100.0000	0.000000	0.000000	0.000000
2	0.017339	92.06415	6.855042	0.096409	0.984396
3	0.017571	89.78777	7.439363	0.218565	2.554301
4	0.017997	85.66662	8.603302	2.347883	3.382190
5	0.018051	85.40421	8.751852	2.348273	3.495667
6	0.018080	85.13562	8.945382	2.376595	3.542402
7	0.018089	85.04578	9.023286	2.391178	3.539758
8	0.018092	85.03156	9.021411	2.406599	3.540428
9	0.018112	84.85199	9.174388	2.436934	3.536693
10	0.018120	84.78198	9.169256	2.495850	3.552910

Variance Decomposition of LEC:

Period	S.E.	LGDP	LEC	ELEC PR...	COAL EXP
1	0.012880	50.10161	49.89839	0.000000	0.000000
2	0.015414	35.21648	50.82195	13.27355	0.688013
3	0.016948	30.01830	53.76880	14.26054	1.952359
4	0.017134	30.00019	53.95510	14.05077	1.993940
5	0.017401	29.16256	55.00914	13.86380	1.964499
6	0.018097	27.76972	52.67765	17.11802	2.434610
7	0.018584	27.02674	51.33941	18.97864	2.655211
8	0.018770	27.11903	50.95725	19.32072	2.602996
9	0.018961	27.16677	50.23852	19.99863	2.596085
10	0.019415	26.82624	48.16618	22.18978	2.817804

Variance Decomposition of ELEC PRICE:

Period	S.E.	LGDP	LEC	ELEC PR...	COAL EXP
1	2.262342	0.707528	0.615986	98.67649	0.000000
2	3.318789	3.285941	40.00638	56.51184	0.195840
3	3.741293	11.67755	31.83468	56.15306	0.334698
4	4.532070	12.57056	25.98834	57.98982	3.451288
5	5.443060	14.17192	18.15499	62.80154	4.871554
6	6.045752	15.79919	16.07705	63.24884	4.874920
7	6.537716	18.00873	13.75617	63.63026	4.604849
8	7.169753	19.30424	11.61620	64.34360	4.735958
9	7.916274	20.20476	9.532324	65.33283	4.930086
10	8.606907	21.06861	8.267295	65.74917	4.914918

Variance Decomposition of COAL EXP:

Period	S.E.	LGDP	LEC	ELEC PR...	COAL EXP
1	19.63805	3.385968	13.35014	20.45585	62.80804
2	29.65518	5.619532	36.20577	21.41231	36.76239
3	31.25094	7.676525	37.43512	20.41396	34.47439
4	31.33191	7.636902	37.70302	20.36135	34.29872
5	31.44974	7.580312	37.79777	20.55886	34.06305
6	31.53100	7.544564	37.61021	20.85177	33.99345
7	31.60782	7.593627	37.42786	21.11679	33.86172
8	31.65415	7.637495	37.31940	21.25803	33.78507
9	31.73113	7.717452	37.16340	21.47447	33.64468
10	31.81846	7.799785	36.95981	21.74214	33.49827