THE EFFECTS OF ELECTRICITY PRICES AND ELECTRICITY SUPPLY ON THE ECONOMIC GROWTH OF SOUTH AFRICA FOR THE PERIOD 1993 TO 2022

by

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DECLARATION

I declare that “THE IMPACT OF ELECTRICITY PRICES AND ELECTRICITY SUPPLY ON THE ECONOMIC GROWTH OF SOUTH AFRICA” is my work. All the sources that I have used or quoted have been indicated and acknowledged using complete references and this work has not been submitted before for any other degree at any other institution.

Full names | Date
20/02/2025

DEDICATION

This research is dedicated to the most important women in my life. To my mother, Phola Sabina Maringa, whose unwavering love, support, and sacrifices have been the foundation of all my achievements; you are my greatest inspiration. To the university, which provided the platform for my intellectual growth, fostering an environment of curiosity, challenge, and discovery. And to my late grandmother, Glorious Maringa, whose wisdom, encouragement, and gentle spirit continue to guide me in all I do, even in her absence. I am deeply grateful for the strength and guidance each of you has given me.

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ABSTRACT

As an energy source, electricity is fundamental in driving economic growth, particularly in emerging economies like South Africa. This study investigated the effects of electricity prices and supply on South Africa's economic growth over the 1993 to 2022 period. This is performed by adopting and extending the energy-growth model, this study contributes to the existing literature on energy economics. To achieve the research objective, unit root tests were conducted to identify the integration order of variables, followed by the Autoregressive Distributed Lag (ARDL) approach to estimate short- and long-run relationships. The bounds test confirmed a long-run equilibrium relationship between the variables in the energy-growth model.

The ARDL results revealed that electricity prices positively influence economic growth in the short and long run. The electricity supply negatively impacts economic growth in the short run but is statistically insignificant in the long run. Additionally, the results indicate a negative and statistically significant long-run relationship between labour force participation and economic growth, highlighting potential structural inefficiencies in South Africa's labour market. These findings empirically validate aspects of the energy consumption theory while emphasising developing country-specific dynamics. The study recommends proactive government policies to address high electricity prices and irregular supply, which pose significant risks to economic development.

Keywords: Electricity Prices, Economic Growth, Energy Consumption Theory, ARDL Model, South Africa

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GDP:	Gross Domestic Product
GW:	Gigawatts
CPI:	Consumer price index
NERSA:	National Energy Regulator of South Africa
SADC:	Southern African Development Community
OECD:	Organisation for Economic Co-operation and Development
EAF:	Energy Availability Factor
FDI:	Foreign Direct Investment
IMF:	International Monetary Fund
SARB:	South African Reserve Bank
ADF:	Augmented Dickey-Fuller
PP:	Phillips Perron
ARDL:	Autoregressive Distributive Lag
REIPPP:	Renewable Energy Independent Power Producer Procurement
IPP:	Independent Power Producers
CSIR:	Council for Scientific and Industrial Research
VAR:	Variance
ECM:	Error Correction Model
GLS:	Generalised Least Squares

CHAPTER 1

ORIENTATION TO THE STUDY

1.1 Introduction and Background

In modern economies, electricity is a significant energy source primarily and independently used for good and service creations. Therefore, the stability of electricity prices and reliable supply are important to ensure the well-functioning of any economy (Yakubu, Salisu, and Umar, 2015). As a result, it is crucial to maintain stable electricity costs and a steady supply to keep the economy running smoothly. All digitised modern economies rely on affordable, reliable and cost-effective electricity supply. The manufacturing sector is the catalyst of the economy since it converts raw materials into economic goods that meet the economy's demand. Thus, a sustainable, and cost-effective electricity supply is an impetus for rapid and favourable economic growth. Khobai, Mugano and Le Roux (2017) emphasised that the industrial sector is the source of inclusive growth and that its success relies on a reliable, inexpensive, and efficient energy supply.

Electricity serves as a fundamental driver of economic growth, acting as both a catalyst and foundation for industrialisation, technological innovation, and improved living standards. In the contemporary global economy, no sector operates efficiently without a reliable and sustainable supply of electricity (Ozturk, 2010). Electricity is crucial to economic growth for several interrelated reasons:

- Productive sector enablement: whereby electricity powers key sectors such as manufacturing, mining, agriculture, and services. Interruptions in supply can halt production, reduce output, and decrease national competitiveness.
- Energy consumption theory support: the theory posits that energy, particularly electricity, is a necessary input for production (Ozturk, 2010). This highlights the interdependence between energy usage and economic expansion.
- Infrastructure and investment: Electrification supports infrastructure development and is a key condition for attracting both foreign and domestic investment. Reliable energy supply lowers operational risks for investors and encourages long term economic planning (Calderón and Servén, 2010).

- Bilateral relationships: According to Apergis and Payne (2011), economic growth increases electricity demand, while increased electricity access stimulates economic activities.
- Poverty alleviation and inclusive growth: by expanding electricity access in underdeveloped areas promotes entrepreneurship, enhances productivity, and integrates marginalised communities into the economy (Ozturk, 2010).

In the context of South Africa, the Eskom dominated electrical industry is fundamental in maintaining economic momentum. However, persistent load shedding and infrastructure challenges have imposed significant constraints on economic output, underlining the urgent need for energy sector reform. Empirical evidence indicates that fluctuations in electricity supply can have measurable impacts on GDP growth rates, particularly in energy-intensive industries (Inglesi-Lotz, 2011).

According to the International Energy Agency (IEA, 2023), in the global context, energy crises are becoming increasingly frequent across several countries. These crises are driven by high demand and inadequate supply, leading to widespread blackouts in regions such as Europe, Africa, and South Asia. These outages can last for hours or even days, profoundly affecting the daily lives of individuals and families.

The Russia-Ukraine conflict has generated a major energy crisis across Europe, especially the supply disruptions. Russia's deliberate reduction of gas supplies is the main cause of the high gas prices in the (European Union) EU. Hence, it has impacted the electricity price produced in gas-fired power plants and affected electricity prices across the globe and the lessened supply of electricity (Kerber et al, 2021). Russia accounted for nearly half of Europe's total natural gas imports in 2021, but some countries were always more vulnerable than others. Higher energy prices hit Europe much harder than the rest of the world (International Monetary Fund (IMF), 2022). Countries such as Poland, Finland, and Slovakia had significant gross domestic product reductions because they were almost fully dependent on Russia's natural gas because of their geographical proximity to their supply pipelines. Germany, Europe's largest economy, relied on Russia for its energy needs (Milne, 2022). In 2021, nearly half of Germany's natural gas imports came from Russia, making it a key supplier for industrial and residential energy consumption. This dependence has been a concern for German policymakers, especially as geopolitical tensions with Russia have escalated. The reliance on Russian gas has not only shaped Germany's energy strategy but, also its broader foreign and economic policies, creating a delicate balance between energy security and political considerations (International Energy Agency, 2022).

Developing countries oftentimes suffer from frequent power cuts or load-shedding due to a lack of reliability and security of electricity supply, such power cuts affect operations for the local producers and policymakers. Frequent power outages, or load-shedding, pose significant disruptions to daily operations across key sectors of the economy (Lenoke, 2017). Small businesses and manufacturers face considerable challenges, as these interruptions hinder productivity, increase operational costs, and undermine overall business efficiency (Olajuyin and Mago, 2022). The ripple effects of these power cuts are felt throughout the economy, with long-term implications for economic growth and competitiveness.

As a result, policymakers have worked hard to restrict energy consumption and balance it with each country's ability to provide electricity to avoid the total breakdown of the power utilities in various emerging countries (Motlagh, Paevere, Hong, and Grozev, 2015). A few African countries that have similar electricity problems blamed the power outrages on a variety of issues that include, insufficiently trained personnel, deficiency in local manufacturing, poor utility performance, theft of grid equipment, weather, gas supply, insufficient funding, and the age of grid infrastructure (Akpeji, 2020).

South Africa's electricity supply and distribution have been inconsistent since 2008 when the first wave of power cuts experienced serious consequences for the economy (World Bank, 2010). Since then, power cuts have been common occurrences in the country with the most notable and prolonged waves occurring again in 2014 and 2013. Since 2008, the country's electricity prices have increased significantly. From 2008 to 2018, the average electricity price increased by over 33% annually. These increases have altered the weight of electricity costs significantly in business budgets as well as the attractiveness of the country as a business destination where production costs are affordable (Department of Energy, 2018).

In 1997, Eskom had an installed generation capacity of approximately 39,000 megawatts (MW), while the maximum electricity demand peaked at around 28 330

MW, indicating a significant reserve capacity. However, to accommodate anticipated increases in future demand, the requested additional generation capacity covers the anticipated demand increases. However, the required capacity did not increase at the expected rate.

As a result, Eskom did not meet electricity consumption from 2002 to 2008, and onward. The electricity sector continued to be haphazard over the study period, with demand and supply mismatches (Hondroyiannis, Sardianou, Nikou, Evangelinous and Nikolaou, 2023). A growing economy creates room for increasing electricity generating capacity, this may be through higher tax revenue, consumers' ability to afford electricity, a better financial position for the national utility, and better credit rankings which attract investment in the energy sector (Inglesi-Lots and Ajmi, 2021). Thus, potentially, space for a more significant surplus can be created, therefore, when electricity supply exceeds electricity consumption, it enhances economic growth because there's less risk of power interruptions. When electricity consumption rises, it must be met with a sufficiently rising supply for the market to maintain an increasing surplus. Simultaneously, demand must be increased at a conducive level for economic growth.

1.2 Statement of the problem

The electricity supply and provision in South Africa have been inconsistent since 2008 when power cuts were experienced with severe economic consequences. Since 2008, load-shedding has been a common occurrence in the country with the most significant and long waves experienced again in 2014, 2019, and 2021 respectively (Eskom, 2021). Since 2008, the electricity prices in the country underwent a restructuring, with an estimated annual increase of 25% from 2008 until 2018 in real average electricity prices (Department of Energy, 2018) The damaging consequences on the real economy were vast in the sense of expensive energy. The National Energy Regulator of South Africa (NERSA) estimated that approximately R50 billion (approximately USD5 billion) was lost during this crisis.

According to Inglesi-Lots and Ajmi (2021), the price increase has significantly changed the weight of electricity costs in the business budgets as well as the attractiveness of the country as a destination for investment. Analysts attributed some of the losses in investors' confidence partially to these interruptions, unreliable provision of electricity, and the increasing electricity costs in Africa (Inglesi-Lots and Ajmi, 2021). It has also been argued that South Africa's historically low electricity tariffs have served as a disincentive for consumers to use energy efficiently, leading to higher electricity consumption. Since the crisis, Eskom and NERSA have changed the electricity tariff structure resulting in up to 25% increases per annum from 2008 to date (Blignaut and Inglesi-Lotz, 2015).

This increase and inadequate supply of electricity not only affected several jobs in the real business sector but also caused a major loss to the country's investor confidence. As a developing nation, South Africa needs a stable and affordable energy source to promote a reliable and inclusive economy. Stability in the provision of adequate, affordable energy gives life to small businesses and creativity in rural areas. Therefore, it is imperative to investigate the prices of electricity and electricity supply in a developing country to inform policy.

1.3 Research aim and objectives

1.3.1 Aim of the study

To investigate the effects of electricity prices and electricity supply on the economic growth of South Africa for the period 1993 to 2022.

1.3.2 Objectives of the study

The objectives of the study are as follows:

- To analyse the effects of electricity prices and electricity supply on economic growth in South Africa.
- To examine the causal relationship between electricity prices and economic growth.
- To examine the long-run and short-run effects of electricity supply and prices on economic growth.

1.4 Research questions

- What are the effects of electricity prices and electricity supply on economic growth in South Africa?

- Is there a causal relationship between electricity prices and economic growth in South Africa?
- What are the long-run and short-run effects of electricity supply and electricity prices on economic growth?

1.5 Definition of key concepts

The study focuses on electricity price, electricity supply, economic growth rate, electricity generation, and total investment. The definitions concerning these variables of interest are presented below:

- Electricity supply

Electricity is supplied to consumers through complex networks and generated at power plants. It moves through a complex system, sometimes called the grid, of electricity substations, transformers, and power lines that connect electricity producers and consumers. Most local grids are interconnected for reliability and commercial purposes, forming larger, more dependable networks that enhance the coordination and planning of electricity supply (U.S. Energy Information Administration).

- Electricity price

Electricity prices generally reflect the cost to build, finance, maintain, and operate power plants and the electricity grid (the complex system of power transmission and distribution lines). Profit utilities also include a financial return for owners and shareholders in electricity prices. A few factors that influence the price of electricity are fuels, power plant costs, transmission and distribution, weather conditions, and regulations (Eskom, 2018).

- Real economic growth

Refers is the rate at which a country's Gross Domestic Product (GDP) changes or grows from one year to another (Moran, Görg, Seric, and Krieger-Boden, 2012; Oleyede et al., 2021).

- Total investment

It is defined as a set of capital, technology, management, and entrepreneurship, which allows firms to operate and provide goods and services domestically or in a foreign market. By investment, economists mean the production of goods that will be used to produce other goods, and that Investment is the result of forgoing consumption (Almfraii and Almsafir, 2014).

1.6 Ethical considerations

The study employed secondary data, which is an incorporation of quantitative statistical analysis obtained from reliable sources. The study was executed considering the plagiarism policy of the University to maintain and uphold academic standards. Furthermore, the study is conducted by the University of Limpopo's rules and regulations. The information presented is handled with honesty and integrity and all sources utilised have been referenced.

1.7 Significance of the study

The primary objective of this study is to examine the effects of electricity prices and electricity supply on South Africa's economic growth from 1993 to 2022. This empirical analysis contributes to the limited body of literature by jointly analysing electricity prices and electricity supply within a single model an approach that distinguishes this study from previous research conducted in South Africa, which often treats these variables in isolation. By integrating both electricity supply constraints and pricing dynamics, this study provides a more holistic understanding of their combined impact on economic growth in the context of a developing economy.

Over the past decade, South Africa's electricity sector has been constrained by chronic underinvestment, ageing infrastructure, and operational inefficiencies. These factors have led to insufficient electricity supply amid rising demand and frequent electricity price hikes. The situation has been exacerbated by recurrent planned power cuts (load shedding) from 2008 to 2021, as well as the broader economic downturn resulting from the COVID-19 pandemic (Inglesi-Lotz & Ajim, 2021). This study applies the Energy Consumption Theory to explore the interplay between electricity market conditions specifically prices and supply and economic performance over time.

The significance of this study lies in its potential to inform evidence-based policy. By offering robust empirical findings on the short-run and long-run effects of electricity prices and supply on economic growth, the study provides valuable insights to stakeholders such as Eskom, the National Energy Regulator of South Africa (NERSA), and the Department of Mineral Resources and Energy. The findings will support the design of targeted policy interventions that promote energy security and foster sustainable economic development.

Additionally, this research contributes to academic literature by addressing inconsistencies found in previous studies. For instance, while Hondroyiannis et al. (2002), Odhiambo (2010), Bhattacharya et al. (2016), and Mabungu & Inglesi-Lotz (2022) suggest a positive relationship between electricity variables and economic growth, their findings differ in scope, method, and variable isolation. By modelling both electricity prices and supply simultaneously, this study fills a critical empirical gap and provides a foundation for future research in energy economics within the South African context.

1.8 Structure of the Dissertation

The dissertation is prearranged as follows: Chapter 2 will review the South African electricity sector. It further examines how Eskom, the state-owned utility, plays a central role in electricity generation and the energy crisis in South Africa. Chapter 3 reviews the theoretical framework and empirical literature review. The theoretical framework discusses the theories of energy and growth while the empirical literature reviews the findings of other authors in SADC and the rest of the world. Chapter 4 presents the methodology of the study which is the Autoregressive Distributed Lag (ARDL). Chapter 5 discusses the research findings from the econometrics tests performed in the study. Chapter 6 presents the conclusion and policy recommendation of the study.

CHAPTER 2

THE SOUTH AFRICAN ELECTRICITY SECTOR

2.1 Introduction

This chapter examines South Africa's electricity structure. Furthermore, it will discuss how South Africa's acute supply limitations necessitate extra generation capacity. It illustrates the consequences and growth rate of electricity in the South during various periods.

2.2 The structure of the South African electricity sector

The structure of the South African electricity sector is a multifaceted framework involving various entities, regulatory bodies, and key stakeholders. The electricity sector operates within state-driven and private initiatives dynamics, reflecting efforts to balance traditional energy sources with a growing emphasis on renewables (Department of Mineral Resources and Energy, 2023).

South Africa has a well-established electricity sector with a comprehensive power network that serves 88% of South African citizens. In recent years, the country has experienced severe supply constraints, requiring urgent additions to the installed generation capacity (Department of Energy, 2018).

The general overview of the electricity structure of South Africa as depicted in Figure 2.1 below is as follows:

- Generation:

In the South African electricity generation landscape, the state-owned utility Eskom plays a central role by operating numerous power plants such as the newly built Kusile and Medupi, which are predominantly coal-fired. However, recognising the importance of diversification and sustainability, Eskom has progressively increased its focus on renewable energy sources. The Renewable Energy Independent Power Producer Procurement (REIPPP) program signifies a strategic move to incorporate private investment in renewable energy projects. The Independent Power Producers (IPPs) participating in this program, significantly contribute to the generation mix, particularly in solar and wind energy. This dual approach, involving Eskom and IPPs, reflects

South Africa's commitment to balancing traditional and renewable energy sources for a more resilient and sustainable electricity generation infrastructure (Department of Planning, Monitoring and Evaluation, 2019).

- Transmission:

Eskom is also responsible for electricity transmission, operating the national grid that transports electricity from power generation facilities to distribution points. The elements of transmission used by Eskom include transmission lines, transmission towers, and transformers (Department of Energy, 2018).

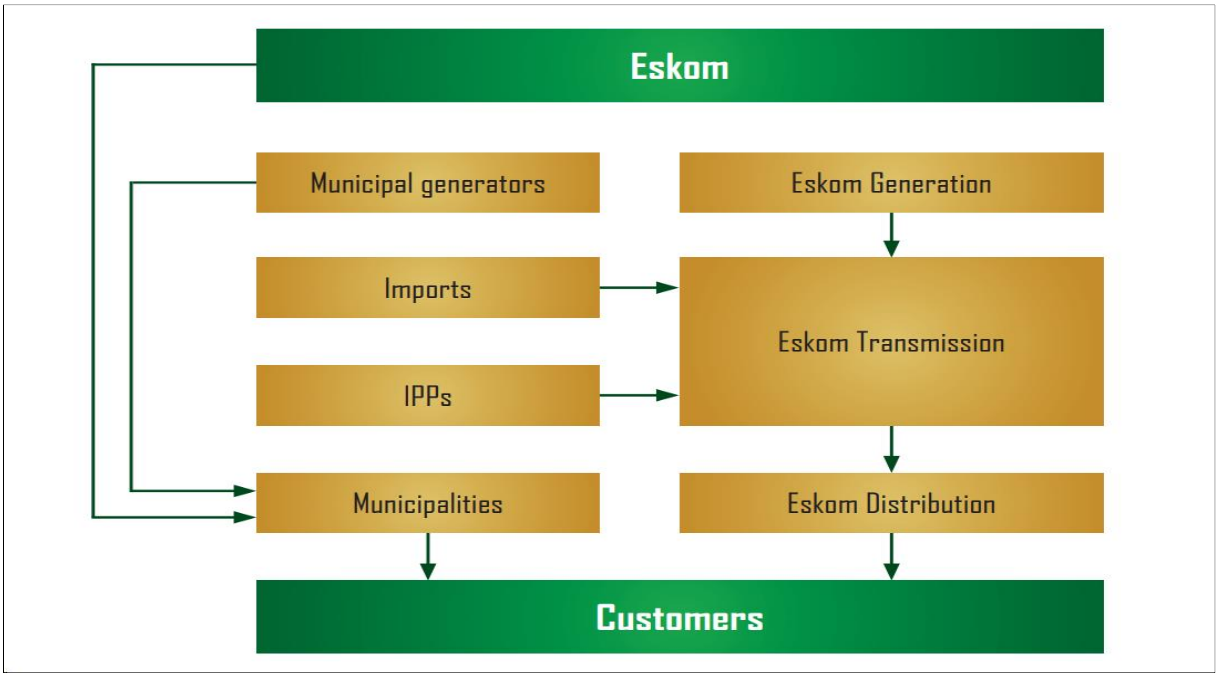
- Distribution:

Electricity is primarily distributed by municipalities and private firms, who purchase power from Eskom and distribute it to residential, commercial, and industrial customers within their respective domains (Department of Energy, 2018).

- Imports of electricity:

In 2022, South Africa occasionally imported electricity from neighbouring countries, such as Mozambique, Namibia, and Lesotho, during high demand or when facing challenges in its generation capacity (OEC, 2022).

Figure 2.1: Structure of the electricity supply industry in South Africa



Source: Department of Mineral Resources and Energy (2018)

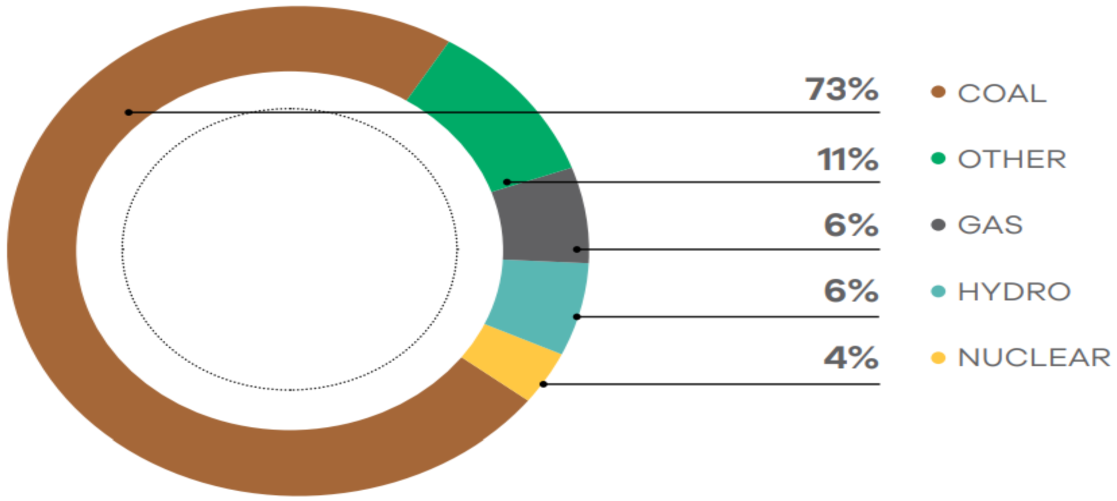
South Africa's economy is primarily driven by large-scale mining and mineral sectors, resulting in above-average energy intensity. Electricity is generated from coal, gas turbines, hydroelectric power, renewable energy, nuclear, and wind (Department of Mineral Resources and Energy, 2018).

2.3 National Electricity Landscape

South Africa's electricity landscape shows a dynamic relationship of diverse energy sources, policy initiatives, and challenges that impact both the reliability and sustainability of the nation's power supply. Historically dominated by coal-based generation, the country has been actively working towards diversifying its energy mix, embracing renewable sources, and navigating the complex landscape of power generation and distribution. This introduction provides a glimpse into the intricate web of factors shaping South Africa's electricity sector, including the role of Eskom, the rise of renewable energy, governmental policies, and the ongoing challenges such as load shedding. As the nation deals with issues of financial strain, supply constraints, high electricity prices, and a growing need for cleaner energy solutions, a deeper exploration of South Africa's national electricity landscape is warranted to understand the complex dynamics at play in the energy sector (Department of Trade and Industry, 2014).

Poorun and Radmore (2023) highlighted that Eskom accounted for roughly 95% of electricity demand in South Africa in 2022, which translates into an estimated 54 gigawatts (GW). Eskom’s dominant position in the power generation sector means it plays a key role in the national electricity generation landscape. The remaining 5% of demand was met through municipal generation, power imported from neighbouring countries, as well as IPPs in the renewable energy sector. Although the involvement of these renewable IPPs currently makes up a smaller portion of the overall supply, their involvement shows South Africa's ongoing efforts to diversify its energy mix and reduce reliance on conventional coal-fired power generation. As South Africa looks to build a more sustainable and resilient energy future, the contribution of these alternative sources is expected to grow, potentially transforming the national energy landscape over time (Council for Scientific and Industrial Research [CSIR], 2023).

Figure 2.2: National generation mix



Source: CSIR, 2022

Figure 2.2 above depicts South Africa's energy supply dominated by coal-fired power generation with an installed capacity of 39.3 GW. The generation mix comprises a nuclear power plant, two conventional hydroelectric power plants, and four non-dispatchable small hydro units. There are three hydro-pumped storage facilities for responding to peak and abrupt demand. Lastly, four diesel-powered gas turbine power stations run on diesel reserved for use during extreme demand response emergencies due to their very high operating costs. The Degradation of the existing Eskom coal fleet has led to the annual average energy availability factor (EAF) declining from 94% in 2002 to 53% in 2022 (Eskom, 2022).

The utility's most optimistic scenario suggests an improvement to 69% by 2030, although it is more likely to continue at about 60% for the rest of the decade. Historic underperformance and delayed activation of new generations have caused supply and demand imbalances, resulting in nationwide load shedding (CSIR, 2022).

2.3 The South African energy crisis

Load shedding is a critical issue in South Africa due to Eskom's financial struggles, insufficient generation capacity, and high electricity prices. Load shedding, or scheduled rolling blackouts, has become a major worry, affecting individuals' everyday lives, impacting enterprises, and highlighting the complexities of the country's electricity sector (Eskom, 2022).

The causes of Load Shedding in South Africa are as follows (Eskom, 2019):

- Eskom's Financial Struggles:

The state-owned power utility (Eskom), has faced severe financial challenges, burdened by debt and operational inefficiencies. Additionally, insufficient funds hinder Eskom's ability to maintain and upgrade infrastructure, leading to breakdowns and a reduced capacity to meet demand.

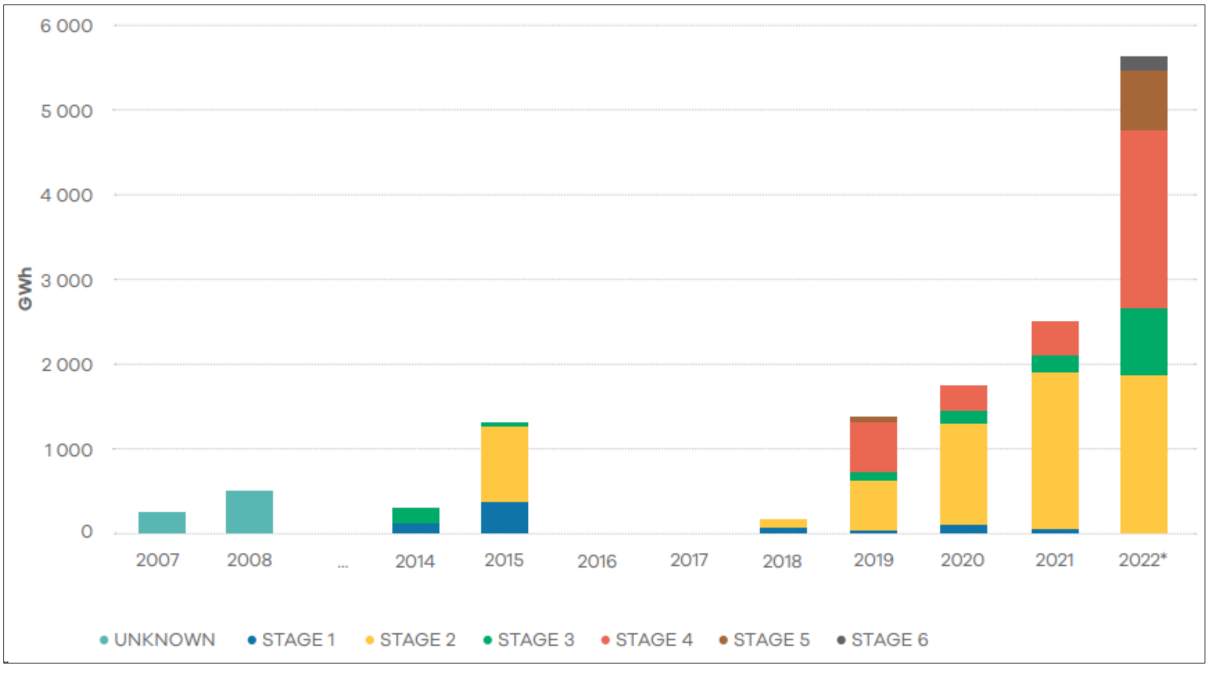
- Insufficient Generation Capacity:

The ageing coal-fired power plants, which have historically served as the backbone of South Africa's electricity infrastructure, are prone to malfunctions and require substantial maintenance. Therefore, the slow pace of introducing new, reliable power plants contributes to a supply-demand gap.

- Inadequate Investment in Renewables:

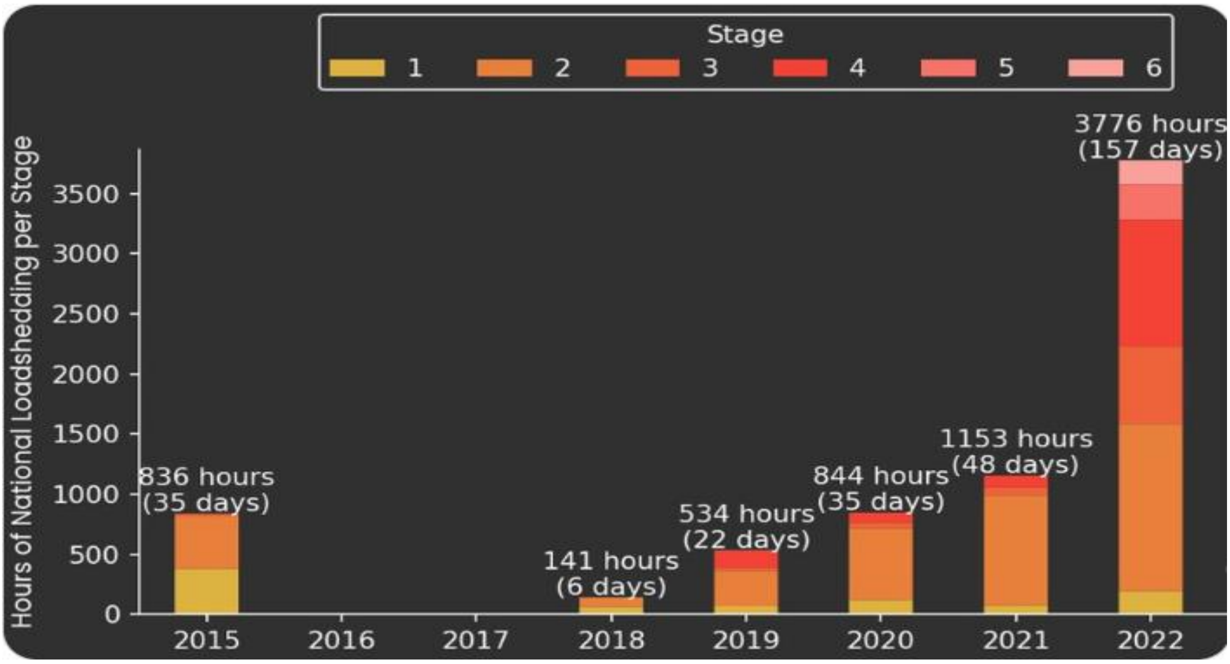
There is a greater emphasis on renewable energy sources, nonetheless, the transition has been slow with delays in establishing renewable projects like solar and wind farms which influence the overall ability to satisfy power demand.

Figure 2.3: Load shedding-energy basis (Gwh)



Source: CSIR, 2022

Figure 2.4: Load shedding outrage records (hours)

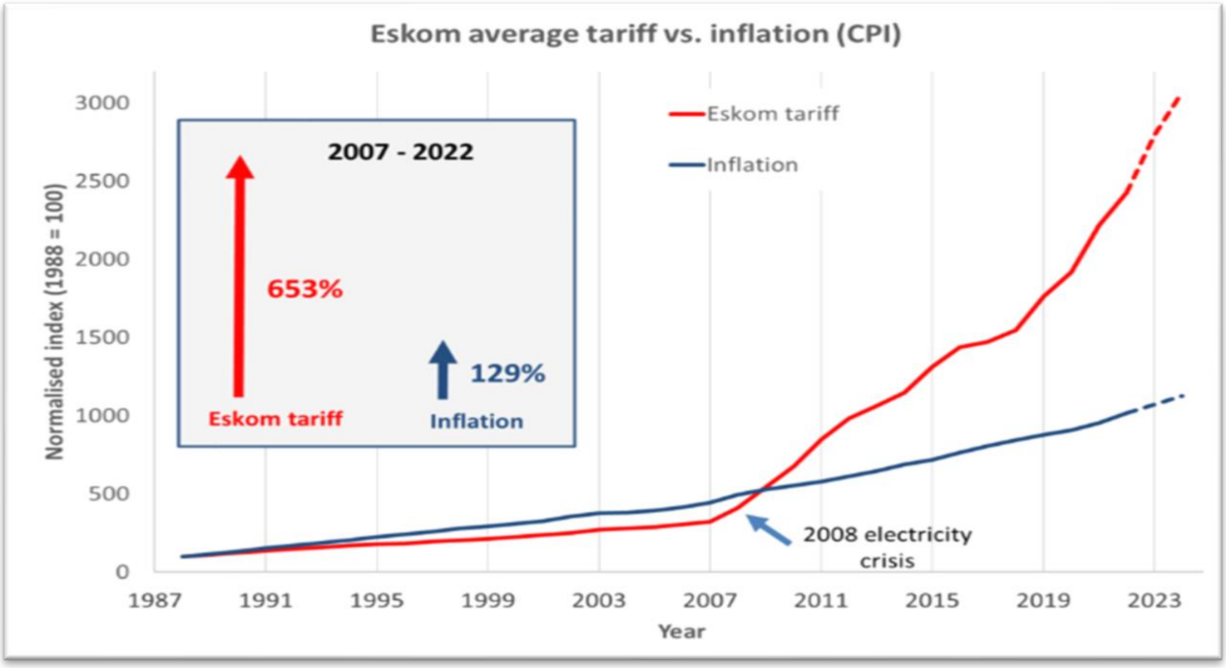


Source: Eskom, 2022

As depicted in Figures 2.2 and 2.3 above, from 2008 load shedding has been an almost constant part of the South African electricity landscape. In 2022 the supply shortfall has been between 4 GW and 6 GW resulting in load shedding and has already hit an all-time high. Figure 2.3 above shows the hourly load shedding distribution from 2015 to 2022. The unplanned outages increased in 2022, making it a particularly dark year for most South Africans. South Africa has experienced 3776 hours (157 days) of national load shedding in 2022. This is significantly higher than the 1,153 hours over 48 days in 2021 and the 844 hours over 35 days in 2020. Load shedding has been a constant struggle in the country, and 2022 has proven to be the most intensive year yet, particularly during July and September. Regular power outages disrupt business operations leading to downtime, reduced productivity, and financial losses for companies. Manufacturing, mining, and other industries that rely heavily on a stable power supply were also affected. Several businesses lost revenue due to interrupted operations and the inability to meet production targets (Eskom, 2022).

Electricity prices have been an issue in South Africa. Figure 2.5 shows average increases in electricity tariffs from 1988 to 2008, which did not keep pace with inflation due to government policy to keep electricity tariffs as low as possible for poor South African communities and Eskom's oversupply of electricity. Between 1988 and 2007, tariffs increased by 223%, while inflation was 335%. From 2008 to 2022, tariffs increased by 653%, with inflation at 129%. This represents a four-fold increase in real money terms in 14 years.

Figure 2.5: Eskom's average tariff compared to the inflation rate (CPI)



Source: Moolman, 2023

Due to Eskom's severe debt situation and the imperative to prevent its failure, consumers in South Africa can expect electricity prices to rise significantly, surpassing inflation rates in the coming years. Eskom has already applied for a substantial 32% tariff increase in April 2023 and is seeking to restructure residential tariffs. Proposed options include Homepower, with a grid connection fee increase, and Homeflex, introducing time-of-use charges to encourage electricity usage during off-peak hours. The government acknowledged the need for Eskom's restructuring in 2019, but as of October 2022, the process remains ongoing. This restructuring is crucial for addressing financial challenges and ensuring the stability of South Africa's power supply (Moolman, 2023).

2.4 Electricity prices

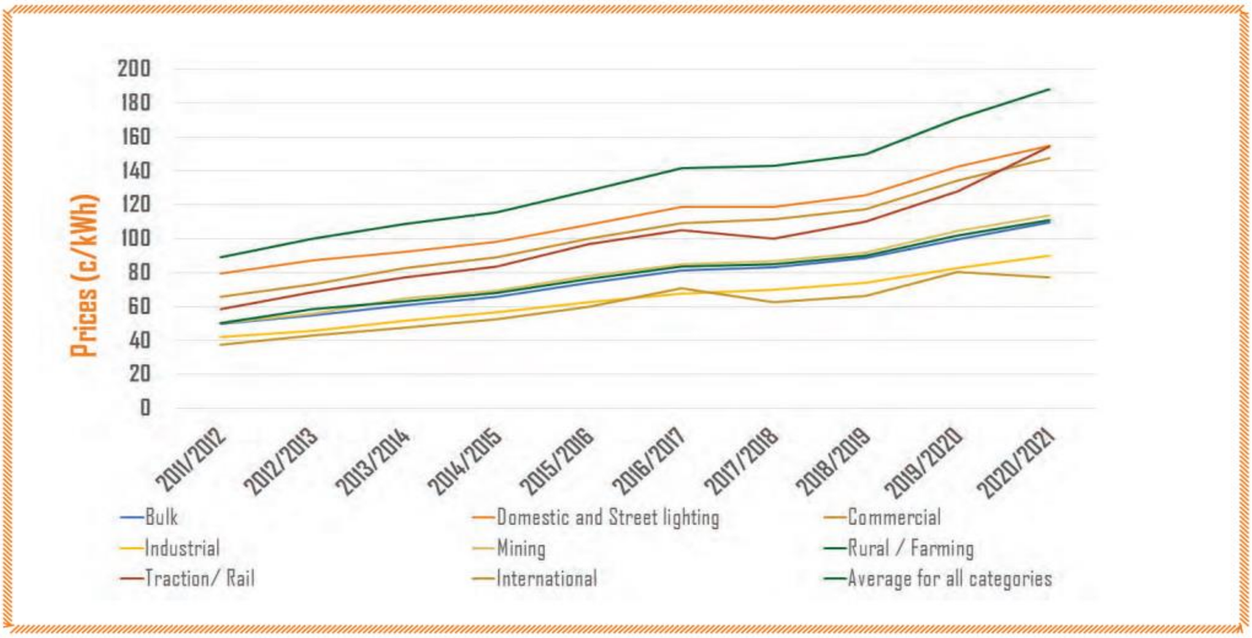
South Africa's electricity industry is governed by a robust regulatory framework designed to ensure both the financial sustainability of electricity providers and the energy for consumers. Central to this framework is the National Energy Regulator of South Africa (NERSA), which operates under the Electricity Regulation Act of 2006 and the National Energy Regulatory Act of 2004. These laws grant NERSA the authority to issue licenses, set guidelines, and establish pricing regulations for the sector. One of NERSA’s most crucial responsibilities is determining Eskom’s revenue requirements based on the Electricity Pricing Policy, which directly influences how electricity prices are set across the country. This ensures that Eskom's pricing is aligned with national energy goals and the financial needs of the utility (Mabugu and Inglesi-Lotz, 2022).

Eskom is a major player in South Africa's energy sector the country's main electricity supplier. The company generates, transmits, and distributes electricity to consumers, including residential homes, commercial businesses, industrial users, and even international customers within the Southern African Development Community (SADC). Each consumer category requires a different pricing structure due to their varying electricity demand levels and the associated supply costs. For instance, industrial and mining operations typically use far more electricity than households, meaning their pricing is structured differently to reflect the higher costs of serving these larger-scale users (Khobai, Mugano and Le Roux, 2017).

Table 2.1 and Figure 2.6 below show various types of electricity users in South Africa from 2011/12 to 202/21. Electricity is used for domestic and street lighting, commercial, industrial, international, mining, and farming. The price data in the table below applies only to Eskom’s direct sales to the categories listed. Sales by local authorities to the Domestic, Commercial and Industry categories are not included in this table. The prices are in c/kWh for each number of sale categories and the prices are exclusive of VAT. Annual Average Eskom Prices by Customer Category in cents per kilowatt hour (2011/2012 to 2020/2021) (Eskom, 2023).

These rates are set based on several factors, including the cost of power generation, transmission, and the maintenance and development of South Africa's electricity infrastructure. NERSA’s role in setting these prices is critical because it ensures that Eskom remains financially viable while keeping energy affordable for consumers (Eskom, 2023).

Figure 2.6: Annual Average Eskom Prices by Customer Category in cents per kilowatt hour



Source: Eskom, 2023

Table 2.1: Annual Average Eskom Prices by Customer Category in cents per kilowatt hour 2011-2021

	Average Price Adjustment (%)	Consumer Price Index (%)
2012/2013	16,00	5,20
2013/2014	8,00	6,00
2014/2015	8,00	6,00
2015/2016	12,69	5,70
2016/2017	9,40	6,59
2017/2018	2,20	5,30
2018/2019	5,23	4,5
2019/2020	13,87	4,2
2020/2021	8,76	3,9
2021/2022	15,06	4,6

Source: Eskom, 2022

Figure 2.7: Annual Eskom Average Tariff Adjustment

Source: Eskom, 2023

Eskom's tariffs are adjusted annually, on the 1st of April every year. Eskom's average price tariffs are adjusted at the end of the financial year (end of April) from 2005 to 2015. Eskom's average tariff adjustment figures are published on Eskom's website. The adjustments are according to Eskom's financial year end, which is end of the March (Ratshomo, 2021).

Table 2.2: Real interest rate trends in BRICS

	Average Price Adjustment (%)	Consumer Price Index (%)
2012/2013	16,00	5,20
2013/2014	8,00	6,00
2014/2015	8,00	6,00
2015/2016	12,69	5,70
2016/2017	9,40	6,59
2017/2018	2,20	5,30
2018/2019	5,23	4,5
2019/2020	13,87	4,2
2020/2021	8,76	3,9
2021/2022	15,06	4,6

Source: Eskom, 2022

Table 2.2 and Figure 2.7 above depict the average tariff adjustment against the consumer price index for the past 10 years. The year 2017/2018 is the only year electricity price adjustment was lower than the consumer price index. In all other years, electricity tariff adjustments were always higher than the consumer price index. The higher electricity could be attributed to continuous rolling blackouts and the constrained capacity at Eskom.

From 2019 to 2022, electricity prices have been on an upward trend, with the CPI slowly rising below electricity prices. As depicted in the above Figure 2.7, the average electricity prices more than doubled as compared to the CPI in the last 3 years (2019/21-2021/22). In terms of Section 4 of the National Energy Regulator Act, 2004 (Act No.40 of 2004), NERSA's mandate is to regulate the electricity industry in terms of the Electricity Regulation Act, 2006 (Act No. 4 of 2006). The Energy Regulator determines Eskom's allowed revenue on a multi-year basis. The Multi-Year Price Determination (MYPD) incorporates some of the Rate of Return (RoR) and incentive-based principles through the introduction of the transmission and distribution service incentive schemes and the Energy Efficiency Demand Side Management (EEDSM) schemes.

2.5 Summary

Chapter 2 has shown that the South African electricity sector is characterised by a multifaceted framework involving state-driven and private initiatives, aiming to balance traditional and renewable energy sources. Eskom, the state-owned utility, plays a central role in electricity generation, with a focus on coal-fired power plants but an increasing emphasis on renewables through programs like REIPPP. Eskom also manages the national grid for transmission, while distribution is primarily handled by municipalities and private firms. The country occasionally imports electricity during peak demand or capacity challenges.

Despite a well-established electricity sector serving 88% of the population, South Africa faces severe supply constraints, prompting additional generation capacity. The energy mix is dominated by coal, with efforts to diversify through renewables. The sector faces load shedding due to Eskom's financial struggles, insufficient generation capacity, and slow adoption of renewable projects.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

This chapter critically reviews the literature relating to the effect of electricity prices and electricity supply on economic growth, with specific reference to South Africa. The review combines empirical and theoretical contributions that offer light on the role of energy in promoting or hindering economic performance. It highlights key growth theories classical and modern and evaluates how electricity as a factor of production fits into these models. The chapter also explores various empirical findings in South Africa and other developing economies to present a rational view of the relationship between electricity variables and economic growth.

3.2 Theoretical Framework

To understand the potential influence of electricity supply and electricity prices on South Africa's economic growth, it is important to explore the fundamental theories of growth. Several foundational and contemporary economic growth theories offer insight into how energy, particularly electricity, may affect productivity and national output. The study draws on several key frameworks: Energy Consumption Theory, Neoclassical Growth Theory, and the Endogenous Growth Theory.

3.2.1 Energy Consumption Theory (Energy Cost Theory)

The energy consumption theory, also known as the energy cost theory, posits that the expense of employing energy resources in manufacturing and service operations can be offset by the processes' overall favourable economic effects (Hasanov and Mikayilov, 2020). According to Hasanov and Mikayilov (2020), the traditional Cobb-Douglas production function can model the total output with various production factors. Therefore, the study follows the work of Hasanov and Mikayilov, (2020) to model and link the electricity prices and electricity supply to the economic growth of the South African economy. Thus, the modified Cobb-Douglas production function suitable for studying the South African economy is presented as follows:

$$Y = AK^{\alpha}L^{\beta}E^{\delta}M^{\gamma} \quad (3.2)$$

Where Y represents total output which in the model denotes economic growth. Where, $K, L, E,$ and M represent capital, labour, energy supply and materials, respectively. $\alpha, \beta, \delta, \gamma$ denotes positive constants in the model. A denotes factor productivity in the functional Cobb-Douglas production function. Therefore, the cost is used to define the quantities of capital, labour, energy supply, and materials in the model thus:

$$C = P_K K + P_L L + P_E E + P_M M \quad (3.3)$$

Where C denotes the total costs of all factors of production and P_K, P_L, P_E and P_M represents prices of the capital, labour, energy, and material respectively. Therefore:

$$C = P_K K + P_L L + P_E E + P_M M \rightarrow min \quad (3.4)$$

Equation (3.3) is subject to

$$Y = f(K, L, E, M) = AK^{\alpha} L^{\beta} E^{\delta} M^{\gamma} \quad (3.5)$$

considering the total cost function as an objective function and the production function as a constraint to examine the impact of electricity prices and electricity supply on economic growth. Equation 3.1 is extended to incorporate electricity prices, electricity supply and foreign direct investment. Thus:

$$Y_t = A_t K_t^{\varphi} L_t^{\delta} E_t^{\sigma} PE_t^{\alpha} \quad (3.6)$$

Where Y represents total output which in the model denotes economic growth. Where, $K, L, E, and\ PE$ and represent capital, labour, electricity supply and electricity prices, respectively. Where $\varphi, \delta, \sigma, \alpha$ represent capital output elasticities, labour, electricity consumption and electricity prices, respectively. While t signifies time trend to do notes time series variables. Lin and Chen (2019) found that electricity prices significantly influence the innovation of renewable energy technologies, which can indirectly affect economic growth through enhanced productivity and sustainability. Similarly, reliable electricity supply and access are crucial for economic development, as highlighted by Stern, Burke and Bruns (2019), emphasising the importance of infrastructure and supply quality. Thus, the study will add to the Cobb-Douglas production function labour force participation, domestic investment, and research and development (R&D) as control variables to enhance the model.

$$Y_t = A_t K_t^{\varphi} L_t^{\delta} E_t^{\sigma} PE_t^{\alpha} R\ and\ D_t^{\mu} \varepsilon_t \quad (3.7)$$

Transforming the electricity supply and electricity prices growth model in a log-linear form:

$$GDP_t = \propto_t + \beta_1 ELS_t + \beta_2 ELP_t + \beta_3 INV_t + \beta_4 LLP_t + \beta_5 RandD_t + \varepsilon_t \quad (3.8)$$

Where GDP_t represents the real economic growth. ELS_t represents electricity supply, ELP_t represents electricity price, INV_t represents investment, LLP_t represents the labour force participation, and $RandD_t$ represents research and development in the model.

3.2.2 Neoclassical Growth Model

The Solow-Swan growth model is also known as the Neo-classical growth model. It was derived from the Harrod-Domar model, but it considers the effect of population growth, investment, and technological advancement (Gorlach, 2014). This model is used in contemporary economies as a source of growth accounting to measure the effects of labour, capital, and technological progress on economic growth. This model assumes the existence of a closed economy, where there is no government intervention and that the market is a perfectly competitive market with flexible price factors and full employment (Pasche 2013).

Assuming that output can be expressed using the traditional Cobb-Douglas production function:

$$Y(t) = f(K(t), L(t)) = AK^{\alpha}L^{1-\alpha} \quad (3.9)$$

Where Y represents total output at time. Where, $K, L, E,$ and M represent capital, labour, energy supply and materials, respectively. $\alpha, \beta, \delta, \gamma$ denotes positive constants in the model. A denotes factor productivity in the functional Cobb-Douglas production function.

The major contributing factors of production to the economic growth in South Africa, are capital, labour and energy and overall productivity. The need to investigate the relationship between energy and economic growth has been increasing in literature because of the realisation of the importance of energy on economic growth and development. Several studies have determined whether energy can be used as a substitute for other factors of production or as a complement (Ebohon, 1996).

3.2.3 Endogenous Growth Theory

The Endogenous Growth Theory, as advanced by Romer (1990) and Lucas (1988), argues that long-run economic growth is driven by internal mechanisms such as human capital development, technological innovation, and knowledge spillovers. This theory rejects diminishing returns and proposes that deliberate investment in R&D and education can generate increasing returns over time.

This theory also justifies the inclusion of R&D and labour force participation in the extended Cobb-Douglas model used in the study (log-linear form):

$$LGDP_t = \propto_t + \beta_1 ELS_t + \beta_2 ELP_t + \beta_3 INV_t + \beta_4 LLP_t + \beta_5 R\&D_t + \varepsilon_t \quad (3.10)$$

Incorporating R&D and investment aligns with endogenous growth thinking, where energy acts as both a facilitator of innovation and a barrier when supply is constrained. The South African Government’s Integrated Resource Plan (IRP) and initiatives to diversify electricity sources (e.g., renewables) support the view that energy reliability and innovation are central to long-term growth.

Electricity, within this framework, is more than an input; it is a platform upon which technological economies are built. In South Africa, the lack of reliable electricity supply curtails the effectiveness of universities, R&D centres, and technology hubs. Power outages disrupt research schedules, limit access to high-performance computing, and reduce time spent on innovation activities (Ngepah, 2017). This stagnates the productivity gains expected from knowledge production and ICT adoption.

Equally important is the question of electricity affordability. High electricity costs, particularly for small and medium-sized businesses (SMEs), reduce the incentive to develop. With energy bills accounting for a large amount of operational spending, businesses frequently reduce R&D operations or fail to adopt innovative technology (Mohammed et al., 2013). For technology driven industries like fintech, biotechnology, and digital services, this results in underperformance and premature business collapse.

Energy disruptions have an impact on education and skill development. Online learning platforms, computer labs, and vocational training centres all rely on consistent electricity. Without it, South Africa risks expanding the digital gap and reducing the workforce's preparedness for the Fourth Industrial Revolution (World Bank, 2020).

In the endogenous model, electricity facilitates the accumulation of technology and innovation. If energy infrastructure fails to facilitate the spread of technology and education, the country's long-term growth trajectory will deviate from its potential. This emphasizes the importance of viewing energy policy as a developmental imperative rather than simply infrastructure planning.

This study selects the Endogenous Growth Theory as the pillar framework, for three reasons:

1. Relevance to South Africa's policy goals: The country aims to transition toward a knowledge-based economy. Endogenous theory aligns with this direction by emphasising innovation, R&D, and education.
2. Sensitivity to electricity shocks: Unlike models that treat technology as exogenous, this theory acknowledges how energy disruptions or affordability affect internal growth mechanisms.
3. Empirical alignment with extended production modelling: The incorporation of labour force participation, investment, and R&D into the empirical Cobb-Douglas function reflects the very structure promoted by endogenous theorists.

3.3 Empirical literature

This section provides empirical evidence on the effects of electricity prices and supply on the economy. The empirical literature is aligned to the objectives.

3.3.1 The influence of electricity prices on economic growth

The influence of electricity prices has not been given much attention by growth economists. It is crucial to reflect on the degree of influence electricity prices and supply have on the country's economic growth.

Empirical evidence was reviewed by different authors such as Gonese, Hompashe and Sibanda, (2019), who examined the impact of electricity prices on production at the sectoral level in South Africa from 1994 to 2015, the generalised least-squares methodology was employed in this study. Diagnostic checks indicate that heteroscedasticity, serial, and cross-sectional correlations exist in the model. The findings show that electricity prices negatively impact production. This thus implies that for a 1% increase in electricity prices, sectoral output is expected to decline by 26, holding other variables constant.

Khobai, Mugano, and Le Roux, (2017) examined the impact of electricity prices and economic growth in South Africa from 1985 to 2014. The autoregressive distributed lag (ARDL) bounds test was implemented to determine long-run relationship among the variables. The bounds test results suggested a long-run relationship between electricity prices and economic growth. Furthermore, the results revealed that high prices would negatively impact economic growth. Other variables such as electricity supply, trade openness, capital, and employment positively impact economic growth. After the findings, the paper recommends the creation of electricity policies that will enhance the economic growth of South Africa.

Blignaut, Inglesi-Lotz, and Weideman (2015) investigated and estimated the price elasticity of electricity for various industrial sectors from 2002 to 2011. Over 11 sectors ranging from 2002 to 2012, the cross-sectional dimension for the panel analysis was performed to investigate whether the series are cointegrated. Firstly, unit root tests were used to determine if the panel data set exhibits stationarity. Their results showed that before the 2007 increase in electricity prices, there was an insignificant elasticity. At the same time, there were statistically significant and negative elasticities for 9 of the 11 sectors considered after 2007. This implies that industrial sectors are more sensitive to changes in electricity prices after the 2008 sharp increases, which will disproportionately affect small- and medium-sized enterprises. Thus, the authors concluded that further tariff increases will result in reduced electricity consumption or that consumers will turn to alternative forms of energy.

Mazambani (2015) investigated the impact of electricity prices on economic growth in South Africa from 1986 to 2013. Mazambani used the VECM to test the long run connection between the variables. The results indicated a negative long-run relationship between electricity prices and economic growth, suggesting an increase in electricity prices will reduce GDP. Mazambani (2015) argued that a significant electricity price increase is fatal to businesses slightly above the break-even point, they will be unable to absorb it. This could cause a reduction in production, retrenchment of employees, and in extreme cases, businesses closing causing a decline in overall economic growth.

Hondroyiannis et al. (2012) examined the relationship between energy consumption and economic growth using a trivariate framework where price development was used as the third variable. The study considered the data for Greece from 1960 to 1996, using the Vector Error Correction Model estimation. Their empirical results or findings supported the conception of a long-term relationship between economic growth, energy consumption and price developments. The empirical results indicated cointegration between the variables.

Roula Inglesi-Lotz and Blignaut (2011) conducted a sectorial decomposition study of electricity consumption in response to electricity price increases and economic output per sector from 1993 to 2006. The empirical results show that the increase was mainly due to output or production-related factors, with structural changes playing a secondary role in the industrial sector. While there is some evidence of efficiency improvements, indicated here as a slowdown in the rate of increase of electricity intensity, it was not nearly sufficient to offset the combined production and structural effects that propelled electricity consumption forward.

A few scholars have examined the relationship between electricity prices and economic growth in developed countries. Abbas et al. (2014) investigated the relationship between economic growth, electricity consumption, employment, and inflation. The study utilised data from 1990 to 2012 for the following five developing countries: China, India, Malaysia, Pakistan, and South Africa. The study used the random generalised least squares (GLS) model and Hausman’s specification tests. The results showed a significant impact of employment and electricity consumption on economic growth but an insignificant impact of inflation on economic growth.

Dagoumas et al. (2020) investigated the long-run relationship between energy prices and economic growth within the borders of the European Union. The study was from 1990 to 2018 using the Engle–Granger method to estimate annual data and employing the VECM. The study found a causality between crude oil and industrial electricity and residential electricity prices. The results also suggest that electricity price increases would not negatively impact European growth rates.

Campbell (2018) investigated the impact of electricity prices on electricity consumption in residential, commercial, and Jamaican industrial sectors. The bounds testing approach to cointegration was employed to obtain long-run price elasticity of demand estimates for the 1970–2014 period. The results were that residential and industrial consumers are responsive to price changes (decrease or increase) while commercial consumers are less responsive in the long run. This implies that increasing prices as an instrument of rationing electricity supply would be the least distortionary and most cost-effective based on current electricity supply constraints, but the vulnerable low-income households would be negatively affected. According to the findings in the study, Jamaica's sector faces supply-side challenges.

Table 3.1. A summary of empirical studies on the relationship between electricity supply and economic growth

Author (s)	Country	Sample Period	Analysis Technique	Findings
			Single Country Studies	
Khobai et al.	South Africa	1985 – 2014	ARDL-bounds test	The (ARDL) bound testing was employed and established that there is a long run relationship between these variables (economic growth, electricity supply, trade openness, electricity prices, employment, and capital).
Khobai et al.	South Africa	1990 – 2012	VECM	The results from the VECM suggested a unidirectional causality flowing from electricity supply to economic growth.
			Multi-Country studies	
Onayemi et al	Nigeria	1986 - 2017	ARDL	The result from the study showed that, in the long-run, increased FDI inflows, gross fixed capital formation, and electricity power supply, have the potency of increasing economic growth by 30%, 20% and 6%, respectively.
Cerdeira	Portugal	1970 - 2017		The co-integration results revealed long term relationships between these variables. The Granger-causality results validated the unidirectional causality flowing from renewable electricity production to foreign direct investment in the short term.
Ghosh	India	1970–2006	ARDL bounds test	The results show evidence from cointegration and granger-causality tests, that the author finds a unidirectional short-term causality from economic growth to electricity supply.
Akinwale et al	Nigeria	1970 - 2006	Vector Auto-Regressive (VAR) and Error Correction Model (ECM)	The results support the existence of a long run relationship between economic growth and electricity supply.

3.3.2 The relationship between electricity supply and economic growth

Khobai et al. (2016) investigated the short and long-run relationship between economic growth, electricity supply, trade openness, electricity prices, employment, and capital in South Africa within a multivariate framework. The autoregressive distributed lag (ARDL) bound testing was employed to establish the long-run relationship between these variables. The empirical analysis used time series data from 1985 to 2014 to achieve the stated objective. Major findings of the study include that economic growth, electricity supply, trade openness, electricity prices, employment, and capital correlate with the variables (co-integrated).

Another South African study by Khobai et al. (2017) examined the impact of electricity prices on economic growth. They incorporated electricity supply as one of the independent variables and established a long-run relationship between electricity prices, electricity supply, and economic growth. It established that electricity prices negatively affect economic growth while electricity supply positively affects economic growth. This was based on economic growth supporting expansion of the major sectors of the economy such as industrial and commercial sectors where electricity has been used as basic energy input. Policymakers should allow more players into the electricity supply industry to help boost supply instead of increasing electricity prices.

Onayemi, Olomola, Alege and Onayemi (2020) investigated foreign direct investment (FDI) inflows stimulation through constant electricity power supply for economic growth in Nigeria. The study utilised time series data from the World Development Indicators (WDI) from 1986 to 2017. Furthermore, the ARDL econometric approach to cointegration was employed to achieve the stated objective. The gross domestic product growth rate per capita FDI, labour force participation rate, gross fixed capital formation and electricity power supply. The result from the study showed that, in the long-run, increased FDI inflows, gross fixed capital formation, and electricity power supply, have the potency of increasing economic growth by 30%, 20%, and 6%, respectively. Therefore, based on the results obtained, the study recommended that there should be a constant electricity power supply to keep pace with productivity for efficient economic growth in Nigeria (Onayemi et al..2020).

Cerdeira (2012) conducted a study to determine the relationship between electricity supply and economic growth incorporating inward foreign direct investment, carbon dioxide emissions from electricity production and population size as additional variables to form a multivariate framework. They employed the bounds testing approach to co-integration and the error correction model of the 1970 to 2008 period. The cointegration results revealed a long-term relationship between these variables. The Granger-causality results validated the unidirectional causality flowing from renewable electricity production to foreign direct investment in the short term. The results further evidenced bidirectional causality between renewable electricity production, real income, inward foreign direct investment, and population.

Akinwale et al. (2013) investigated the relationship between electricity consumption and real GDP growth in Nigeria from1970-2000 period. The paper adopted Vector Auto-Regressive (VAR) and Error Correction Model (ECM) to test the causality between real GDP and electricity consumption. The result showed a unidirectional causality from real GDP to electricity consumption without a feedback effect. The results support a long-run relationship between economic growth and electricity supply.

Ghosh (2009) examines the connection between electricity supply, employment, and real GDP for India within a multivariate framework using the Autoregressive Distributed Lag (ARDL) bounds-testing approach of cointegration. A long run equilibrium relationship was established amongst the variables used in the study for the 1970 to 2006 period. The results show cointegration, and the author finds a unidirectional short-term causality from economic growth to electricity supply.

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		Single Country Studies		
Khobai et al.	South Africa	1985 – 2014	ARDL-bounds test	The (ARDL) bound testing was employed and established that there is a long run relationship between these variables (economic growth, electricity supply, trade openness, electricity prices, employment, and capital).

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Akinwale et al	Nigeria	1970 - 2006	Vector Auto-Regressive (VAR) and Error Correction Model (ECM)	The results support the existence of a long run relationship between economic growth and electricity supply.

3.3.3 The causal relationship between electricity and economic growth

Various studies have come to varying conclusions about the direction and existence of a causal relationship between energy consumption and economic growth, even for the same countries. One reason for this is the existence of several statistical approaches to examining causality. For example, a study in the United States case found that energy consumption unidirectionally Granger caused economic growth using three models (Arora and Shi, 2016). In comparison, the two models determined the relationship to follow the Feedback hypothesis (Stern, 2000).

Even when countries are categorised as highly developed OECD countries, there is no evidence of commonality in these countries' energy and economic growth causal relationships (Yildirima and Aslanb, 2012). For South Africa, by 2016, a limited number of studies, as discussed in Inglesi-Lotz and Pouris (2016) had been executed to examine the causality between energy consumption and economic growth. There was no consensus reached amongst these studies about whether there is a causal relationship between energy consumption and economic growth, nor about the direction of the causality in cases where such a relationship was found (Inglesi-Lotz and Pouris 2016; Ranjibar et al. 2017). The studies examining the South African case have had mixed results: the neutrality hypothesis, by Bah and Azam, 2017, the growth hypothesis, Acheampong 2018, and Bekun, Emir, and Sarkodie, 2019 feedback hypothesis by Khobai and Le Roux 2017, while Dlamini et al. (2016) stressed the change of direction over time. Compared to these studies, fewer studies have been done to test the relationship between electricity prices and supply economic growth in South Africa.

However, a recent study found that electricity supply, amongst other variables, has a long-run positive relationship with economic growth in South Africa. Electricity is one of the components of energy. Although the energy market is far broader than the electricity market, it is useful to use general trends in the energy market to understand the electricity market better. Thus, throughout the paper energy market outcomes are used to describe and understand the electricity market (Khobai, Abel, and Le Roux 2016).

Other international case studies on energy supply and economic growth reinforce the vast potential for differing causal relationship outcomes across countries. For example, a study done for Nigeria found that energy supply significantly impacts economic growth (Samuel and Lionel 2013), while a similar study done for Portugal found evidence of a bidirectional causality relationship between energy supply and economic growth (Cerdeira and Paulo 2012). Merging these two common approaches to choose consumption or supply as a proxy of electricity conditions to examine the causality relationship between energy and economic growth would entail studying the effect of electricity consumption and supply on economic growth. The interlinkage between the electricity market and economic growth is indisputable. Thus, inefficiency in the South African electricity market resulting from load-shedding might be significant enough to impact economic growth. Similarly, the persistently low levels of economic growth in South Africa may also be affecting the electricity market.

3.4 Summary

The study provided important theories such as the Endogenous Growth Model, Neo-classical Model, and Energy Consumption Theory. The chapter began by paving the way for discussion with theoretical perspectives regarding the supply and prices of electricity, and how they affect the economic growth of South Africa. The empirical studies were discussed to highlight differing views by other researchers and academics on matters relating to electricity in South Africa in addition to the theoretical perspectives.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

This chapter presents the research methodology to be followed to examine the effects of electricity supply and prices on the economic growth of South Africa. The study applied the quantitative method by following econometric techniques. Following econometric techniques, the study begins by deriving a chosen empirical model. This uses the Autoregressive Distributive Lag. The variables employed include economic growth, electricity supply, electricity prices, investment, labour participation, and research and development.

4.2 Data

This study is quantitative and uses secondary annual data from the period 1993 to 2023. The data will be searched from the South African Department of Energy (DOE), International Monetary Fund, World Bank, StatsSA, and South African Reserve Bank to examine the impact of electricity prices and supply on the economic growth of South Africa. The data will be analysed, interpreted, and tested to facilitate a valued conclusion on the effects of the above variables on the Gross Domestic Product. To enable the interpretation of coefficients as elasticities, variables must be transformed to their natural logarithms wherever necessary (Inglesi-Lots and Ajmi, 2021).

4.3 Model specifications

To explore the impact of the effects of electricity prices and electricity supply on the economic growth of South Africa the proposed research uses econometric models which balance the theoretical and empirical literature outlined above. The theoretical economic growth function will be presented as follows:

$$GDP_t = f(ELS_t + ELP_t + INV_t + LLP_t + RandD_t) \quad (4.1)$$

Where GDP_t represents the real gross product (as a proxy for real economic growth). ELS_t represents electricity supply (electricity generation), ELP_t represents electricity price, INV_t represents investment, LLP_t represents the labour participation, and

$RandD_t$ represents research and development in the model. Therefore, the liner econometrics model can be expressed as follows:

$$GDP_t = \propto_t + \beta_1 ELS_t + \beta_2 ELP_t + \beta_3 INV_t + \beta_4 LLP_t + \beta_5 RandD_t + \varepsilon_t$$
(4.2)

Therefore, $\beta_1 - \beta_5$ represents the slope coefficient and ε represents the random error term. Where, $\propto$ is the constant, $\beta's$ are the coefficients of the clarifying variables and ε is the error term. The above variables are sources from different data collection institutions, as mentioned in section (4.2).

4.4 Estimation techniques

The Autoregressive Distribution Lag (ARDL) method is used in the proposed study. In a single-equation time series setup, the technique is used to model the relationship between electricity prices, electricity supply, and economic growth. The cointegration of non-stationary variables is equivalent to an error correction process, which contributes to its popularity.

4.4.1 Unit root test

A unit root test is a statistical test used in econometrics to determine whether a time series variable follows a unit root process. The presence of a unit root suggests that a variable has a stochastic, non-stationary behaviour, which can complicate the analysis of time series data. Unit root testing of a series is the initial stage when working with time series data because the problem in dealing with time series data is the issue of stationarity. Analysts must deal with the stationarity problem in time series data before regressing (Mutyaba, 2013). In cases where the time series data is non-stationary, the regression will only generate spurious results (Gujarat and Porter, 2009). To remove the unit roots variables are differentiated, however, some variables do not become stationary at level, which requires further differencing.

4.4.1.1 *Informal unit root testing (visual inspection)*

Before the formal unit root testing of ADF and PP can be executed, the stationarity is first tested using graphs, hence visual inspection is conducted. The stationarity visual inspection can be done through graphs or correlogram tests. For the investigation, a graphical presentation is adopted. According to Mah (2012), visual inspection helps analysts to know the characteristics of time series data. Furthermore, Mah stressed that graphical presentation helps to show if our variables are increasing, decreasing or constant over time, thus observing the trends. According to Gujarati and Porter (2009) when the time series fluctuates around the mean of zero and is constant not decreasing or increasing, the time series data is stationary.

The standard version of Augmented Dickey-Fuller (ADF) as recommended by Dickey and Fuller (1979), and the Phillip-Perron test (PP) as recommended by Phillips and Perron (1988), are employed to test for non-stationarity assumption are regarded to be sufficient to test for formal unit root testing.

4.4.1.2 *Augmented Dickey-Fuller (ADF)*

The Augmented Dickey-Fuller (ADF) test was developed by Dickey and Fuller (1979) as an extension of the Dickey-Fuller test to account for higher-order serial correlation in the data by including lagged differences of the dependent variable. A unit root presence indicates that a time series variable is non-stationary, implying trend over time is stochastic or unpredictable. Because many statistical approaches presume that the underlying data is steady, stationarity is essential in time series analysis (Musthtaq, 2011).

The ADF test's null hypothesis is that the time series has a unit root, suggesting non-stationarity. The alternative idea is that the unit root does not exist, which indicates stationarity. The ADF test determines whether a time series is stationary or not. Stationarity is an important assumption in many time series models, including ARDL models and thus accommodates huge samples of time series data (Cheung and Lai, 1998). The ADF test is typically applied to the following autoregressive model:

$$\Delta y_t = a + \beta t + \Upsilon y_{t-1} + \delta_1 \Delta y_{t-1} + \ldots \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \quad (4.3)$$

Where Y_t represents the time series variable. ΔY_t represents the first difference of Y_t, which helps in removing the trend component. t represents the time trend. a represents a constant term. β represents the coefficient on the time trend. Υ represents the coefficient on the lagged level of the dependent variable. $\delta_1 \ldots \delta_p$ represent the coefficient on the lagged differences of the dependent variable. ε_t represents the error term.

The null hypothesis of the ADF test is $\Upsilon = 0$, which implies the presence of a unit root, while the alternative hypothesis is $\Upsilon < 0$ indicating stationarity. The test statistic is compared to critical values from statistical tables to determine whether to reject the null hypothesis. If the test statistic is more negative than the critical value, the null hypothesis is rejected, suggesting that the time series is stationary.

4.4.1.3 Philips-Perron test

The Phillips-Perron (PP) test was introduced by Phillips and Perron (1988) as a non-parametric method to handle serial correlation and heteroskedasticity in the error terms, making it a robust alternative to the ADF test. The PP test is an alternative to the more widely known ADF test, and it has some advantages in certain situations (Vogelsang and Wagner, 2013). Unlike the ADF test, which assumes homoskedasticity in the error terms, the PP test is non-parametric and robust to heteroskedasticity in the error terms. This makes the PP test more suitable when dealing with economic data that often exhibit changing variances over time (Phillips and Perron, 1988). The PP test takes the form of:

$$\Delta Xt = \alpha_0 + \alpha_1 t + \beta_0 X_{t-1} + \varepsilon_t \quad (4.4)$$

Where Δ represents the first difference operator. The t represents the time trend. The ε represents the error term. The test is conducted under the null hypothesis of a unit root, and the critical values are used to determine whether to reject the null hypothesis. While the ADF test includes lags in the dependent variable, the PP test corrects for autocorrelation and heteroscedasticity in the residuals, making it more robust under certain conditions. The null hypothesis stipulates that the series is non-stationary has a unit root *Xt* and can be rejected if β_0 is statistically significant.

4.4.2 Auto-Regressive Distribution Lag approach

The Auto-Regressive Distributed Lag (ARDL) model is an econometric technique used in time-series analysis to study the long-run relationship between variables. It is particularly applied in the context of cointegration analysis, which deals with non-stationary time series that share a common stochastic trend. The ADF test determines whether a time series is stationary or not. Stationarity is an important assumption in many time series models, including (ARDL) models and thus accommodates huge samples of time series data (Pesaran and Shin, 1995).

The general form of an ARDL model is given by:

$$\Delta y_t = \alpha + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-2} + \beta_3 \Delta Y_{t-p} + \dots \beta_p \Delta Y_{t-p} + \Upsilon_0 X_t + \Upsilon_1 \Delta X_{t-1} + \dots + \Upsilon_q \Delta X_{t-q} + \varepsilon_t \quad (4.5)$$

Where y_t is the dependent variable at time t. Δ represents the differencing operator i.e., the change in the variable from one period to the next. α represents a constant term. $\beta_1, \beta_2, \beta_p$ represent coefficients on the lagged differences of the dependent variable. X_t, X_{t-1}, X_{t-q} represent independent variables. $\Upsilon_0, \Upsilon_1 \dots \Upsilon_{t-q}$ represents the coefficients on the lagged values of the independent variable(s). ε_t represents the error term, representing the random disturbance or shocks to the model.

The ARDL is specified by selecting lags for each variable included in the regressed model. This model is recommended over the Johansen framework because of its ability to incorporate variables with different levels of integration. The bounce test technique used for integration can also be utilised. It is also assumed that all the variables of the model are endogenous. According to Pesaran, Shin and Smith (1997), a small sample of data can be used in the model without giving spurious results. It also accommodates structural breaks in the time series data. The ARDL for electricity prices and electricity supply hypothesis is constructed as follows:

$$\Delta GDP_t = \alpha + \beta_1 \Delta ELS_{t-1} + \beta_2 \Delta ELP_{t-2} + \beta_3 \Delta INV_{t-3} + \beta_4 \Delta LLP_{t-4} + \beta_5 \Delta R\&D_{t-5} \dots + \Upsilon_1 ELS_{t-1} + \Upsilon_2 \Delta ELP_{t-2} + \Upsilon_3 \Delta INV_{t-3} + \Upsilon_4 \Delta LLP_{t-4} + \Upsilon_5 \Delta R\&D_{t-2} + \varepsilon_t \quad (4.6)$$

Where Δ denotes the first difference operator in the model and ε_t represents the error term which is also known as the white noise disturbance. $\Upsilon_1 - \Upsilon_5$ coefficients represent the long run relationship in the model. The short run relationship in the model is represented by $\beta_1 - \beta_5$ coefficients.

Therefore, for South Africa's economic growth, the long-term relationship between electricity price and electricity supply is presumed to be the same, while short-term coefficients are assumed to be country-specific. The model is employed to determine the impact of electricity price and electricity supply on the economic growth of South Africa.

Furthermore, Pesaran et al. (2001) developed the ARDL limits testing approach to evaluate the presence of a long-run relationship between the variables. This approach offers numerous advantages over traditional cointegration testing. The technique is applied regardless of whether the series is I (0) or I (1). The bounds test is a two-stage process that begins with estimating the boundaries of the cointegrating relationship and ends with assessing the significance of the bounds. The bounce test determines whether a long-run relationship exists between the variables.

The test assumes that if the variables are cointegrated, there should be a linear combination of the variables that is stationary. The ARDL limits testing technique is frequently utilised in applied econometric research and has been demonstrated to be an effective tool for assessing variable long-run relationships. This test is recommended over the Johansen and Juselius framework of 1990 and Engle Grager (1987). It can incorporate small sample size data and generate valid results. In contrast, the Johansen and Juselius framework requires a large data sample size to produce positive and valid results.

The ARDL cointegration approach provides two critical values, the lower and upper bound critical values. The lower bound critical value assumes variables are I (1). If the computed F-statistics lies above the upper bounce test, the null, hypothesis is rejected as there is no cointegration amongst the variables. If the computed F-statistics is below the lower critical value, the null hypothesis of no cointegration is accepted, meaning there is no cointegration amongst the variables. If the computed F-statistics is between the two-bounce test the cointegration becomes inconclusive.

The null hypothesis of no cointegration H_0 is defined by:

$$H_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0 \quad (4.7)$$

The alternative hypothesis of cointegration H_1 is defined by: (4.8)

$$H_1 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$$

The hypothesis above is tested against the F-statistics test. The F-statistics tests cointegration between variables.

4.4.3 Diagnostic tests

The diagnostic tests include the normality test assessing with a probability value, Jarque-Bera, Kurtosis and Skewness. In the normality test, the Jarque-Bera and the related p-value are important things to be tested along with kurtosis. If the p-value is greater than 0.05 per cent, the residuals of the model are usually distributed, which is a positive indicator (Stock and Watson, 2012).

Another test used is the serial correlation and heteroskedasticity are diagnostic test that will be used in the study. With serial correlation the Breusch-Godfrey correlation LM test for serial correlation and the null hypothesis of H0: v=0 is tested against the alternative hypothesis of HA: v≠ 0. The null hypothesis suggests that the serial correlation exists in the model (Asteriou and Hall, 2011).

Heteroskedasticity is when the error term does not have constant variance in the model. The study adopted the Breusch-Pagan-Godfrey, where the null hypothesis of $H_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ is tested against the alternative hypothesis of $H_0 = \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$. The null hypothesis of heteroskedasticity states that the error term has a constant variance as it does not contain heteroskedasticity. The study adapts the ARCH and White test of heteroskedasticity (Stock and Watson, 2012).

The normality of the model will further be assessed by visual inspection whereby for it to be evenly distributed the shape of it has to be bell shaped. However, the issue may occur if it is found that the residuals are serially correlated as shown by the serial correlation test (Magableh and Ajlouni, 2016).

4.4.4 Stability test

The stability tests employed are the cumulative sum of recursive residual (CUSUM) and the cumulative sum of squares of recursive residual (CUSUMsq) to test the stability of the long-run and short-run parameters of the model. The CUSUM and CUSUMsq tests are important if there is uncertainty that structural change and the methods are perfect for the stationary data. Their null hypothesis is that the coefficient vectors in every period are the same. The alternative hypothesis states that the coefficient vectors are different in every period.

4.4.5 Granger causality test

Granger causality is a statistical test that determines if one time series may be used to forecast another. It is based on the causality or the link between cause and effect. The 1969 Granger test is used on multivariate time series data with a certain lag to see if one variable may predict the future values of another variable (Granger, 1969).

The time series X is said to be Granger cause Y if it can be seen, usually by a series of t-tests on the lagged values of X (and the lagged values of Y also included), that such X values have statistically relevant details on the potential values of Y. Therefore, if the null hypothesis states that x does not induce Granger Y, and vice versa, the 5 percent likelihood denies the null hypothesis and the alternate hypothesis must be weighed. This study's null hypothesis indicates that economic growth does not Granger cause electricity prices, electricity supply and total investment in South Africa and vice versa. The Granger-causality model will be as follows:

$$LGDP_{it} = \alpha_{it} \sum_{i=1}^{n} \alpha_j LELS_{t-1} + \sum_{i=1}^{n} \beta_j ELP_{t-1} + \sum_{t=1}^{n} \eta_j LLP_{t-1} + \sum_{I=1}^{n} \theta_j INV_{t-1} + \sum_{I=1}^{n} \theta_j RandD_{t-1} + \varepsilon_{it} \quad (4.9)$$

Four types of causality can be distinguished depending on the significance of the estimated coefficients of the parameters:

- One-way (uni-directional) causality means X causes Y, and Y Causes X. It is found that the estimated coefficients of the lagged X are statistically significant and the coefficients of the lagged Y are not statistically different from zero.

- On the other hand, one-way causality from Y to X exists if the set of the lagged X coefficients is not statistically different from zero and the set of lagged Y coefficients is statistically different from zero.
- Bilateral also known as two-way or feedback causality is confirmed if the sets of X and Y coefficients are statistically different from zero.
- Finally, the variables are independent if the sets of X and Y coefficients are not statistically significant.

Before the error correction models came into practice, the standard Granger tests provided inferences on causality. However, Granger (1988) argues that the standard Granger tests are not likely to give valid causal inferences in the presence of cointegrated variables. The alternative causality test is then based on the error correction models incorporating information from the cointegrated properties.

4.5 The apriori expectations

The expected results of the study will depend on the methodology applied. The determinant of South African economic growth is sensitive to the choice of modelling because of the instability of some variables such as real exchange rate, investments, and prices in South Africa.

4.6 Summary

This chapter covered the methodology that was applied in the study. The research begins by testing the stationarity of the data using the ADF and PP tests to ensure that the time series variables are appropriately transformed to avoid spurious results. The study also employs various diagnostic tests to check for normality, serial correlation, and heteroskedasticity in the model's residuals, ensuring the robustness of the results. The ARDL approach is then used to analyse both the short- and long-term relationships between electricity prices, supply, and economic growth, with additional factors like investment, labour participation, and research and development considered. Stability tests, including CUSUM and CUSUMsq, will be used to confirm the consistency of the model's parameters. The Granger causality test is applied to assess causality, which will help determine the dynamic relationship between these variables.

CHAPTER 5

INTERPRETATION OF FINDINGS

5.1 Introduction

This chapter presents, analyses and interprets the results from the empirical analysis of the relationship between electricity prices, electricity supply, and economic growth in South Africa. The impact is measured by economic growth, electricity supply, electricity prices, investment, labour participation, and research and development in the period 1993 to 2022.

This study employed the ADF and PP tests for unit root testing. Following the order of integration from unit root testing, cointegration was done using the Johansen framework and the ARDL bounce test. The study also employed the Granger causality, variance decomposition, impulse response functions, as well as diagnostic and stability tests. All analyses are conducted using the EViews 13 statistical software package.

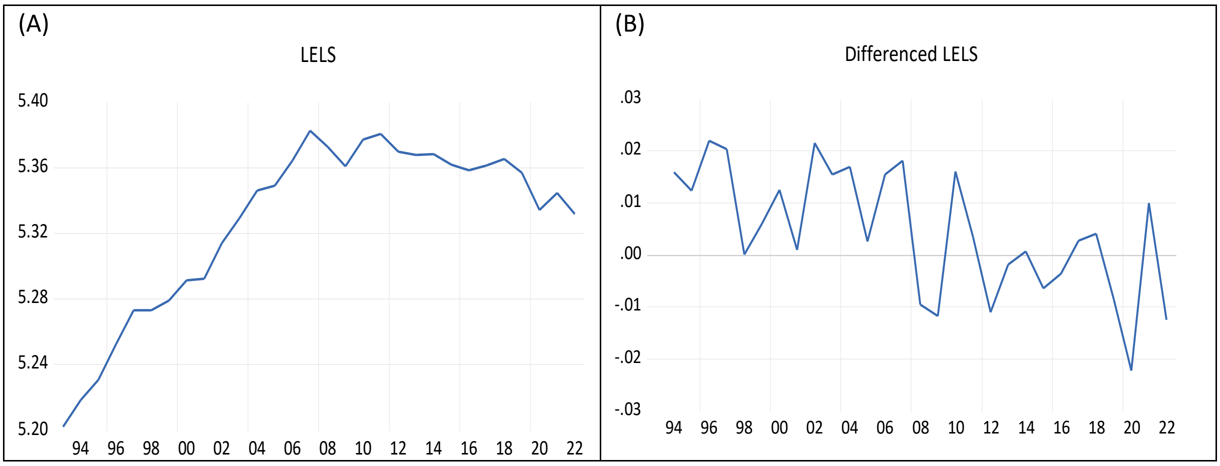
5.2 Empirical test results

The following section presents all the tests executed in the study and their interpretations.

5.2.1 Informal unit root test results

Before performing any econometrics techniques, it is of utmost importance to determine the order of integration in data employed to avoid spurious regressions (Mongale and Eita, 2014). The purpose of visual inspection was to get an initial sense of the characteristics of the data, especially whether it shows trends, seasonality, or fluctuations around a stable mean (Letsoalo and Ncanywa, 2021). This helps us decide on the appropriate model for analysis, such as whether to include a trend, intercept, or neither in the estimation process. The study used informal and formal methods of unit root testing to check the order of integration in the variables employed by the financial flow analysis. When analysing informal tests (Ncanywa et al., 2021), one starts by visualising graphs of different variables to check for stationarity.

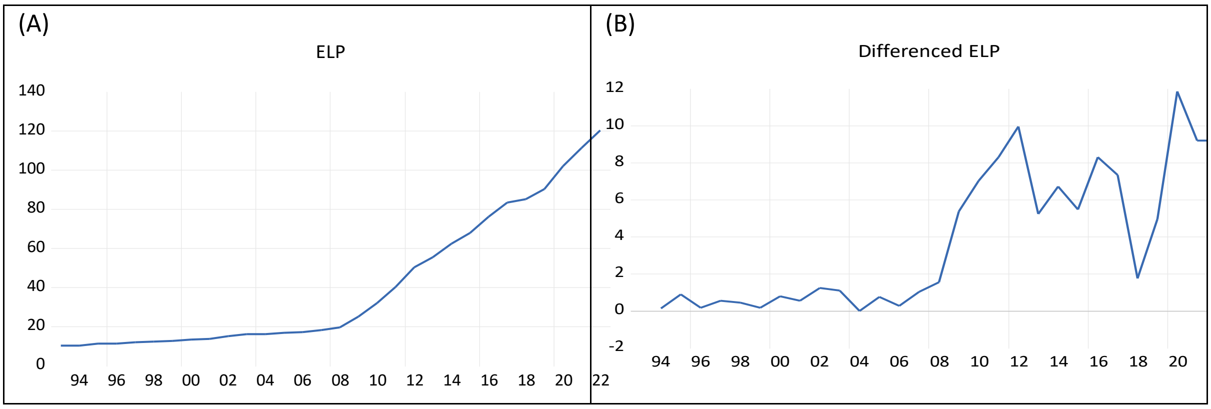
Figure 5.1: Electricity Supply (LELS)



Source: Source: Author's computation

Figure 5.1 illustrates the results of the visual inspection of the electricity supply in South Africa. Figure 5.1 A reveals an upward trend, indicating that the electricity supply series is likely non-stationary at its level. However, after applying the first-order differencing (Figure 5.1 B), the series appears to fluctuate around a mean of zero, suggesting that it may achieve stationarity at this level.

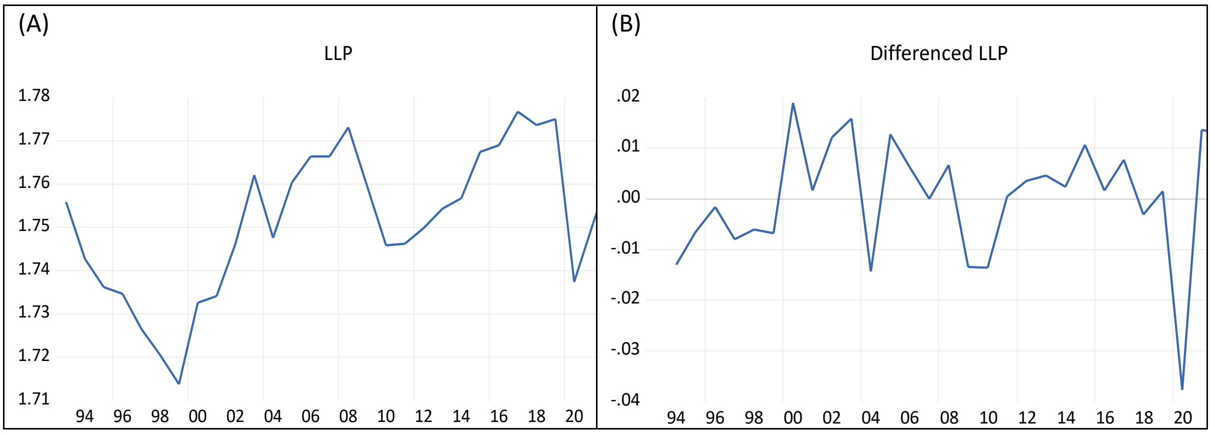
Figure 5.2: Electricity Prices (ELP)



Source: Source: Author's computation

Figure 5.2 A presents the informal unit root test results for electricity prices in South Africa. The figure indicates that electricity prices exhibit steady oscillations above the mean of zero, with limited crossings of the mean. Additionally, an upward trend is observed, suggesting that electricity prices are likely non-stationary at their level. However, after applying first-order differencing (Figure 5.2 B), the series appears stable, fluctuating around a mean of zero, which indicates that the data achieves stationarity after differencing.

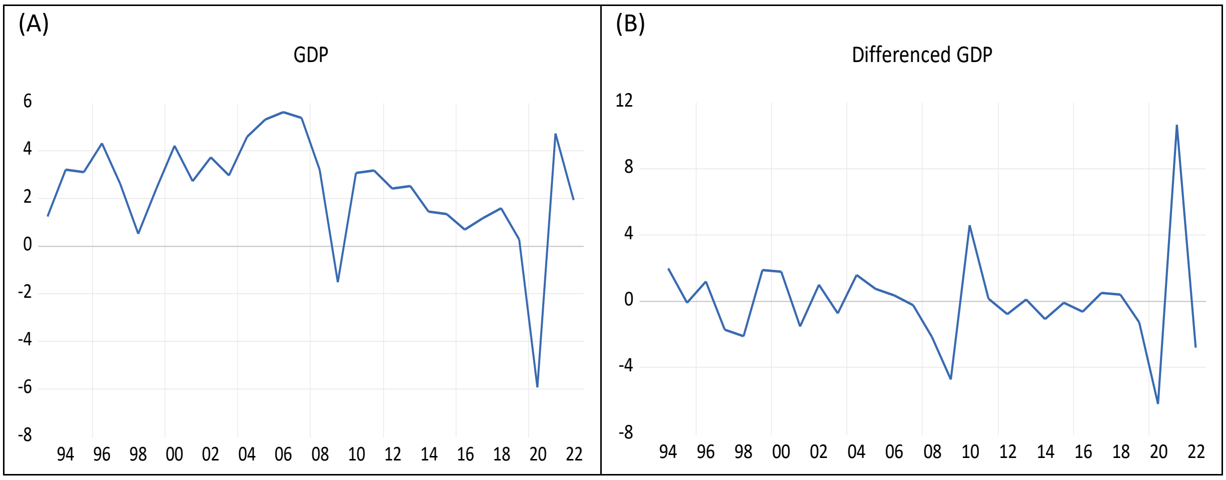
Figure 5.3: Labour Participation (LLP)



Source: Source: Author’s computation

Figure 5.3 exhibits unit root test results for labour participation in the South African economy. The first impression upon the visualisation of Figure 5.3 A is that labour participation illustrates a downward trend with fluctuation. For this reason, the analysis concludes that labour participation seems non-stationary at level in South Africa. Differenced labour participation for the South African economy is illustrated in Figure 5.4 above. After the first difference (Figure 5.3 B) labour participation appears stationary, as it depicts constant variances over time and covariances. Labour participation frequently crosses the mean value of zero. The empirical study, therefore, concludes that labour participation occurs to integrate at order I(1).

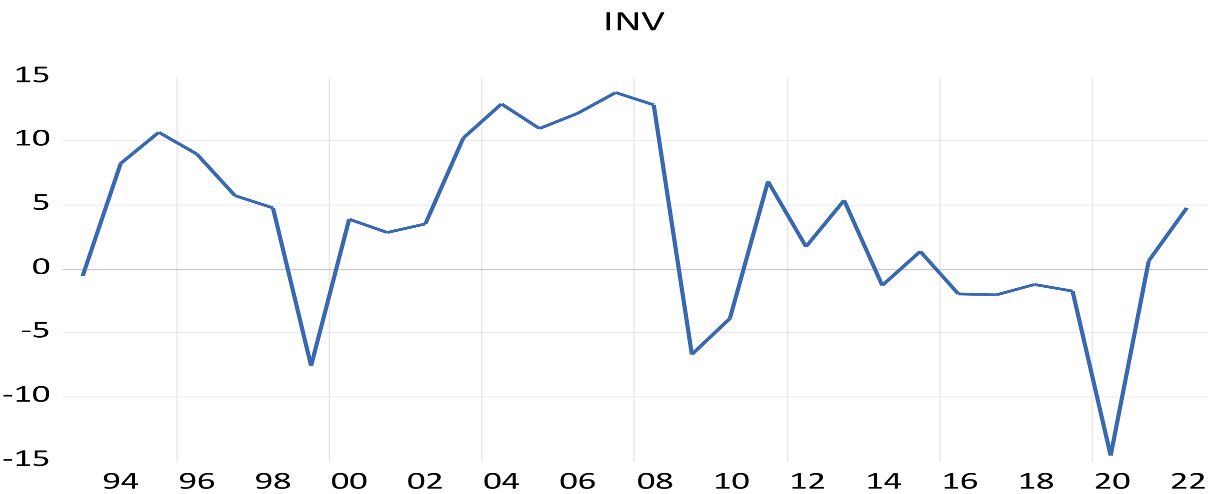
Figure 5.4 Gross Domestic Product (GDP)



Source: Source: Author’s computation

Figure 5.4 A depicts the results of a visual inspection of economic growth within South Africa. Economic growth is hovering strongly above the mean of zero, thus showing a trend even though it crosses the mean value of zero several times. The analysis concludes that economic growth seems to be non-stationary at level. Economic growth after the first-order differences (Figure 5.4 B) appears to be hovering along the mean of zero with constant variance and covariance. Therefore, the analysis concludes that economic growth appears be integrate at order I(1).

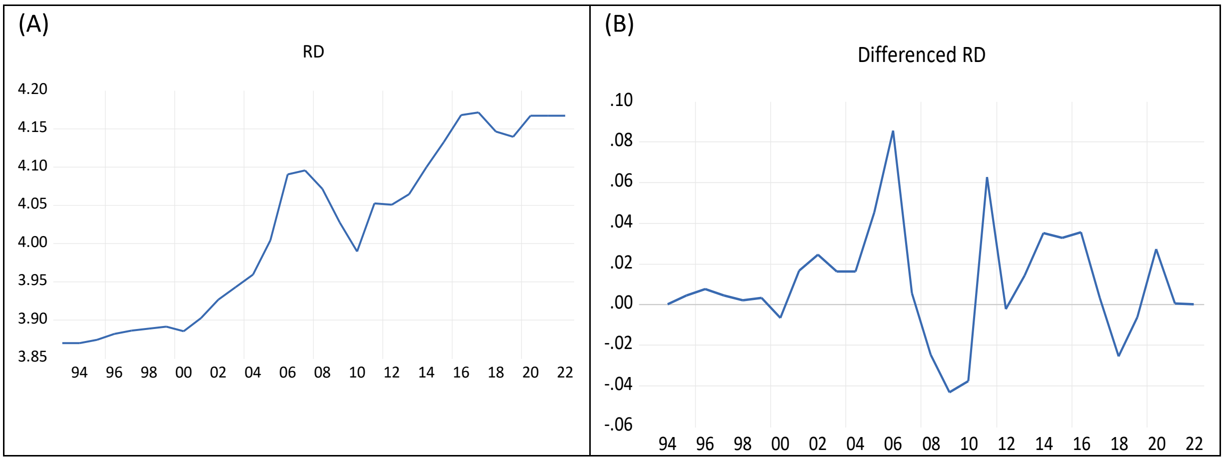
Figure 5.5: Investment (INV)



Source: Author's computation

Figure 5.5 illustrates the unit root test results of the investment at level for the South African economy. Figure 5.5 shows that investment is hovering along the mean of zero. The empirical investigation concludes that investment looks to integrate at order I(1) in South Africa.

FIGURE 5.6: Research and Development



Source: Source: Author's (2024)

Figure 5.6 A shows upward trending with no constant variance over time R&D the visual inspection results. This suggests that the variable is non-stationary at level. The next step was a differencing process, and the results are displayed in Figure 5.6 B. They show constant variance and covariance over the period because the line graph hovers along the mean of zero. and. The analysis concludes that R&D might be stationary at first difference.

5.2.2 Formal Unit Root Test Results

Table 5.1 presents the results from unit root tests, specifically the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, for each variable under the "Trend and Intercept" condition. These tests determine whether each time series variable is stationary at level I(0), or whether it becomes stationary after first differencing, I(1). The table also reports the statistical significance levels namely, 1%, 5%, and 10% at which the null hypothesis of a unit root is rejected.

These significance levels are critical in interpreting the results:

- The 1% level *** indicates very strong evidence against the null hypothesis, suggesting with 99% confidence that the variable is stationary. This means there is only a 1% probability of wrongly rejecting the null when it is true.
- The 5% level ** reflects moderate to strong evidence against the null hypothesis, implying a 95% confidence level in the stationarity of the variable.
- The 10% level * suggests weaker evidence against the null hypothesis, meaning the results should be interpreted with some caution.

By including these significance levels, the study provides a nuanced understanding of the robustness of the results and the statistical reliability of each variable's stationarity status.

Table 5.1: Formal unit root test results

VARIABLES	TEST MODEL	TEST USED	I (0) LEVEL	SIGNIFICANCE LEVEL	I (1) 1ST DIFFERENCE
GDP	Trend and intercept	ADF	-4.9001***	1%	-
	Trend and intercept	PP	-4.8986***	1%	-

LELS	Trend and intercept	ADF	-0.6597	1%	-5.8864***
	Trend and intercept	PP	-0.4232	1%	-6.6602***
ELP	Trend and intercept	ADF	-0.4286	5%	-3.9079**
	Trend and intercept	PP	0.0214	5%	-3.9724**
LLP	Trend and intercept	ADF	-2.8157	1%	-5.3808***
	Trend and intercept	PP	-2.8799	1%	-53878***
INV	Trend and intercept	ADF	-3.7860**	5%	-
	Trend and intercept	PP	-3.7860**	5%	-
R&D	Trend and intercept	ADF	-3.3942*	10%	
	Trend and intercept	PP	-2.4679	10%	3.8740**

Notes: Asterisks (*) represent significance at ***1%, **5% and *10% level

Source: Author's computation, 2024

The unit root test results in Table 5.1 indicate that GDP is stationarity at levels in the ADF and PP tests. This implies that GDP does not require differencing to achieve stationarity. This is in line with Narayan and Smyth (2005) who determined that GDP across OECD countries was stationary at level for many countries.

Electricity supply was non-stationary at levels and became stationary after the first difference. This suggests electricity supply is integrated into order one I (1). Similarly, Apergis and Payne (2010) determined that electricity variables are generally non-stationary at levels but become stationary after first differencing. Similarly, Lean and Smyth (2010) highlight that electricity production often exhibits I(1) behaviour.

Electricity prices are commonly found to be I(1). Electricity prices are non-stationary at levels according to both ADF and PP tests. However, electricity prices become stationary after first differencing, indicating I (1) behaviour. Inglesi-Lotz's (2011) analysis of electricity prices and economic growth in South Africa, found that electricity prices are non-stationary at levels but achieve stationarity after first differencing. A similar conclusion was reached by Bekhet and Yusof (2009) in the study of energy prices in Malaysia.

The results for labour force participation show non-stationarity at levels for ADF and PP tests. However, the first difference is significant at the 1% level, confirming that labour participation is also I (1). Arestis and Demetriades (1997) confirm that labour market variables often require first differencing to achieve stationarity. Furthermore, Kapsalyamova et al. (2015) show that labour force participation follows a non-stationary trend and becomes stationary after differencing.

For domestic investment, the ADF and PP tests show stationarity at levels, with both tests significant at the 5% level. This indicates that domestic investment is integrating at order I (0). Odhiambo (2009) finds that domestic investment in sub-Saharan African countries often exhibits stationary behaviour at first difference. On the contrary, Alfaro et al. (2004) note that domestic investment data tend to stabilise without differencing for developed economies.

The R&D outcomes in Table 5.1 show a mixed result. The ADF test suggests weak stationarity at the 10% level, while the PP test indicates non-stationarity at levels but stationarity after first differencing. Therefore, R&D is considered I(1) based on the more robust PP results. These results are in line with Coe and Helpman (1995) who reported that R&D was weakly stationary depending on the data frequency and country. However, Wang and Tsai (2003) observed that R&D indicators often require first differencing to achieve stationarity, particularly in developing countries.

5.3. Bounds Test (Cointegration) results

The bounds test is used to determine the existence of a long-run relationship among the variables in the energy growth model. The model includes GDP as a function of electricity supply (ELS), electricity prices (ELP), labour participation (LLP), total domestic investment (INV), and Research and Development (R&D). The test results are:

Table 5.2: Bounds Test

Model $GDP = F\ (ELS, ELP, LAB, INV, and\ RandD)$	Calculated F-statistics 12.64		Conclusion
Critical values	Lower bounds	Upper bounds	
10	2.08	3	Cointegration
5	2.39	3.38	Cointegration

2,5	2.7	3.73	Cointegration
1	3.06	4.15	Cointegration

Source: Author's computation

Table 5.2 shows that the calculated F-statistic of 12.64 is significantly higher than the upper bound critical values at all significance levels (10%, 5%, 2.5%, and 1%). The study then concludes that there is a long-run cointegration relationship among GDP, electricity supply, electricity prices, labour force participation, total investment, and R&D. This implies variables move together in the long run, confirming their interdependence and long-term equilibrium relationship. Furthermore, the cointegration results support the validity of the energy consumption model adopted in explaining the long-term relationships between electricity prices and supply and GDP.

5.4 Short Run and ECM ARDL Estimates

The cointegration term, represented by the coefficient of -1.750953, signifies the speed at which the system adjusts to the long-run equilibrium following a shock. A negative and statistically significant coefficient indicates a rapid adjustment process, with deviations from the long-run equilibrium corrected at 175.09% per period. This implies not only strong adjustment but also a potential overshooting effect, where the system may overcorrect before stabilising at the equilibrium. This rapid correction suggests that short-term imbalances in economic factors such as energy supply and investment are quickly mitigated, allowing the economy to revert to its long-term path.

These findings are consistent with Ouedraogo (2013) who observed a similarly strong adjustment in the context of energy consumption and economic growth, where significant deviations were quickly corrected. Likewise, Rafindadi and Ozturk (2017) documented rapid cointegration adjustments in their energy-growth models, emphasising the critical role of energy infrastructure in stabilising long-term economic performance. The current results align with these studies, reinforcing the view that electricity supply and electricity prices exhibit strong long-run relationships with economic growth, and the economy adjusts swiftly to restore equilibrium following shocks to these variables.

Table 5.3 Short run and ECM results

Variable	Coefficient	Standard Error	T-Statistic	Probability
SHORT RUN ESTIMATES				
COINTEQ (-1)	-1.750953	0.155708	-11.24511	0.0000
D(INV)	0.155990	0.023745	6.569310	0.0000
D(L)	0.187675	0.107399	1.747447	0.1024
D(LELS)	122.9361	14.497	8.479975	0.0000
D(ELP)	-0.129324	0.027068	-4.777674	0.0003
D(LR&D)	-7.996496	0.155708	-11.24511	0.1350

Source: Author’s computation

The implication of the values of coefficients in Table 5.3 are as follows

- D(INV) Investment

The coefficient for investment is positive and statistically significant at a 1% significance level. This implies that a 1% increase in investment leads to approximately a 0.156% increase in economic growth in the short run, showing a strong positive short-run impact of investment on economic growth. The findings are in line with the prior expectation and the Energy consumption model. Furthermore, the results corroborate the observations made by Nguyen, (2021) who found that domestic investment positively influences economic growth in Vietnam.

- D(L) Labour

The positive coefficient for labour indicates that an increase in labour contributes positively to economic growth. However, this effect is not statistically significant at conventional levels, suggesting that the relationship between labour and growth is weak or uncertain in the short run. These findings are consistent with Maestas, Mullen, and Powell (2023), where labour had a negative short-run impact on growth, though their coefficient was also statistically insignificant. Both studies suggest that labour's influence on economic growth is not robust in the short run, regardless of the direction of the coefficient.

- D(LELS) Electricity Supply

The electricity supply coefficient is highly significant with a large positive impact. A 1% increase in electricity supply results in a 122.94% increase in economic growth in the short run. This underscores the critical role of electricity supply in promoting economic output. The results are in line with the findings of Cai, Sam, and Chang, (2018) that the is a strong correlation between electricity supply and economic growth in the short run.

- D(ELP) Electricity Prices

Electricity prices have a negative and significant effect on the economy. A 1% increase in electricity prices leads to a 0.129% decrease in economic growth. This is consistent with the idea that higher electricity costs reduce production efficiency and economic activity in the short run. The finding of this study suggests that higher electricity prices lower production efficiency in South Africa, constraining economic activity in the short run. The results are in line with Mazambani (2015) who found a negative short run relationship between electricity prices and economic growth in South Africa.

- D(LR&D) Research and Development

The R&D coefficient is negative but not statistically significant. This suggests that in the short run, R&D does not have a significant impact on economic growth, although the negative sign could indicate initial costs or lagged effects associated with R&D investment. Cohen and Levinthal (1990) and Hall, Mairesse, and Mohnen (2010), suggest that R&D investments often face a lag before their positive effects materialise due to the time required for innovations to be developed and commercialised.

5.5 Long run results (Energy Consumption Model)

Table 5. 4: Long run results

Variable	Coefficient	Standard Error	T-Statistic	Probability
LONG-RUN ESTIMATES				

INV	0.202054	0.050713	3.984303	0.0018
L	-0.608184	0.179132	-3.395170	0.0053
LELS	15.65986	9.738751	1.607995	0.1338
ELP	0.000605	0.011984	0.05519	0.0800
LR&D	9.411654	4.920686	1.912671	0.0365

Source: Author's compilation from E-Views

The implication of the values of coefficients in Table 5.4 are as follows,

- Investment (INV)

The ARDL long run estimates show that investment has a positive and statistically significant impact on economic growth. A 1% increase in investment leads to approximately a 0.202% increase in economic growth. This suggests that capital accumulation continues to play a vital role in fostering long-term economic growth in South Africa. Investment is closely tied to energy availability and costs. If energy is abundant and affordable, capital investments are more likely to be productive, as machines, factories, and infrastructure depend on reliable electricity. In the long run, positive and statistically significant investment reflects the role of energy in supporting capital productivity. A stable energy supply ensures that investment leads to sustained economic growth by enabling the efficient use of capital.

- Labour (L)

Interestingly, the coefficient for labour is negative and statistically significant at a 1% significance level. A 1% increase in labour results in a 0.608% decrease in economic growth in the long run. This counterintuitive result might suggest diminishing returns to labour or inefficiencies in labour utilisation in the long term, possibly due to structural issues like overpopulation in labour-intensive industries, low productivity, or skill mismatches. If energy costs are high or supply is unreliable, labour productivity can suffer, particularly in energy-dependent sectors. In South Africa, where industries may rely heavily on manual labour combined with energy-intensive processes, energy shortages or high electricity prices could reduce the efficiency of labour over time, leading to a negative impact on growth. The result may indicate inefficiencies in labour allocation when energy resources are insufficient or poorly managed.

- Electricity Supply (LELS)

In the long run, electricity supply has a positive impact on economic growth, but the result is not statistically significant at all conventional levels. While the magnitude of the coefficient suggests that electricity supply is important, the lack of significance could be due to other long-run factors at play, or inefficiencies in how electricity is used in the economy. Electricity supply is a direct component of the Energy Consumption Theory, which emphasizes the crucial role of energy availability in economic productivity. While the coefficient for electricity supply is positive, it is not statistically significant. This could suggest that, although increased electricity supply is expected to boost economic growth by enabling more production and services, other factors such as energy efficiency, infrastructure quality, and grid reliability might dilute the overall impact in the long run. In energy-intensive economies, reliable and efficient energy infrastructure is essential for sustained economic growth, as it powers industries, homes, and public services. However, issues like load shedding or inconsistent supply could weaken the positive relationship between electricity supply and long-term growth.

- Electricity Prices (ELP)

Electricity prices appear to have a small positive coefficient in the long run, but the impact is statistically insignificant. The small size of the coefficient indicates that changes in electricity prices might not have a substantial long-term effect on economic growth, perhaps because price adjustments are absorbed over time. According to the Energy Consumption Theory, higher energy costs which are high electricity prices can discourage economic activity by increasing the cost of production for businesses and reducing disposable income for households. The small, positive coefficient for electricity prices suggests that in the long run, price changes may not have a strong or immediate effect on economic growth. This may be because, over time, economies and industries adapt to higher energy costs through improved energy efficiency, technology upgrades, or shifting towards alternative energy sources. The nonsignificance of electricity prices in the long run, could indicate that industries have developed resilience to fluctuations in energy prices, possibly by diversifying their energy sources or investing in energy-saving technologies.

- Research and Development (LR&D)

R&D has a large positive coefficient and is statistically significant in the long run. A 1% increase in R&D spending leads to a 9.41% increase in economic growth, indicating that innovation and technological advancements play a crucial role in boosting long-term economic growth. R&D plays a crucial role in enhancing energy efficiency and developing new technologies that reduce energy consumption, as highlighted by the Energy Consumption Theory. Over the long run, investment in R&D can lead to innovations such as renewable energy technologies, more efficient production processes, and cost-saving measures that mitigate the impact of energy price fluctuations. The strong positive coefficient for R&D in the long run, indicates that technological advancements driven by research efforts can significantly boost economic growth by making energy use more efficient and sustainable. For instance, breakthroughs in energy-efficient technologies or renewable energy solutions can lower production costs, reduce reliance on fossil fuels, and stimulate long-term economic development.

5.6 Diagnostic test results and stability test results

5.6.1 Diagnostic test results

The diagnostic tests for assessing the stability of the model include the normality test, which evaluates the residuals using key statistical measures such as the Jarque-Bera test, kurtosis, and skewness. These tests examine whether the residuals follow a normal distribution, which is crucial for ensuring the reliability of the model.

Table 5.5: Diagnostic tests

Testing procedure	Null hypothesis	T-statistic	Prob.	Conclusion
Jarque-Bera Normality test	H_O: Residuals are normally distributed. Reject H_0 if *p*-value ≤ level of significance.	Kurtosis= 3.091138 JB=0.048948	0.975823	Residuals are normally distributed

Breusch-Godfrey Serial Correlation LM test	H_0 : No autocorrelation up to order p. Reject H_0 if p-value ≤ level of Significance.	nR^2(2)= 0.348515	0.8455	There is no serial correlation in the model
Breusch-Pagan Godfrey heteroscedasticity test	H_O: No autoregressive conditional heteroscedasticity up to order q. Reject H_O if p-value ≤ level of significance.	$nR^2 =$ 9.703161	0.7835	No heteroscedasticity was detected in the model
ARCH test	H_O: No autoregressive conditional heteroscedasticity up to order q. Reject H_O if $p$value ≤ level of significance.	nR^2= 0.045097	0.8318	No heteroscedasticity was detected in the model
Ramsey Reset	H_0 = no misspecification H_1 : misspecification of the form Reject H_0 if p- value ≤ level of significance.	Likelihood ratio=0.276866	0.5988	No Misspecification was detected in the model
LJung-Box Q Test (correlogram Q statistics)	H_O: No Autocorrelation Up to Order K Reject H_0 p-value ≤ level of significance.	$LR_Q = 14.452$ For 12 lags	0.273	No serial correlation was detected in the model

Source: Author's computation

Jarque-Bera Normality Test evaluates whether the residuals of a model follow a normal distribution. The null hypothesis (H_0) assumes that residuals are normally distributed. The Jarque-Bera test statistic is based on the skewness and kurtosis of the data. If the p-value is greater than all conventional significance levels, we fail to reject the null hypothesis, indicating that the residuals are normally distributed. In this case, with a p-value of 0.9758, the residuals are normally distributed, implying no violation of the normality assumption, essential for valid inference in many statistical models (Bera and Jarque, 1981).

Breusch-Godfrey Serial Correlation LM test checks for serial correlation in the residuals of a regression model. The null hypothesis is that there is no autocorrelation up to a certain order (p). If the p-value is greater than the significance level, we do not reject indicating no autocorrelation in the model. The test result probability value of 0.8455 suggests no serial correlation in the model, which is important as autocorrelation can bias standard errors and lead to incorrect inferences (Breusch,1978).

Breusch-Pagan-Godfrey Heteroscedasticity test checks for heteroscedasticity, which refers to the non-constant variance of residuals. The null hypothesis assumes no heteroscedasticity. A p-value greater than the significance level indicates that heteroscedasticity is not present. With a p-value of 0.7835, the test results suggest that the model does not suffer from heteroscedasticity, meaning the variance of the residuals is constant (Breusch and Pagan, 1979).

The Autoregressive Conditional Heteroscedasticity (ARCH Test) test detects time-varying volatility or conditional heteroscedasticity in residuals. The null hypothesis assumes no ARCH effects. A high p-value means no evidence of ARCH effects, which would otherwise suggest varying volatility over time. With a p-value of 0.8318, the ARCH test indicates no evidence of time-varying volatility in the residuals, confirming that the model does not have ARCH effects (Engle, 1982).

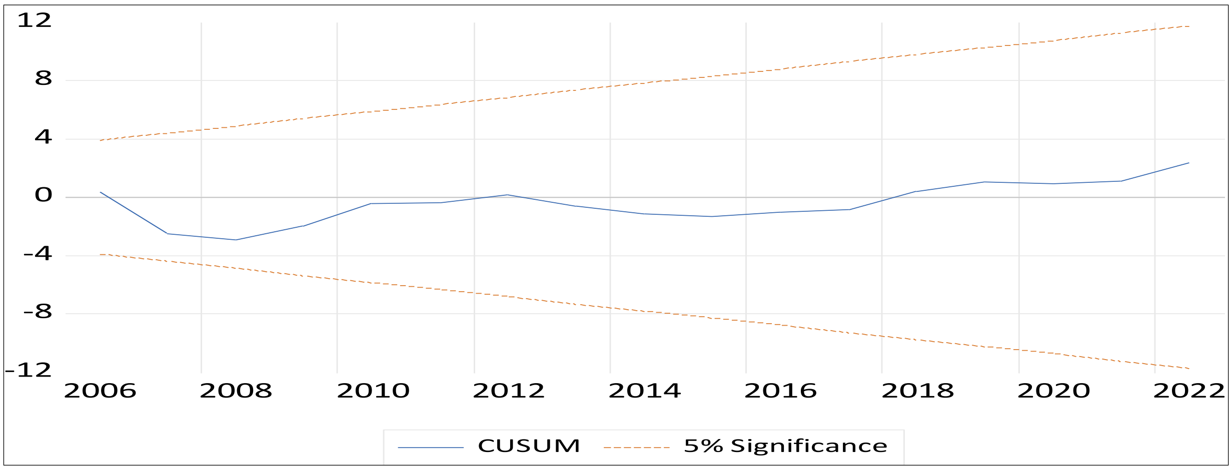
The Ramsey Regression Equation Specification Error Test (RESET) detects model misspecification, such as omitted variables or incorrect functional form. The null hypothesis assumes no specification error. A high p-value suggests that the model is correctly specified. The p-value of 0.5988 indicates that no specification error is detected in the model, confirming that it is well-specified and that no important variables are omitted (Ramsey, 1969).

The Ljung-Box Q test checks for autocorrelation up to a specified lag. The null hypothesis assumes no autocorrelation. A high p-value means the residuals are not autocorrelated, which is crucial for validating the model's reliability. A p-value of 0.273 for 12 lags suggests no autocorrelation in the residuals, supporting the reliability of the model's forecasts (Ljung, and Box, 1978). Detailed results of these tests, as well as graphical representations, are in Appendix [D, F and G].

5.6.2 Stability test results

The stability of the model was assessed using the CUSUM and CUSUMsq tests, which were used to determine whether there have been any structural changes in the model's long-run and short-run parameters. The CUSUM and CUSUMSq test results are presented in Figures 5.7 and 5.78 as follows.

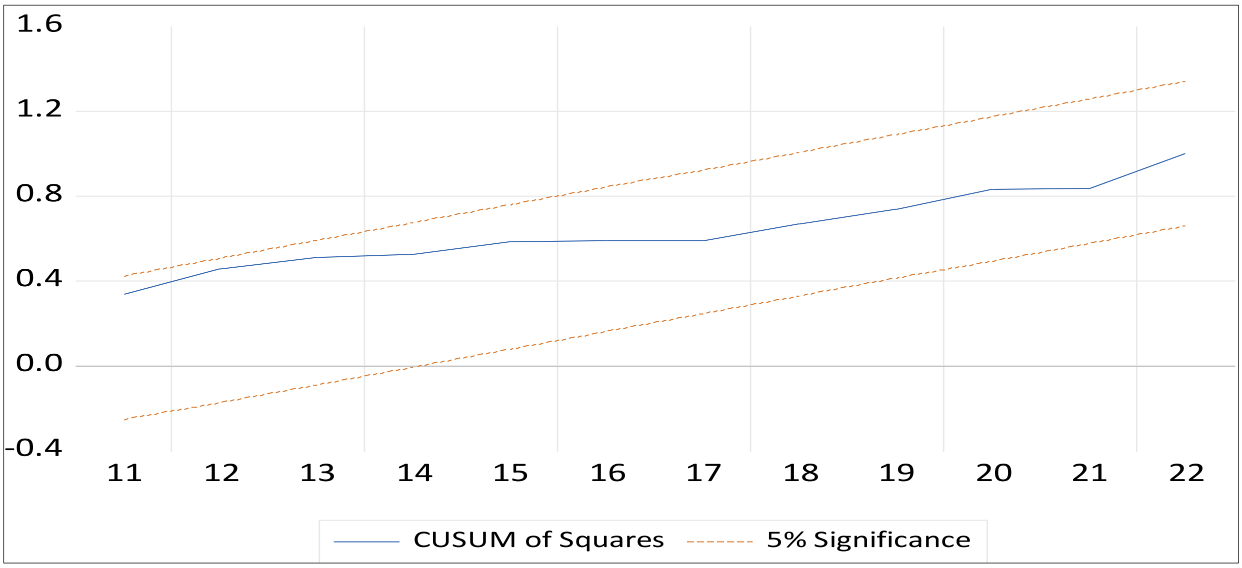
FIGURE 5.7 CUSUM (Cumulative Sum of Recursive Residuals) test results



Source: Source: Author's computation

The CUSUM test shows that the model remains stable throughout the observation period. This suggests that the relationship between electricity supply, electricity prices, and economic growth is consistent and that there have not been significant changes in the dynamics over the period analysed. Karanfil and Li (2015) used the CUSUM test to check for stability in their model assessing the relationship between electricity consumption and GDP growth in emerging markets. Furthermore,

Figure 5.8 CUSUM of squares test results



Source: Author'scomputation

The CUSUM of Squares line remains within the critical bounds throughout the observation period, suggesting that the variance of the model's residuals has not changed significantly. This indicates that the model is robust and stable over time. Lean and Smyth (2010) employed both CUSUM and CUSUMQ tests in their analysis of energy consumption and economic growth in ASEAN countries.

5.7 Granger Causality Test Results

Granger causality test is used to predict the future values of one variable on another in forecasting their correlations. The results of the Granger causality test are presented in Table 5.6, which shows the relationship between the variables below.

Table 5.6: Granger causality test results

Null hypothesis	Obs	F-statistics	P-value	Conclusion
INV does not Granger Cause GDP	27	0.65127	0.5311	No Causality
GDP does not Granger Cause INV	27	2.98134	0.0715	Causality
L does not Granger Cause GDP	27	3.39720	0.0518	Causality
GDP does not Granger Cause L	27	1.26635	0.3016	No Causality
LELS does not Granger Cause GDP	27	0.91849	0.4139	No Causality
GDP does not Granger Cause LELS	27	1.16916	0.3292	No Causality

ELP does not Granger Cause GDP	27	3.85890	0.0366	Causality
GDP does not Granger Cause ELP	27	0.02369	0.9766	No causality
R&D does not Granger Cause GDP	27	8.05737	0.0024	Causality
GDP does not Granger Cause R&D	27	3.03870	0.0683	Causality

Source: Author's computations

The outcomes of each variable in Table 5.6 are discussed in detail as follows:

- Electricity Supply and Economic Growth

Neither electricity supply Granger causes economic growth, nor does economic growth Granger cause electricity supply. Apergis and Payne (2010) and Lean and Smyth (2010) suggest that in constrained energy systems like South Africa, the mutual causality between electricity supply and growth is often weak in the short term.

- Electricity Prices and Economic Growth

Electricity prices Granger causes economic growth, but economic growth does not Granger cause electricity prices. Inglesi-Lotz (2011) found that electricity prices significantly affect South Africa's production costs and industrial activity, influencing economic growth.

- Investment and Economic Growth

The results in Table 5.6 investment does not Granger cause economic growth. However, economic growth weakly Granger causes investment, significant at the 10% level. Levine and Renelt (1992) and Odhiambo (2009) suggest that in developing economies economic growth often leads to higher investment rather than the reverse.

- Labour Force Participation and Economic Growth

Labour Granger causes economic growth, close to the 5% significance level. However, economic growth does not Granger cause labour. Arestis and Demetriades (1997) and Fedderke and Bogetic (2009) argue that labour inputs play a crucial role in driving economic growth in emerging economies, though the reverse relationship is often weak.

- R&D and Economic Growth

Finally, R&D strongly Granger causes economic growth, while economic growth weakly Granger causes R&D. Coe and Helpman (1995) and Wang and Tsai (2003) highlight that R&D investments enhance innovation and productivity, driving economic growth. However, economic growth also weakly stimulates R&D in developing countries.

5.8 Summary

This chapter examined the relationship between electricity prices, electricity supply, and economic growth in South Africa from 1996 to 2022 by advanced econometric methods. Unit root tests revealed a mix of I(0) and I(1) variables, while the bounds test confirmed a long-run cointegration among the key variables. Long-run estimates highlighted the significant impact of electricity prices on economic growth, while short-run dynamics demonstrated an overshooting adjustment to equilibrium. Granger causality tests indicated that electricity prices predict economic growth, but electricity supply and economic growth lack a bidirectional relationship. Diagnostic and stability tests validated the robustness and consistency of the model. The findings emphasize the critical role of energy affordability and reliability in driving economic growth, providing essential insights for policymakers in addressing South Africa’s electricity challenges.

CHAPTER 6

SUMMARY, RECOMMENDATIONS, LIMITATIONS, AND CONCLUSION

6.1 Introduction

This chapter provides a summary of the most important results from the empirical analysis and offers some conclusions based on the findings. Specifically, Section 6.2 summarizes the study's aims and objectives, theoretical literature, and methodology and further summarises the findings of the empirical investigation. Section 6.3 highlights the study's contributions, policy implications, and recommendations. Finally, Section 6.4 presents the limitations and suggests further research.

6.2 Summary and interpretation of findings

The study determined the effects of electricity prices and electricity supply on the economic growth of South Africa. To achieve this stipulated aim, the study formulated three objectives. The first objective analysed the effects of electricity prices on economic growth. The second objective determined the relationship between electricity supply and economic growth, and the third examined the causal relationship between prices and the supply of electricity on economic growth in South Africa.

Chapter 2 presented an overview of South Africa's electricity supply, encompassing the structure of the electricity sector and the primary sources of electricity generation. Furthermore, it emphasised the trend of electricity prices outpacing inflation in recent years. Chapter 3 provided a comprehensive review of both theoretical and empirical literature relevant to the study. The energy consumption theory was adopted as a conceptual framework to clarify the relationship between electricity prices, electricity supply, and economic growth. Furthermore, the empirical literature review in Chapter 3 informed the selection of appropriate variables for the analysis.

In Chapter 4, various econometric techniques were employed to analyse the effects of electricity prices and supply on economic growth. The study adopted the Autoregressive Distributed Lag (ARDL) technique as the primary method, given its suitability for time series data that integrate at different orders, provided no variable is integrated at the second order, I (2). The ADF and PP tests were conducted to confirm that all variables were either stationary at levels I (0) or first-differenced I (1). Following the unit root testing, the ARDL bounds testing approach was applied to examine the existence of a long-run relationship between electricity prices, electricity supply, and economic growth. To gain deeper insights into these relationships, the ARDL framework was utilised to estimate both long-run and short-run dynamics, including the error correction term, to capture the adjustment process toward equilibrium. The Granger causality test was employed to identify the directional relationships among electricity prices, electricity supply, and economic growth.

Chapter 5 employed the two widely recognised tests to detect unit roots in the times series. The ADF and PP test showed that all economic growth and investment are integrated at order I (0) while research and development showed mixed results. However, the ADF and PP tests showed electricity prices, electricity supply, and labour participation are integrated at I (1). For the energy consumption model, the empirical investigation adopted a bounds test for cointegration to examine the long-run relationship. The result of the cointegration is presented in Table 5.2. The null hypothesis of no cointegration in the energy consumption model was rejected as the bounds test stressed the existence of long-run relationships among the variables.

Chapter 5 presented the short-run estimates which corroborated several key relationships outlined in the energy consumption framework. The error correction model (ECM) coefficient for the energy-growth model is -1.74, indicating a negative and statistically significant value. This suggests a rapid adjustment process toward equilibrium following short-term shocks. The short-run results reveal that investment and electricity prices are positively associated with economic growth within the energy-growth framework. However, labour force participation and R&D were statistically insignificant in the short run. Additionally, the analysis showed that electricity supply has a negative relationship with economic growth in the short run, with this relationship being statistically significant at the 1% level.

The ARDL long-run results of the energy consumption theory are presented in Table 5.4. The estimates revealed several critical relationships within the framework of the energy consumption theory. The empirical findings demonstrate that investment plays a significant role in enhancing economic growth within the energy-growth model. In contrast, labour force participation exhibits a negative and statistically significant relationship with economic growth in the long run. Electricity supply, while positively associated with economic growth, was statistically insignificant. However, electricity prices and R&D were confirmed to have a significant and positive long-run relationship with economic growth underscoring their importance in the energy economics context.

6.3 Contribution of the Study

This study makes a significant contribution to the literature on developing economies by empirically analysing the impact of electricity prices and supply on South Africa's economic growth. By incorporating key factors such as labour force participation and R&D into the analysis offered valuable insights into the dynamic relationship between energy variables and economic growth. These findings provide a broader understanding of the economic implications of energy market dynamics, offering valuable policy guidance for fostering sustainable growth in a similar developing country.

6.3.1 Methodological Contribution

The empirical analysis employed the ARDL bounds testing approach, which is well-suited for analysing time-series data with mixed integration orders of I(0) and I(1) but not I(2). This methodology is significant for South Africa's context, where the variables in the energy-growth nexus exhibit diverse integration properties. Furthermore, Granger causality applications to examine directional relationships among key variables introduced a cover of understanding often overlooked in economic regressions. Thus, it allowed the analysis to address not only correlations but also causal dynamics.

6.3.2 Theoretical contribution

This study contributes to the theoretical literature by contextualising the Energy Consumption Theory within South Africa's unique socio-economic and policy environment. It advances the understanding of the dynamic relationship between electricity prices, electricity supply, and economic growth under conditions characterised by energy market distortions, including price elasticity challenges and supply-side inefficiencies. The study introduces a novel augmentation to the traditional Energy-Growth Nexus by integrating investment and R&D as endogenous factors driving economic expansion within the energy consumption model. This refined framework emphasises the essential role of capital deepening and technological innovation in enhancing total factor productivity and mitigating energy intensity, thereby promoting long-run growth convergence.

6.3.3 Empirical Contribution

This contributes empirical evidence on the relationship between electricity prices, electricity supply, and economic growth in South Africa, a country with unique energy challenges such as load-shedding and price volatility. These insights are valuable for policymakers navigating the balance between energy affordability, supply stability, and economic growth. The ARDL results differentiate between short-run and long-run effects, showing that electricity prices positively impact economic growth in both periods, while the electricity supply's impact is negative in the short run but statistically insignificant in the long run. The negative and statistically significant relationship between labour force participation and economic growth presents a paradox that could prompt further investigations into structural inefficiencies in South Africa's labour market. The study’s results empirically validate key aspects of the energy consumption theory while revealing developing country-specific variations, thus contributing to the global literature on energy economics.

6.4 Policy Recommendation

The key policy recommendation is to prioritise investments in R&D and capital formation to stimulate long-term economic growth, as these factors demonstrated a significant positive impact. Policymakers should implement strategies to stabilise electricity prices, as their positive association with economic growth suggests that predictable pricing encourages productive economic activity. Additionally, addressing the short-run negative impact of electricity supply on growth requires targeted measures to enhance supply efficiency, reduce transmission losses, and improve energy infrastructure reliability. These actions should be complemented by structural labour market reforms to address its inefficiencies linked to the negative long-term impact of labour force participation in economic growth.

6.5 Limitations of the study

This empirical scrutiny is not without some limitations. The study relied on time series data that may not fully capture recent structural changes or policy shifts in South Africa's energy sector, potentially affecting the findings. While the Granger causality tests establish directional relationships, they do not fully account for potential endogeneity issues or simultaneous causation between electricity variables and economic growth. Furthermore, the results and policy recommendations are tailored to South Africa's unique economic and energy context, which may limit their applicability to other economies with different energy market structures or economic conditions.

6.6 Future studies

Future studies could focus on the following areas to expand on the findings and address the limitations of this study.

- They could Investigate the impact of incorporating renewable energy sources into South Africa's energy mix on economic growth, electricity prices, and supply stability.
- Explore the structural inefficiencies in South Africa's labour market that contribute to the negative long-run relationship between labour force participation and economic growth and assess policies for improving labour productivity.
- Conduct sector specific analyses to understand how electricity prices and supply affect different industries, particularly energy intensive sectors like manufacturing and mining.

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APPENDICES

LIST OF APPENDICES

APPENDIX A: Stationarity test results

Economic growth

Null Hypothesis: GDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.900183430624239	0.00247802901791334
Test critical values:	1% level	-4.30982392298219	
	5% level	-3.574244087073583	
	10% level	-3.221727985418371	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDP)
Method: Least Squares
Date: 11/25/24 Time: 14:04
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	-0.9356035634542776	0.1909323552271778	-4.900183430624239	4.373315939012951e-05
C	3.852317892192728	1.117477230203969	3.447334574763172	0.001938545593812352
@TREND("1993")	-0.1057053214776367	0.05214159528830785	-2.027274403346458	0.05300119276958149

R-squared	0.4807543337290636	Mean dependent var	0.02333959416322452
Adjusted R-squared	0.4408123594005301	S.D. dependent var	2.922539018143918
S.E. of regression	2.185441068309845	Akaike info criterion	4.499209666374249
Sum squared resid	124.1799692394372	Schwarz criterion	4.640654062579746
Log likelihood	-62.23854016242661	Hannan-Quinn criter.	4.543508286632148

F-statistic	12.0363187 3013409	Durbin-Watson stat	2.0096839 22066284
Prob(F-statistic)	0.00019945 6156818669 3		

Electricity Supply

Null Hypothesis: LELS has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		- 0.659728197 2754268	0.9669088 179315744
Test critical values:	1% level	- 4.309823922 98219	
	5% level	- 3.574244087 073583	
	10% level	- 3.221727985 418371	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LELS)
Method: Least Squares
Date: 11/25/24 Time: 14:23
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LELS(-1)	- 0.03821079 292584241	0.057918993 13027236	- 0.659728197 2754268	0.5152302 30362947
C	0.21839516 47894983	0.304196999 822002	0.717939903 803424	0.4791962 266070676
@TREND("1993")	- 0.00069236 3018239607 1	0.000359127 1384683421	- 1.927905034 391158	0.0648566 286655666 2

R-squared	0.40625233 94025656	Mean dependent var	0.0044688 628037207 45
Adjusted R-squared	0.36057944 24335321	S.D. dependent var	0.0119504 540007800 3
S.E. of regression	0.00955603 4345496216	Akaike info criterion	- 6.3655905 84623682
Sum squared resid	0.00237426 2602719885	Schwarz criterion	- 6.2241461 88418185

Log likelihood	95.3010634 7704339	Hannan-Quinn criter.	- 6.3212919 64365782
F-statistic	8.89482310 8724808	Durbin-Watson stat	2.2471505 7801391
Prob(F-statistic)	0.00113979 0018389056		

ELECTRICITY SUPPLY

Null Hypothesis: LELS has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		- 0.4232111449 55087	0.9816168 887100396
Test critical values:	1% level	- 4.309823922 98219	
	5% level	- 3.574244087 073583	
	10% level	- 3.221727985 418371	

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

Residual variance (no correction)	8.18711242 3172015e- 05
HAC corrected variance (Bartlett kernel)	4.6940664 48126897e -05

Phillips-Perron Test Equation
Dependent Variable: D(LELS)
Method: Least Squares
Date: 11/25/24 Time: 14:21
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LELS(-1)	- 0.03821079 292584241	0.057918993 13027236	- 0.659728197 2754268	0.5152302 30362947
C	0.21839516 47894983	0.304196999 822002	0.717939903 803424	0.4791962 266070676
@TREND("1993")	- 0.00069236 3018239607 1	0.000359127 1384683421	- 1.927905034 391158	0.0648566 286655666 2

R-squared	0.40625233 94025656	Mean dependent var	0.0044688 628037207 45

Adjusted R-squared	0.3605794424335321	S.D. dependent var	0.01195045400078003
S.E. of regression	0.009556034345496216	Akaike info criterion	-6.365590584623682
Sum squared resid	0.002374262602719885	Schwarz criterion	-6.224146188418185
Log likelihood	95.30106347704339	Hannan-Quinn criter.	-6.321291964365782
F-statistic	8.894823108724808	Durbin-Watson stat	2.24715057801391
Prob(F-statistic)	0.001139790018389056		

ELECTRICITY SUPPLY

Null Hypothesis: D(LELS) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.8864276535567	0.000270217172121391
Test critical values:	1% level	-4.3393297970068	
	5% level	-3.58752689806892	
	10% level	-3.229230337731463	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LELS,2)
Method: Least Squares
Date: 11/25/24 Time: 14:24
Sample (adjusted): 1996 2022
Included observations: 27 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LELS(-1))	-1.695757980729901	0.2880793038720673	-5.8864276535567	5.329410601756991e-06
D(LELS(-1),2)	0.4856189989000487	0.198587821279987	2.445361431380927	0.02254332000942785
C	0.03239734751823405	0.006891136937833276	4.701306592874134	9.799821718653302e-05
@TREND("1993")	-0.001580574828339988	0.0003470188203987374	-4.554723650215426	0.0001412187187300647

R-squared	0.6638975236638729	Mean dependent var	-0.0009218686564136132
Adjusted R-squared	0.6200580702287259	S.D. dependent var	0.01458175798231952
S.E. of regression	0.008988112465233574	Akaike info criterion	-6.449874111202565
Sum squared resid	0.001858081810816804	Schwarz criterion	-6.257898279201924
Log likelihood	91.07330050123462	Hannan-Quinn criter.	-6.392789632303362
F-statistic	15.14383669600252	Durbin-Watson stat	1.828591735843646

ELECTRICITY PRICE

Null Hypothesis: ELP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.4286986872334076	0.9811359406706776
Test critical values:	1% level	-4.323979170705911	
	5% level	-3.580622499099694	
	10% level	-3.225333567134217	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ELP)
Method: Least Squares
Date: 11/25/24 Time: 14:36
Sample (adjusted): 1995 2022
Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ELP(-1)	-0.01401399230721875	0.03268960863318144	-0.4286986872334076	0.6719658458717455
D(ELP(-1))	0.4417995980110473	0.1871000448433838	2.361301400974358	0.02666930834272648
C	-1.201176923725421	1.054713444823016	-1.138865660261856	0.2659996801739418

@TREND("1993")	0.2635058452556223	0.1322547004771574	1.992411946833861	0.05781817642521038

R-squared	0.7166471175253479	Mean dependent var	3.927142857142858
Adjusted R-squared	0.6812280072160164	S.D. dependent var	3.776911198460747
S.E. of regression	2.132440158581438	Akaike info criterion	4.483974549023249
Sum squared resid	109.1352247183399	Schwarz criterion	4.674289479048278
Log likelihood	-58.77564368632549	Hannan-Quinn criter.	4.54215572045887
F-statistic	20.2333461023311	Durbin-Watson stat	1.874207561786907
Prob(F-statistic)	9.274753793268778e-07		

ELECTRICITY PRICES

Null Hypothesis: ELP has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		0.02148122269928354	0.99458651850787
Test critical values:	1% level	-4.30982392298219	
	5% level	-3.574244087073583	
	10% level	-3.221727985418371	

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

Residual variance (no correction)	4.697885391167847
HAC corrected variance (Bartlett kernel)	7.373937107051228

Phillips-Perron Test Equation
Dependent Variable: D(ELP)
Method: Least Squares
Date: 11/25/24 Time: 14:32
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ELP(-1)	0.009146676299403452	0.03252121316960294	0.2812526166137217	0.7807428941566501

C	- 1.47189658 8294623	0.981199088 527444	- 1.500099832 444406	0.1456350 003947364
@TREND("1993")	0.32794504 46309043	0.123473005 2007951	2.656006016 032341	0.0133280 954935671 9

R-squared	0.65867894 34705342	Mean dependent var	3.7958620 68965516
Adjusted R-squared	0.63242347 75836522	S.D. dependent var	3.7756319 4071193
S.E. of regression	2.28909350 838902	Akaike info criterion	4.5918861 08833778
Sum squared resid	136.238676 3438675	Schwarz criterion	4.7333305 05039276
Log likelihood	- 63.5823485 7808979	Hannan-Quinn criter.	4.6361847 29091677
F-statistic	25.0873073 9375796	Durbin-Watson stat	1.1518148 60182305
Prob(F-statistic)	8.53335978 2329531e- 07		

ELECTRICITY PRICES

Null Hypothesis: D(ELP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		- 3.907967380 262106	0.0326443 520456101
Test critical values:	1% level	- 4.323979170 705911	
	5% level	- 3.580622499 099694	
	10% level	- 3.225333567 134217	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ELP,2)
Method: Least Squares
Date: 11/25/24 Time: 14:34
Sample (adjusted): 1995 2022
Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

D(ELP(-1))	-0.5758546906467699	0.1795076515396861	-3.207967380262106	0.003644091829340177
C	-0.9963247198710442	0.9247804767472172	-1.077363487792772	0.2916045085747936
@TREND("1993")	0.2190341715268394	0.08068661675609805	2.714628278304723	0.01184970024704563

R-squared	0.293134331850416	Mean dependent var	0.3235714285714283
Adjusted R-squared	0.2365850783984491	S.D. dependent var	2.400427761702781
S.E. of regression	2.097340595734335	Akaike info criterion	4.42017441379841
Sum squared resid	109.9709393628814	Schwarz criterion	4.562910611317181
Log likelihood	-58.88244179317772	Hannan-Quinn criter.	4.463810292375124
F-statistic	5.183699411689069	Durbin-Watson stat	1.857120083621695
Prob(F-statistic)	0.01308311355449674		

ELECTRICITY PRICES

Null Hypothesis: D(ELP) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.972444583064133	0.0702362039995556
Test critical values:	1% level	-4.323979170705911	
	5% level	-3.580622499099694	
	10% level	-3.225333567134217	

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

Residual variance (no correction)	3.927533548674335
HAC corrected variance (Bartlett kernel)	3.746273058890639

Phillips-Perron Test Equation
Dependent Variable: D(ELP,2)
Method: Least Squares
Date: 11/25/24 Time: 14:37
Sample (adjusted): 1995 2022

Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ELP(-1))	-0.5758546906467699	0.1795076515396861	-3.207967380262106	0.003644091829340177
C	-0.9963247198710442	0.9247804767472172	-1.077363487792772	0.2916045085747936
@TREND("1993")	0.2190341715268394	0.08068661675609805	2.714628278304723	0.01184970024704563

R-squared	0.293134331850416	Mean dependent var	0.3235714285714283
Adjusted R-squared	0.2365850783984491	S.D. dependent var	2.400427761702781
S.E. of regression	2.097340595734335	Akaike info criterion	4.42017441379841
Sum squared resid	109.9709393628814	Schwarz criterion	4.562910611317181
Log likelihood	-58.88244179317772	Hannan-Quinn criter.	4.463810292375124
F-statistic	5.183699411689069	Durbin-Watson stat	1.857120083621695
Prob(F-statistic)	0.01308311355449674		

LABOUR FORCES PARTICIPATION

Null Hypothesis: LLP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.815711895566068	0.2032686493064593
Test critical values:	1% level	-4.30982392298219	
	5% level	-3.574244087073583	
	10% level	-3.221727985418371	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LLP)
Method: Least Squares
Date: 11/25/24 Time: 14:57
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

LLP(-1)	-0.4163630891296205	0.1478713393175175	-2.815711895566068	0.009161346973444212
C	0.720198855231812	0.2563707489936748	2.809208375209688	0.009303790916837176
@TREND("1993")	0.0006085101199556241	0.0002937980502846428	2.071185017620356	0.0484028280593574

R-squared	0.2396863118161465	Mean dependent var	0.0002726395496618459
Adjusted R-squared	0.1812006434943115	S.D. dependent var	0.01184713775676784
S.E. of regression	0.01072018264572749	Akaike info criterion	-6.135679845105328
Sum squared resid	0.00298798021490168	Schwarz criterion	-5.994235448899831
Log likelihood	91.96735775402725	Hannan-Quinn criter.	-6.091381224847428
F-statistic	4.098205914262636	Durbin-Watson stat	1.786408137121557
Prob(F-statistic)	0.02837308250932743		

LABOUR FORCES PARTICIPATION

Null Hypothesis: LLP has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.879980229427908	0.1830133518633452
Test critical values:	1% level	-4.30982392298219	
	5% level	-3.574244087073583	
	10% level	-3.221727985418371	

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

Residual variance (no correction)	0.000103033800513851
HAC corrected variance (Bartlett kernel)	0.0001136215738759651

Phillips-Perron Test Equation

Dependent Variable: D(LLP)
Method: Least Squares
Date: 11/25/24 Time: 14:59
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLP(-1)	-0.4163630891296205	0.1478713393175175	-2.815711895566068	0.009161346973444212
C	0.720198855231812	0.2563707489936748	2.809208375209688	0.009303790916837176
@TREND("1993")	0.0006085101199556241	0.0002937980502846428	2.071185017620356	0.0484028280593574

R-squared	0.2396863118161465	Mean dependent var	0.0002726395496618459
Adjusted R-squared	0.1812006434943115	S.D. dependent var	0.01184713775676784
S.E. of regression	0.01072018264572749	Akaike info criterion	-6.135679845105328
Sum squared resid	0.00298798021490168	Schwarz criterion	-5.994235448899831
Log likelihood	91.96735775402725	Hannan-Quinn criter.	-6.091381224847428
F-statistic	4.098205914262636	Durbin-Watson stat	1.786408137121557
Prob(F-statistic)	0.02837308250932743		

LABOUR FORCES PARTICIPATION

Null Hypothesis: D(LLP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.380843794289522	0.0008296360497589669
Test critical values:	1% level	-4.323979170705911	
	5% level	-3.580622499099694	
	10% level	-3.225333567134217	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LLP,2)

Method: Least Squares
Date: 11/25/24 Time: 14:58
Sample (adjusted): 1995 2022
Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LLP(-1))	-1.070689154288198	0.1989816458571941	-5.380843794289522	1.39574917535249e-05
C	0.0002165652537812418	0.004993578209251582	0.04336875176602066	0.9657521249167884
@TREND("1993")	3.356792449904881e-05	0.0002856643775337568	0.1175082619290958	0.907396288653571

R-squared	0.536641590301551	Mean dependent var	0.0009267414188703996
Adjusted R-squared	0.4995729175256751	S.D. dependent var	0.0172548570282439
S.E. of regression	0.01220623614537021	Akaike info criterion	-5.872782501379634
Sum squared resid	0.003724805020913553	Schwarz criterion	-5.730046303860861
Log likelihood	85.21895501931488	Hannan-Quinn criter.	-5.829146622802919
F-statistic	14.47695722871401	Durbin-Watson stat	2.000797714520897
Prob(F-statistic)	6.667501474600401e-05		

LABOUR FORCES PARTICIPATION

Null Hypothesis: D(LLP) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.387862350901815	0.000815760100649544
Test critical values:	1% level	-4.323979170705911	
	5% level	-3.580622499099694	
	10% level	-3.225333567134217	

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

Residual variance (no correction)	0.0001330287507469126
HAC corrected variance (Bartlett kernel)	0.0001243220092936153

Phillips-Perron Test Equation
Dependent Variable: D(LLP,2)
Method: Least Squares
Date: 11/25/24 Time: 15:01
Sample (adjusted): 1995 2022
Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LLP(-1))	-1.070689154288198	0.1989816458571941	-5.380843794289522	1.39574917535249e-05
C	0.0002165652537812418	0.004993578209251582	0.04336875176602066	0.9657521249167884
@TREND("1993")	3.356792449904881e-05	0.0002856643775337568	0.1175082619290958	0.907396288653571

R-squared	0.536641590301551	Mean dependent var	0.0009267414188703996
Adjusted R-squared	0.4995729175256751	S.D. dependent var	0.0172548570282439
S.E. of regression	0.01220623614537021	Akaike info criterion	-5.872782501379634
Sum squared resid	0.003724805020913553	Schwarz criterion	-5.730046303860861
Log likelihood	85.21895501931488	Hannan-Quinn criter.	-5.829146622802919
F-statistic	14.47695722871401	Durbin-Watson stat	2.000797714520897
Prob(F-statistic)	6.667501474600401e-05		

TOTAL INVESTMENT

Null Hypothesis: INV has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.786009550553662	0.03208575830735517
Test critical values:	1% level	-4.30982392298219	

	5% level	-3.574244087073583
	10% level	-3.221727985418371

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(INV)
Method: Least Squares
Date: 11/25/24 Time: 15:03
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INV(-1)	-0.6913031333951539	0.1825941335235297	-3.786009550553662	0.0008148584150299768
C	6.508437837442904	2.798486810220534	2.32569895047317	0.02810266438227487
@TREND("1993")	-0.2693117002920369	0.1492919967126128	-1.803925905086943	0.08284217886849658

R-squared	0.3556774917651123	Mean dependent var	0.184470727892683
Adjusted R-squared	0.3061142219008902	S.D. dependent var	7.23457145761908
S.E. of regression	6.026384033140705	Akaike info criterion	6.527868662249208
Sum squared resid	944.2499173872239	Schwarz criterion	6.669313058454704
Log likelihood	-91.65409560261352	Hannan-Quinn criter.	6.572167282507108
F-statistic	7.176231365272826	Durbin-Watson stat	1.850429133635488
Prob(F-statistic)	0.003298700890375837		

TOTAL INVESTMENT

Null Hypothesis: INV has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.786009550553662	0.03208575830735517
Test critical values:	1% level	-4.30982392298219	

	5% level	-3.574244087073583
	10% level	-3.221727985418371

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

Residual variance (no correction)	32.56034197886979
HAC corrected variance (Bartlett kernel)	32.56034197886979

Phillips-Perron Test Equation
Dependent Variable: D(INV)
Method: Least Squares
Date: 11/25/24 Time: 15:02
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INV(-1)	-0.6913031333951539	0.1825941335235297	-3.786009550553662	0.0008148584150299768
C	6.508437837442904	2.798486810220534	2.32569895047317	0.02810266438227487
@TREND("1993")	-0.2693117002920369	0.1492919967126128	-1.803925905086943	0.08284217886849658

R-squared	0.3556774917651123	Mean dependent var	0.184470727892683
Adjusted R-squared	0.3061142219008902	S.D. dependent var	7.23457145761908
S.E. of regression	6.026384033140705	Akaike info criterion	6.527868662249208
Sum squared resid	944.2499173872239	Schwarz criterion	6.669313058454704
Log likelihood	-91.65409560261352	Hannan-Quinn criter.	6.572167282507108
F-statistic	7.176231365272826	Durbin-Watson stat	1.850429133635488
Prob(F-statistic)	0.003298700890375837		

RESEARCH and DEVELOPMENT

Null Hypothesis: RD has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

	t-Statistic	Prob.*

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.394257929614942	0.0724754996484928
Test critical values:	1% level	-4.323979170705911	
	5% level	-3.580622499099694	
	10% level	-3.225333567134217	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RD)
Method: Least Squares
Date: 11/25/24 Time: 15:05
Sample (adjusted): 1995 2022
Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RD(-1)	-0.4814761155182078	0.1418501850779585	-3.394257929614942	0.002391097033976614
D(RD(-1))	0.5153784942146315	0.1753432410115907	2.93925497921282	0.007165958649086076
C	1.848490636606817	0.5418965486582609	3.411150414564718	0.002293833449241203
@TREND("1993")	0.00592488923251322	0.001861212371095221	3.183349371907919	0.003998551308092865

R-squared	0.3778264650828581	Mean dependent var	0.01063012890555994
Adjusted R-squared	0.3000547732182154	S.D. dependent var	0.02784241871701401
S.E. of regression	0.02329372739162572	Akaike info criterion	-4.549701658331661
Sum squared resid	0.01302234565908899	Schwarz criterion	-4.359386728306632
Log likelihood	67.69582321664325	Hannan-Quinn criter.	-4.491520486896041
F-statistic	4.858148974570901	Durbin-Watson stat	2.093172568327833
Prob(F-statistic)	0.00883456340381957		

RESEARCH and DEVELOPMENT

Null Hypothesis: RD has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.467900831249563	0.340177440808558
Test critical values:	1% level	-4.30982392298219	
	5% level	-3.574244087073583	
	10% level	-3.221727985418371	

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

Residual variance (no correction)	0.0006107768072107622
HAC corrected variance (Bartlett kernel)	0.000801697690810696

RESEARCH and DEVELOPMENT

Phillips-Perron Test Equation
Dependent Variable: D(RD)
Method: Least Squares
Date: 11/25/24 Time: 15:06
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RD(-1)	-0.3180344458228185	0.1439225700929028	-2.209760745778272	0.03613126286129575
C	1.228160916901992	0.5511383362729096	2.228407708321417	0.03471390863611883
@TREND("1993")	0.003914704814072274	0.001869942408903572	2.09348950825049	0.04620567255402549

R-squared	0.1581302581598245	Mean dependent var	0.01026357273640269
Adjusted R-squared	0.09337104724904189	S.D. dependent var	0.02741187872176228
S.E. of regression	0.0261007864670132	Akaike info criterion	-4.356005338374948
Sum squared resid	0.0177125274091121	Schwarz criterion	-4.21456094216945
Log likelihood	66.1620774064367 4	Hannan-Quinn criter.	-4.311706718117049
F-statistic	2.441818792042987	Durbin-Watson stat	1.281585499711637

Prob(F-statistic)	0.10670473 8838868

APPENDIX B: The ARDL Short run and the bounce test (Cointegration results)

ARDL Error Correction Regression
Dependent Variable: D(GDP_PER)
Selected Model: ARDL(2, 1, 1, 1, 1, 1)
Case 2: Restricted Constant and No Trend
Date: 08/01/24 Time: 15:57
Sample: 1994 2022
Included observations: 27

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP_PER(-1))	0.295627	0.088577	3.337524	0.0049
D(INV)	0.155990	0.023745	6.569310	0.0000
D(L)	0.187675	0.107399	1.747447	0.1024
D(LELS)	122.9361	14.49723	8.479975	0.0000
D(ELP)	-0.129324	0.027068	-4.777674	0.0003
D(LR_D)	-7.996496	5.041091	-1.586263	0.1350
CointEq(-1)*	-1.750953	0.155708	-11.24511	0.0000

R-squared	0.964282	Mean dependent var	-0.044059
Adjusted R-squared	0.953567	S.D. dependent var	3.007945
S.E. of regression	0.648161	Akaike info criterion	2.189060
Sum squared resid	8.402264	Schwarz criterion	2.525018
Log likelihood	-22.55231	Hannan-Quinn criter.	2.288958
Durbin-Watson stat	2.019310		

* p-value incompatible with t-Bounds distribution.

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	12.64525	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

APPENDIX C: ARDL Long Run Estimates

ARDL Long Run Form and Bounds Test
Dependent Variable: D(GDP_PER)
Selected Model: ARDL(2, 1, 1, 1, 1, 1)
Case 2: Restricted Constant and No Trend
Date: 08/01/24 Time: 15:56
Sample: 1994 2022
Included observations: 27

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-153.2831	47.99510	-3.193724	0.0065
GDP_PER(-1)*	-1.750953	0.281505	-6.219968	0.0000
INV(-1)	0.318232	0.071083	4.476928	0.0005
L(-1)	-0.596824	0.216065	-2.762244	0.0153
LELS(-1)	32.38918	12.53639	2.583614	0.0217
ELP(-1)	-0.002085	0.016229	-0.128489	0.8996
LR_D(-1)	3.974475	5.762847	0.689672	0.5017
D(GDP_PER(-1))	0.295627	0.145902	2.026197	0.0622
D(INV)	0.155990	0.046892	3.326580	0.0050
D(L)	0.187675	0.182136	1.030407	0.3203
D(LELS)	122.9361	29.26487	4.200809	0.0009
D(ELP)	-0.129324	0.092494	-1.398186	0.1838
D(LR_D)	-7.996496	8.326000	-0.960425	0.3531

* p-value incompatible with t-Bounds distribution.

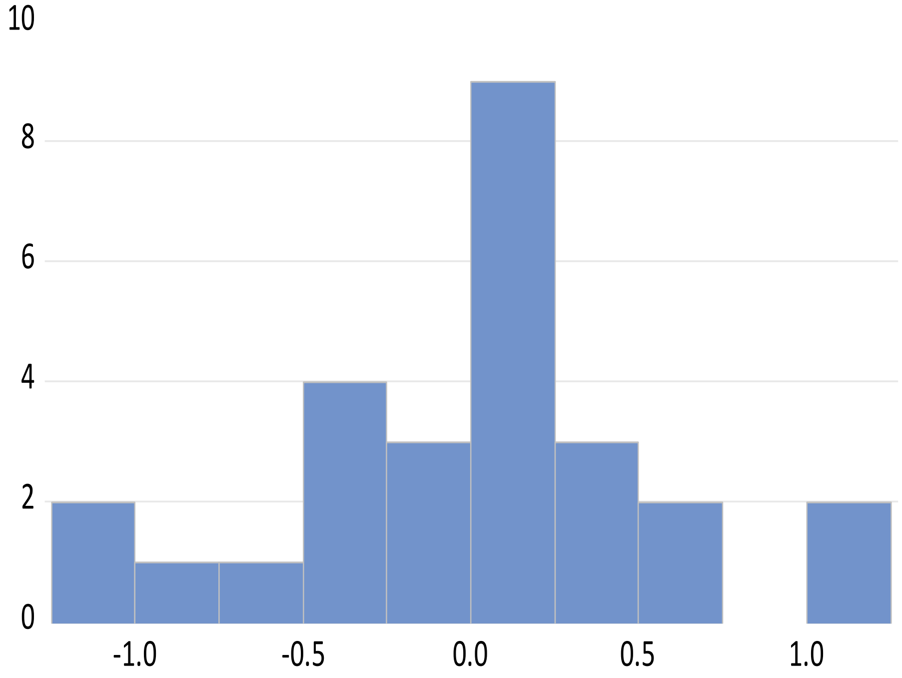
Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INV	0.181748	0.033103	5.490360	0.0001
L	-0.340857	0.150645	-2.262650	0.0401
LELS	18.49803	7.623747	2.426369	0.0293
ELP	-0.001191	0.009166	-0.129925	0.8985
LR_D	2.269892	3.347361	0.678114	0.5088
C	-87.54265	29.84243	-2.933496	0.0109

EC = GDP_PER - (0.1817*INV -0.3409*L + 18.4980*LELS -0.0012*ELP + 2.2699*LR_D - 87.5426)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	12.64525	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15
Actual Sample Size	27		Finite Sample: n=35	
		10%	2.331	3.417
		5%	2.804	4.013
		1%	3.9	5.419
			Finite Sample: n=30	
		10%	2.407	3.517
		5%	2.91	4.193
		1%	4.134	5.761

APPENDIX D: Normality Test for the ARDL ECM



Series: Residuals	
Sample 1996 2022	
Observations 27	
Mean	1.58e-14
Median	0.107792
Maximum	1.245858
Minimum	-1.173358
Std. Dev.	0.568475
Skewness	-0.093813
Kurtosis	3.091138
Jarque-Bera	0.048948
Probability	0.975823

APPENDIX E: GRANGER

Pairwise Granger Causality Tests
Date: 08/01/24   Time: 16:35
Sample: 1994 2022
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
INV does not Granger Cause GDP_PER	27	0.65127	0.5311
GDP_PER does not Granger Cause INV		2.98134	0.0715
L does not Granger Cause GDP_PER	27	3.39720	0.0518
GDP_PER does not Granger Cause L		1.26635	0.3016
LELS does not Granger Cause GDP_PER	27	0.91849	0.4139
GDP_PER does not Granger Cause LELS		1.16916	0.3292
ELP does not Granger Cause GDP_PER	27	3.85890	0.0366
GDP_PER does not Granger Cause ELP		0.02369	0.9766
LR_D does not Granger Cause GDP_PER	27	8.05737	0.0024
GDP_PER does not Granger Cause LR_D		3.03870	0.0683
L does not Granger Cause INV	27	0.84195	0.4443
INV does not Granger Cause L		0.24996	0.7810
LELS does not Granger Cause INV	27	6.59936	0.0057
INV does not Granger Cause LELS		2.93037	0.0744
ELP does not Granger Cause INV	27	1.48165	0.2491
INV does not Granger Cause ELP		0.03083	0.9697
LR_D does not Granger Cause INV	27	8.19909	0.0022
INV does not Granger Cause LR_D		1.43491	0.2596
LELS does not Granger Cause L	27	2.51318	0.1040
L does not Granger Cause LELS		0.21131	0.8111
ELP does not Granger Cause L	27	0.67083	0.5214
L does not Granger Cause ELP		0.80334	0.4605
LR_D does not Granger Cause L	27	9.12336	0.0013
L does not Granger Cause LR_D		0.67977	0.5171
ELP does not Granger Cause LELS	27	2.51653	0.1037
LELS does not Granger Cause ELP		2.08615	0.1480
LR_D does not Granger Cause LELS	27	1.41635	0.2639
LELS does not Granger Cause LR_D		7.41068	0.0035
LR_D does not Granger Cause ELP	27	2.41019	0.1131
ELP does not Granger Cause LR_D		2.71208	0.0885

CAUSLAITY

Appendix F: Serial Correlation Test for the ARDL ECM

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

F-statistic	0.670951	Prob. F(2,12)	0.5294
Obs*R-squared	2.715607	Prob. Chi-Square(2)	0.2572

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 08/01/24 Time: 15:58
Sample: 1996 2022
Included observations: 27
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP_PER(-1)	0.049173	0.203021	0.242206	0.8127
GDP_PER(-2)	0.083005	0.178296	0.465545	0.6499
INV	0.008778	0.048635	0.180491	0.8598
INV(-1)	0.004676	0.063206	0.073972	0.9423
L	0.047505	0.191555	0.247994	0.8083
L(-1)	-0.028067	0.177572	-0.158061	0.8770
LELS	13.26294	34.29846	0.386692	0.7058
LELS(-1)	-10.45993	29.07394	-0.359770	0.7253
ELP	0.047033	0.109394	0.429938	0.6749
ELP(-1)	-0.038932	0.109374	-0.355949	0.7281
LR_D	-4.072688	9.378220	-0.434271	0.6718
LR_D(-1)	0.971572	8.252109	0.117736	0.9082
C	-3.312304	49.29982	-0.067187	0.9475
RESID(-1)	-0.170674	0.384120	-0.444326	0.6647
RESID(-2)	-0.392610	0.340180	-1.154124	0.2709

R-squared	0.100578	Mean dependent var	1.58E-14
Adjusted R-squared	-0.948748	S.D. dependent var	0.568475
S.E. of regression	0.793577	Akaike info criterion	2.675650
Sum squared resid	7.557181	Schwarz criterion	3.395559
Log likelihood	-21.12127	Hannan-Quinn criter.	2.889716
F-statistic	0.095850	Durbin-Watson stat	2.134003
Prob(F-statistic)	0.999948		

APPENDIX G: The stability test results Ramsey RESET

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: GDP_PER GDP_PER(-1) INV INV(-1) L L(-1) LELS LELS(-1) ELP LR_D LR_D(-1) C

	Value	df	Probability
t-statistic	0.398741	16	0.6954
F-statistic	0.158994	(1, 16)	0.6954
Likelihood ratio	0.276866	1	0.5988

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.121333	1	0.121333
Restricted SSR	12.33141	17	0.725377
Unrestricted SSR	12.21008	16	0.763130

LR test summary:

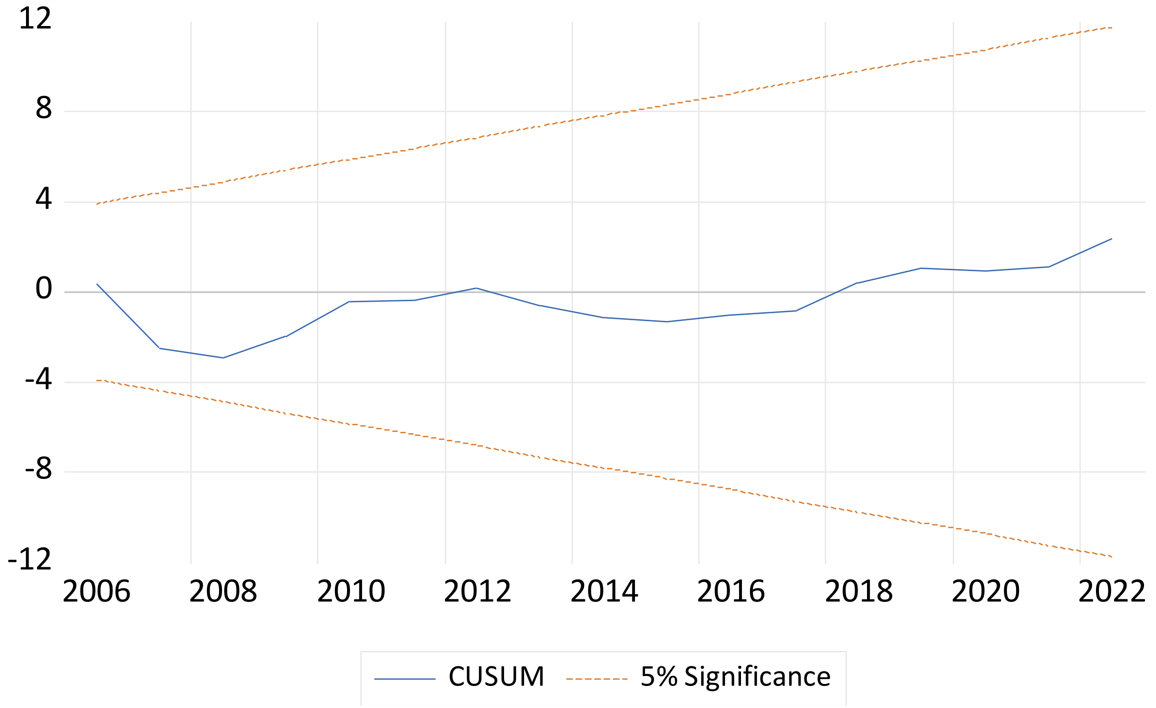
	Value
Restricted LogL	-28.24952
Unrestricted LogL	-28.11108

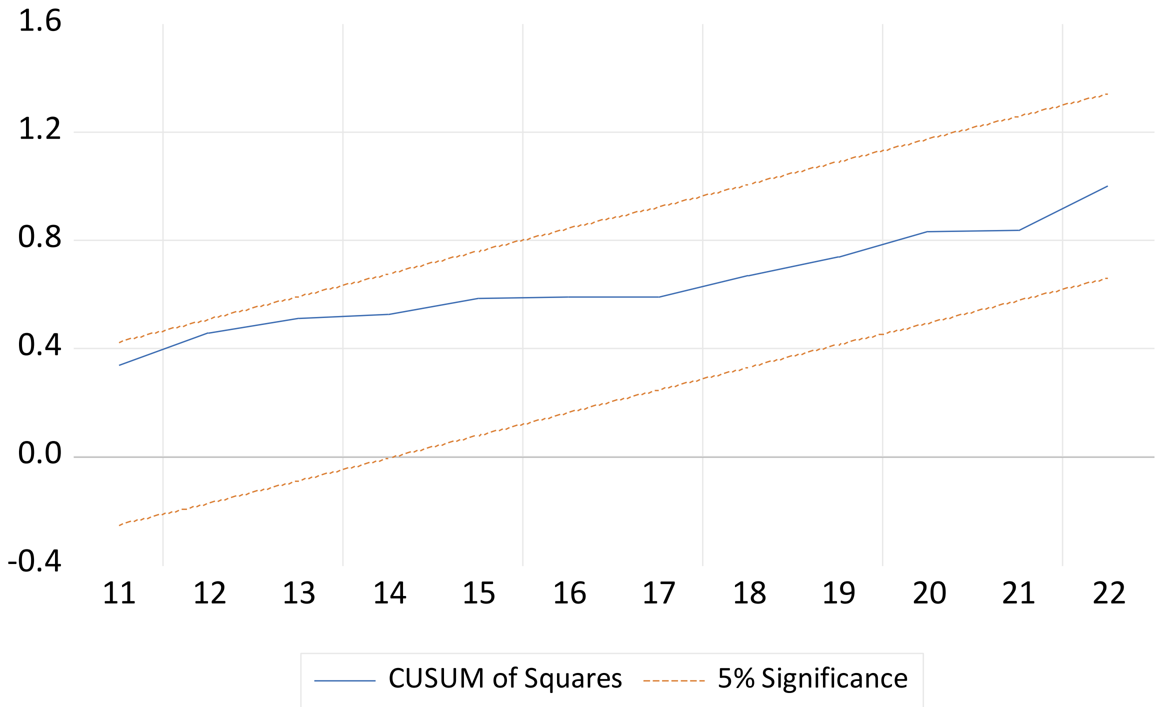
Unrestricted Test Equation:
Dependent Variable: GDP_PER
Method: Least Squares
Date: 08/01/24 Time: 15:59
Sample: 1995 2022
Included observations: 28

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP_PER(-1)	-0.284838	0.147921	-1.925615	0.0721
INV	0.198687	0.048676	4.081837	0.0009
INV(-1)	0.097901	0.057269	1.709503	0.1067
L	0.170511	0.195711	0.871239	0.3965
L(-1)	-0.753012	0.179969	-4.184119	0.0007
LELS	120.6303	29.73961	4.056217	0.0009
LELS(-1)	-101.2135	25.42152	-3.981410	0.0011
ELP	0.006645	0.012638	0.525812	0.6062
LR_D	-9.072319	9.062297	-1.001106	0.3317
LR_D(-1)	14.02727	9.206688	1.523596	0.1471
C	-90.98202	36.85275	-2.468799	0.0252
FITTED^2	-0.009170	0.022998	-0.398741	0.6954

R-squared	0.918399	Mean dependent var	2.393332
Adjusted R-squared	0.862298	S.D. dependent var	2.354121
S.E. of regression	0.873573	Akaike info criterion	2.865077
Sum squared resid	12.21008	Schwarz criterion	3.436022
Log likelihood	-28.11108	Hannan-Quinn criter.	3.039621
F-statistic	16.37048	Durbin-Watson stat	1.721326
Prob(F-statistic)	0.000001		

Appendix H: Stability Test Results CUMUS and CUSUMsq





Appendix I: Heteroskedasticity Test Results

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

F-statistic	0.480839	Prob. F(14,12)	0.9038
Obs*R-squared	9.703161	Prob. Chi-Square(14)	0.7835
Scaled explained SS	1.686158	Prob. Chi-Square(14)	1.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 08/01/24 Time: 16:13
Sample: 1996 2022
Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-40.62271	24.80510	-1.637676	0.1274
GDP_PER(-1)	0.012175	0.077286	0.157538	0.8774
INV	-0.020431	0.030581	-0.668101	0.5167
INV(-1)	0.022804	0.026503	0.860404	0.4064
INV(-2)	0.028612	0.021330	1.341390	0.2046
L	-0.047417	0.092911	-0.510348	0.6191
L(-1)	-0.147750	0.088843	-1.663045	0.1222
LELS	16.79902	14.53983	1.155379	0.2704
LELS(-1)	3.229130	17.97993	0.179596	0.8605
LELS(-2)	-9.868092	15.22586	-0.648114	0.5291
ELP	0.000257	0.047913	0.005368	0.9958
ELP(-1)	-0.013002	0.084042	-0.154705	0.8796
ELP(-2)	0.024334	0.054090	0.449883	0.6608
LR_D	-0.349011	4.151943	-0.084060	0.9344
LR_D(-1)	-0.322959	4.172572	-0.077400	0.9396

R-squared	0.359376	Mean dependent var	0.236046
Adjusted R-squared	-0.388018	S.D. dependent var	0.319067
S.E. of regression	0.375906	Akaike info criterion	1.181225
Sum squared resid	1.695664	Schwarz criterion	1.901135
Log likelihood	-0.946544	Hannan-Quinn criter.	1.395292
F-statistic	0.480839	Durbin-Watson stat	2.641351
Prob(F-statistic)	0.903785		

Heteroskedasticity Test: Harvey
Null hypothesis: Homoskedasticity

F-statistic	0.543064	Prob. F(14,12)	0.8624
Obs*R-squared	10.47183	Prob. Chi-Square(14)	0.7269
Scaled explained SS	9.634360	Prob. Chi-Square(14)	0.7884

Test Equation:
Dependent Variable: LRESID2
Method: Least Squares
Date: 08/01/24 Time: 16:13
Sample: 1996 2022
Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-240.5541	165.0132	-1.457787	0.1706
GDP_PER(-1)	0.328257	0.514135	0.638465	0.5352
INV	-0.273755	0.203435	-1.345664	0.2033
INV(-1)	0.253574	0.176310	1.438222	0.1759
INV(-2)	0.124724	0.141895	0.878986	0.3967
L	0.108598	0.618083	0.175701	0.8635
L(-1)	-1.117573	0.591019	-1.890926	0.0830
LELS	157.1926	96.72464	1.625155	0.1301
LELS(-1)	-68.32620	119.6095	-0.571244	0.5784
LELS(-2)	-27.05665	101.2884	-0.267125	0.7939
ELP	0.065743	0.318736	0.206262	0.8400
ELP(-1)	0.070565	0.559077	0.126217	0.9017
ELP(-2)	-0.068124	0.359826	-0.189326	0.8530
LR_D	-6.136440	27.62034	-0.222171	0.8279
LR_D(-1)	-3.021169	27.75757	-0.108841	0.9151

R-squared	0.387845	Mean dependent var	-2.820254
Adjusted R-squared	-0.326335	S.D. dependent var	2.171352
S.E. of regression	2.500673	Akaike info criterion	4.971178
Sum squared resid	75.04038	Schwarz criterion	5.691087
Log likelihood	-52.11090	Hannan-Quinn criter.	5.185244
F-statistic	0.543064	Durbin-Watson stat	2.583186
Prob(F-statistic)	0.862378		

Heteroskedasticity Test: ARCH

F-statistic	0.041700	Prob. F(1,24)	0.8399
Obs*R-squared	0.045097	Prob. Chi-Square(1)	0.8318

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 08/01/24 Time: 16:14
Sample (adjusted): 1997 2022
Included observations: 26 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.253609	0.079671	3.183194	0.0040
RESID^2(-1)	-0.041485	0.203154	-0.204206	0.8399

R-squared	0.001734	Mean dependent var	0.244063
Adjusted R-squared	-0.039860	S.D. dependent var	0.322600
S.E. of regression	0.328967	Akaike info criterion	0.688083
Sum squared resid	2.597257	Schwarz criterion	0.784859
Log likelihood	-6.945076	Hannan-Quinn criter.	0.715951
F-statistic	0.041700	Durbin-Watson stat	2.034381
Prob(F-statistic)	0.839915		