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The impact of petroleum production on economic growth in South Africa

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Abstract

The petroleum industry in South Africa, marked by a historical dependence on imported crude oil and recent challenges faced by local refineries, is a critical concern for the nation's economic growth and energy security. The absence of significant domestic oil reserves maintained South Africa's status as a net importer, accentuated by the recent closure of refineries and a subsequent reduction in refining capacity, has cast doubts on the sustainability of the energy sector. Against this backdrop, this study aimed to investigate the short- and long-term impact of petroleum production on economic growth. The overarching concern is whether focusing on improving petroleum production would stimulate economic growth. Employing a quantitative approach, an autoregressive distributed lag (ARDL) model was used to estimate the dynamic relationship between petroleum production and economic growth, using data for the period spanning from 1980 to 2022. The results of the study revealed that petroleum production has both short- and long-term impact on economic growth in South Africa. The findings underscore the responsiveness of the economy to changes in refinery capacity. Furthermore, the long-term association emphasised the sustained positive contributions of an expansion of refinery capacity to the country's economy. Based on the results, the study recommends substantial investments in refinery infrastructure to enhance the petroleum industry. This study provided an understanding of the complex interactions within the petroleum industry, offering key insights for informed decision-making by policymakers and stakeholders.

1. Introduction

The petroleum industry in South Africa stands as a cornerstone of the nation's economic infrastructure. This industry, characterised by its extensive and multifaceted operations, plays a pivotal role in the economic growth of the country. At its core, the South African petroleum industry revolves around the extraction, processing, and distribution of petroleum products, with a focus on meeting the energy needs of the nation (Department of Minerals Resources and Energy (DMRE), 2022). The primary products that emerge from the South African petroleum industry encompass a range of vital fuels and commodities. Among these, petrol, diesel, and jet fuel occupy a central position (South African Petroleum Industry Association (SAPIA), 2022). These fuels serve as the lifeblood of various economic activities, driving not only transportation but also a multitude of industrial processes (DMRE, 2022). The intrinsic link between energy and economic development is undeniable, with energy serving as the lifeblood of modern economic activities (Ablo and Otchere-Darko, 2021). It is through the provision of energy that nations power their industrial machinery, electrify their homes, and enable the transportation networks that connect cities and regions (Ogbuigwe, 2018).

South Africa's energy landscape is characterised by its historical reliance on imported crude oil, owing to the absence of domestic oil reserves (Akinbami, Oke and Bodunrin, 2021). This dependence on oil imports has

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remained a consistent feature of the nation's energy profile (DMRE, 2022). This reliance has significant implications for both energy security and economic stability. South African petroleum production confronts several challenges that could substantially impact the nation's refining capacity. Notably, the closure of certain refineries has raised concerns about the industry's sustainability (SAPIA, 2022).

The economic implications of diminished refining capacity are multifaceted. The importation of refined petroleum products, necessitated by declining refining capacity, can adversely affect South Africa's economy (SAPIA, 2022). Yang et al. (2022) observe that greater reliance on imported refined products can lead to increased costs, trade imbalances, and heightened vulnerability to international price fluctuations. Of economic concern is the potential loss of refining margin. Historically, South Africa's refineries have made substantial contributions to economic stability and energy security (Akinbami et al., 2021). The erosion of this refining margin jeopardises a significant economic resource, involving substantial financial stakes in the billions of rands (DMRE, 2022). Furthermore, the DMRE (2022) predicts that the loss in refining margin, if unaddressed, will become a pivotal component of importation costs, further impacting South Africa's trade balance and balance of payments.

South Africa boasts six refineries, with four located on the coast and two inlands. These refineries, such as Sasol Secunda and PetroSA, are vital cogs in the nation's energy machinery, converting crude oil into essential products like petrol, diesel, jet fuel, and others (SAPIA, 2022). The downstream industry not only caters to South Africa's energy needs but also serves as a regional supplier, contributing to the economic well-being of neighbouring countries.

The economic growth trends in South Africa, as observed over recent years, have been characterised by volatility and a nuanced set of influencing factors. Data from sources like the World Bank (2023) provide insights into the nation's economic trajectory. The data shows that South Africa’s economic growth rate has been chronically depressed for quite some time now. This pattern of economic instability is a matter of concern, particularly as it relates to the nation's energy sector. The petroleum industry, which has historically played a pivotal role in the South African economy, faces challenges, including reduced refining capacity and increased reliance on imports of refined products (SAPIA, 2023). These challenges intertwine with broader economic trends, and their implications raise critical questions about the link between the petroleum industry and economic growth.

The intricate relationship between the South African petroleum industry and economic growth trends serves as the underpinning for this research. This study seeks to explore the short-term and long-term implications of petroleum production on economic growth in South Africa. Given the historical context, the challenges faced by the petroleum industry, and the economic volatility observed in recent years, it becomes imperative to investigate how the state of the petroleum sector influences the nation's economic prosperity. This research aims to shed light on whether the petroleum industry can act as a catalyst for economic growth or if its challenges pose a hindrance to the nation's development.

Overall, this study endeavours to resolve the practical challenge of South Africa's fuel security and economic growth in the face of a changing petroleum landscape while simultaneously addressing the theoretical complexity of integrating energy-related variables into a growth model. It seeks to unlock the mystery of how petroleum production impacts the nation's short- and long-run economic growth dynamics, providing valuable insights for policymakers, industry stakeholders, and scholars in the energy and real sectors.

This study contributes to the body of literature on economic growth, particularly in the context of non-oil producing countries like South Africa. While extensive research has explored the impact of oil price shocks and oil production on economic growth in oil-producing nations, there exists a notable scarcity of literature addressing the implications of petroleum production on economic growth in non-oil producing countries. Existing studies have predominantly concentrated on oil-producing countries and their economic growth dynamics, often overlooking the nuanced situation of non-oil producing nations like South Africa (Oriakhi and Osaze, 2013; Sadeghi (2017); Akinsola and Odhiambo, 2020; Wang and Liao, 2022). This study aims to bridge this gap by focusing on a country that relies heavily on imported crude oil and petroleum production to meet its energy needs.

Unlike some previous studies that primarily consider oil price shocks, this study takes a novel perspective by examining the role of the petroleum industry in shaping economic growth. This enables an analysis of the specific challenges and opportunities posed by the refining sector in South Africa, offering a new dimension to the literature.

Beyond its academic contributions, this study offers substantial value to policymakers in the South African context. As the nation grapples with energy security and economic growth challenges, the findings of this study could inform evidence-based policy decisions. By understanding how investments in petroleum production can impact economic growth, policymakers will have a valuable understanding of potential strategies for sustainable development.

The rest of the study is organised as follows: Section 2 reviews relevant literature that is aligned with the topic. Pertinent issues will be discussed, such as the economics of the petroleum industry and its contribution to the economic growth of South Africa. Section 3 lays out the methodology adopted in the study, while Section 4 covers data analysis and a comprehensive discussion of empirical findings. Section 5 concludes the empirical study and offers recommendations.

2. The dynamics of petroleum production and economic growth in South Africa

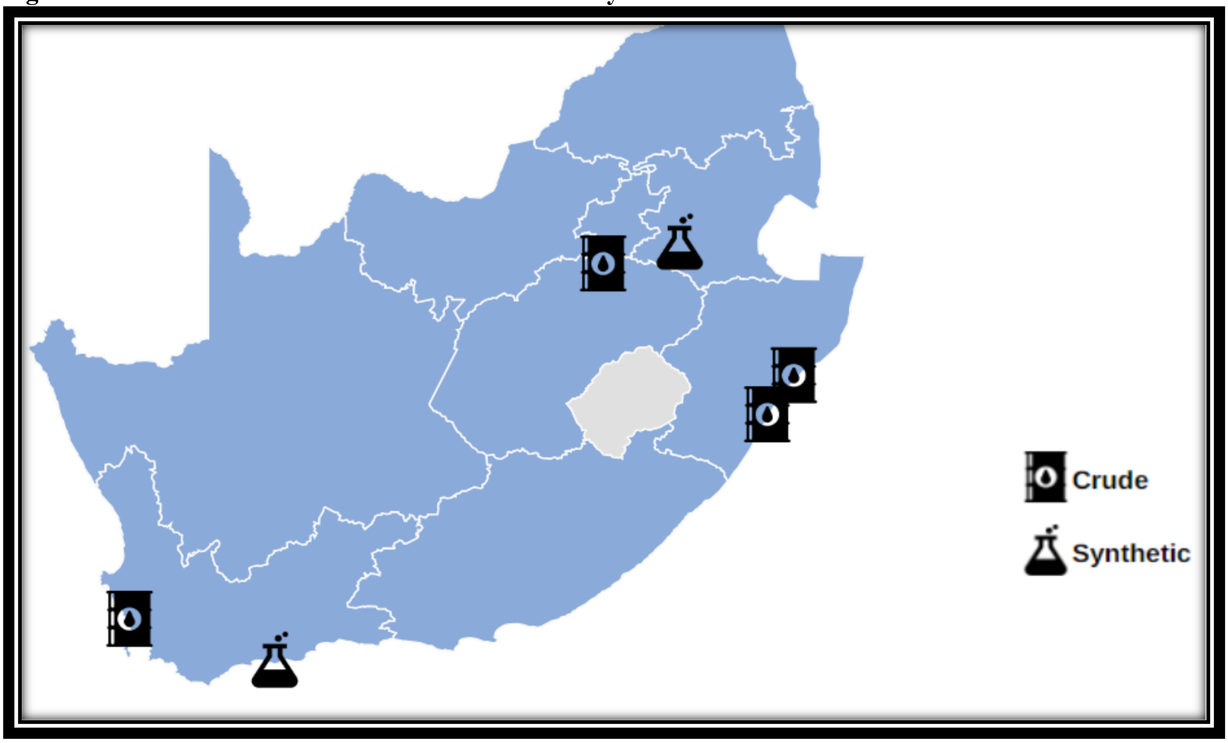
The South African liquid fuels industry has undergone significant reforms aimed at addressing historical disparities and promoting inclusivity. These reforms, initiated in response to the 1998 White Paper on Energy Policy, are centred around the Liquid Fuels Empowerment Charter (Department of Energy, 2017). This charter serves as a commitment by industry leaders to transform the sector and outlines key measures to facilitate the meaningful participation of historically disadvantaged South Africans. The government has collaborated with industry associations like SAPIA and AMEF to create a framework for change, focusing on addressing past imbalances and strengthening the regulatory framework (Department of Energy, 2023). These reforms represent a crucial step in reshaping the industry's landscape and promoting economic and social equity in South Africa.

The petroleum industry in South Africa stands as a linchpin of the nation's economy, primarily due to its integral role in powering various sectors, including transportation and power generation (SAPIA, 2023). The South African economy heavily relies on petroleum products, with petrol, diesel, and other derivatives serving as fundamental energy sources that drive economic activities and sustain daily life.

A salient feature of South Africa's petroleum industry landscape is its increasing dependence on imports, particularly for crude oil, petrol, and diesel products (Akinbami et al., 2021). This reliance on imported petroleum products underscores the country's absence of proven domestic oil resources. While offshore exploration has identified natural gas reserves in the Southern Cape, there has been no significant footprint of crude oil either within the country or externally (DMRE, 2022).

Despite its lack of domestic oil resources, the petroleum sector in South Africa plays a substantial role in employment and economic turnover. Approximately 110,000 individuals are employed within the sector, with a significant portion engaged in retail activities (SAPIA, 2023). Moreover, the sector contributes significantly to the economy, generating an annual turnover of approximately R360 billion. South Africa boasts a noteworthy refining capacity spread across the country. Figure 2.1 depicts this spread.

Figure 1: South Africa oil refineries across the country



Source: Extracted from SAPIA (2023)

As portrayed in Figure 1, South Africa has six refineries, which are located in Cape Town, Durban, Sasolburg and Mossel Bay. Table 1 provides an overview of existing refineries and their production capacities.

Table 1: Existing oil refineries in South Africa

NAME	LOCATION	CAPACITY
ASTRON REF	Cape Town	100 000 Barrels/Day
ENREF	Durban	135 000 Barrels/Day
NATREF	Sasolburg	110 000 Barrels/Day
SAPREF	Durban	180 000 Barrels/Day
SECUNDA	Secunda	150 000 Barrels/Day
PetroSA	Mossel Bay	45 000 Barrels/Day

Source: DMRE (2022)

These refineries represent critical infrastructure responsible for transforming raw materials into essential petroleum products. South Africa's liquid fuels sector has experienced notable growth in recent years. The industry has adapted to changing global dynamics, particularly the shift towards greener energy sources and reduced demand for liquid fuels in some regions (Parker, 2022). While the dependence on imports poses challenges, it also opens opportunities for growth and diversification in the sector. As global refineries seek new markets, Parker (2022) notes that South Africa's sustained demand for liquid fuel products can create favourable conditions for international suppliers. Additionally, the country's strategic assets, such as the Secunda Synfuels Operation, continue to play a crucial role in ensuring a steady supply of liquid fuels.

However, the industry faces formidable challenges that warrant attention. One of the most pressing issues is the closure of local refineries, driven by factors such as policy changes, supply constraints, and rising production costs (Parker, 2022). This trend has raised concerns about job losses, especially in regions where refineries have ceased operations. Furthermore, the efficiency and capacity of South Africa's ports are areas of concern, as the nation's reliance on fuel imports is expected to grow, necessitating rapid upgrades to handle increased volumes (Parker, 2022). Balancing economic and environmental considerations is also a challenge, given the global shift towards greener energy alternatives.

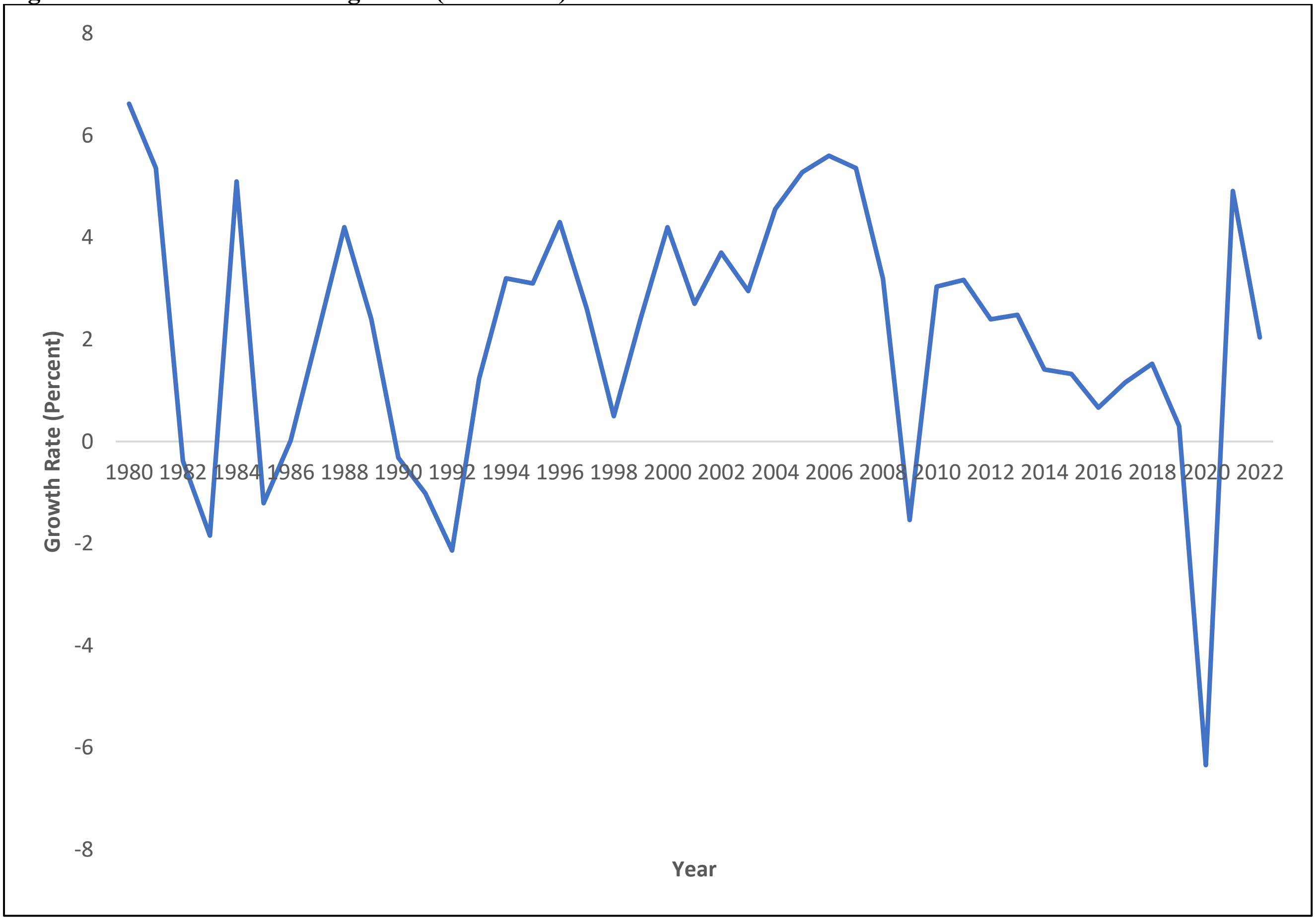
Further, an important facet of South Africa's petroleum industry is the aging nature of its infrastructure. The crude oil refineries constructed during the 1950s and 1960s have experienced decades of service. Similarly, the CTL and GTL plants, built in the 1980s, exhibit a similar vintage. Currently, two crude oil refineries in South Africa are not operational. The Astron Refinery in Milnerton sustained significant damage following a catastrophic incident, while the Engen Refinery suffered a major fire, resulting in extensive facility damage (SAPIA, 2023). The GTL complex in Mossel Bay remains non-operational due to feedstock constraints. Despite these setbacks, the other refineries in the country maintain operational capacity, although they periodically undergo maintenance, operating at an average of 75% of their nameplate capacity (DMRE, 2022).

While South Africa's refining capacity represents a modest portion of the global landscape, accounting for just 3% of the world's refining capacity, the nation plays a role in intra-Africa trade (Amungo and Amungo, 2020). Global developments have also left their mark on South Africa's petroleum industry. The COVID-19 pandemic led to reduced demand for petroleum products, adversely affecting the industry's profitability. Additionally, the pressure on oil majors to reduce greenhouse gas emissions has prompted the adoption of net-zero carbon strategies and divestment from assets contributing to global warming (SAPIA, 2023). The transition to electric vehicles (EVs) in Europe poses a further challenge, potentially diminishing the demand for traditional petroleum and diesel fuels, thus reducing the likelihood of new refineries in the region, and potentially accelerating the closure of existing ones (DMRE, 2022).

Overall, South Africa's petroleum industry is a crucial component of the nation's economy, meeting the energy needs of various sectors. However, it faces challenges such as aging infrastructure, operational setbacks, and evolving global dynamics. These factors underscore the importance of this study, which seeks to model the implications of local petroleum industries on South Africa's economic growth within the context of these domestic and global developments.

From the economic growth front, South Africa has experienced distinctive phases of economic growth over the past four decades, with two major periods dividing the analysis: the apartheid era (1980-1994) and the post-apartheid period (1995-2022). These distinct time frames have been marked by various economic, political, and social factors that have significantly influenced South Africa's economic trajectory (Abrahams, 2016). The growth trends are summarised in Figure 2.

Figure 2: South Africa's GDP growth (1980-2022)



Source: World Bank (2023)

During the apartheid era, South Africa's economic performance was characterised by fluctuation and stagnation, notably the decline in real per capita GDP since 1981. The average growth rate of the economy over the period 1980 to 1994 was 1.6% (World Bank, 2023). This period, spanning from the early 1980s to the mid-1990s, was deeply affected by the apartheid regime's discriminatory policies (Meyiwa et al., 2014). These policies created a socially and economically divided society, resulting in stark disparities in access to education, healthcare, and economic opportunities, primarily for non-white South Africans (Abrahams, 2016).

The apartheid era also coincided with international sanctions and isolation (Fedderke, 2018). Furthermore, political unrest and resistance to apartheid policies contributed to an environment of uncertainty, which discouraged foreign investment. These socio-political and economic factors are reflected in the GDP growth data, which shows inconsistent and volatile growth rates, with some years experiencing negative growth. The apartheid era was marked by economic challenges, and real per capita GDP declined over this period.

The post-Apartheid era, characterised by the transition to democracy in 1994, marked a fundamental turning point for South Africa. The post-apartheid period brought about increased political stability, an end to international sanctions, and a renewed focus on economic reforms (Fedderke, 2018). As a result, South Africa witnessed a remarkable revival in economic growth. The average growth rate post-apartheid was 2.4% (World Bank, 2023). Several factors contributed to this revival. The lifting of international sanctions allowed South Africa to rejoin the global economy, opening opportunities for trade and foreign investment. The South African government introduced a series of economic reforms, liberalising the economy and encouraging private sector growth (Naidoo, 2023). This, in turn, contributed to the expansion of South Africa's manufacturing and services sectors.

South Africa's status as a resource-rich country, with abundant mineral resources such as gold and platinum, played a crucial role in driving economic growth. Naidoo (2023) acknowledges that these resources, coupled with a growing manufacturing sector, contributed to economic development. Additionally, the country's political stability and the peaceful transition of power through democratic elections created an environment conducive to economic growth (World Bank, 2023). As a result, the GDP growth data during the post-apartheid period shows a significant improvement in economic performance, with consistent growth rates, especially up until 2007. This period was marked by economic development, improved living standards, and job creation.

Unfortunately, South Africa could not be shielded from negative global phenomena, The global financial Crisis of 2008 and the global COVID-19 pandemic in 2020 led to a significant decline in GDP growth, reduced economic activity, and disruptions to supply chains (World Bank, 2023). These global events demonstrated the vulnerability of South Africa's economy to external shocks and underscored the need for resilience in the face of global crises. Furthermore, geopolitical tensions such as the Russia-Ukraine war in 2022 had indirect effects on South Africa's economy (UNDP, 2022). While the immediate impact of such events may be subtle, they often lead to uncertainties in global markets, affecting investor sentiment and trade dynamics. Overall, South Africa's economic growth trends from 1980 to 2022 reveal a complex interplay of historical, political, and economic factors, emphasising the multifaceted nature of economic growth and the various factors that affect the growth rate of an economy.

2.2 Literature review

2.2.1 Resource-based growth model

The Resource-Based Growth Model provides a framework for understanding the relationship between a nation's abundant natural resources and its economic development (Pedercini, 2009). It is a critical concept in economics, particularly in the context of resource-rich countries, as it sheds light on the complex dynamics that arise from the presence of valuable resources, such as oil, minerals, and agricultural products (Wright, 2001).

Resource abundance can significantly influence a nation's economic trajectory. While the model recognises that these resources can offer substantial economic benefits, it also highlights the potential downsides. One of the primary challenges is known as Dutch Disease (Hosein and Hosein, 2021). When a country experiences a surge in resource revenue, it can lead to currency appreciation, making other sectors, like manufacturing, less competitive in the international markets. This can result in economic imbalances and hinder diversification, a crucial component of long-term economic growth (Mulwa and Mariara, 2016).

Moreover, Pedercin (2009) notes that the Resource-Based Growth Model underscores the risk of resource abundance fostering rent-seeking behaviour and corruption. In some cases, excessive resource income may lead to political elites or interest groups capturing a disproportionate share of the benefits, while the broader population does not experience commensurate improvements in living standards (Mulwa and Mariara, 2016). This income inequality can exacerbate social tensions and hinder inclusive growth.

The Resource-Based Growth Model also highlights the importance of governance and sound economic policies in determining whether a resource-rich nation reaps the benefits of its natural wealth or falls victim to the resource curse (Acemoglu, 2012). Transparency in resource revenue management is crucial, as it can help prevent corruption and ensure that the wealth generated from resource extraction is used to benefit the entire population (Putri and Lujala, 2023). Well-designed fiscal policies are also vital to manage revenue volatility and avoid over-dependence on resource income.

While the model acknowledges the challenges associated with resource abundance, it also recognises the potential for positive outcomes. Countries with efficient and sustainable resource management practices can avoid the pitfalls of the resource curse (Acemoglu, 2012). The revenues generated from resource extraction can be invested in infrastructure, education, and healthcare, supporting economic diversification and long-term growth. Notable examples of countries that have effectively managed their resource wealth, such as Norway and Canada, underscore the potential for responsible resource management to lead to positive economic outcomes (Todaro and Smith, 2020).

2.2.2 The impact of petroleum production on economic growth

The relationship between petroleum production and economic growth is multifaceted, and various theoretical relationships can exist, each with its implications for a nation's economic development. A positive relationship may emerge when a country effectively manages its petroleum industry. The revenue generated from oil exports can significantly boost a nation's economic growth (Kumhof and Muir, 2014). These revenues can be reinvested in critical areas such as infrastructure development, education, and healthcare, which can stimulate economic expansion. Moreover, the petroleum industry often provides employment opportunities, contributing to increased income levels for local communities (Usman, Madu and Abdullahi, 2015). This, in turn, can stimulate consumer spending and further support economic growth. Additionally, a well-developed petroleum industry can attract foreign direct investment, which can foster economic growth through enhanced production processes and market expansion (Musa, 2022).

Conversely, a negative relationship can arise due to over-dependence on the petroleum sector. When a country relies heavily on oil exports, it can lead to the Dutch Disease effect (Hosein and Hosein, 2021). This phenomenon results from the rise of the exchange rate, driven by oil exports, making other industries less competitive in the global market. This can hinder economic diversification and lead to economic imbalances (Mulwa and Mariara, 2016). Moreover, if the petroleum sector is mismanaged or corruption is prevalent, it can divert resources away from essential public services and infrastructure, undermining economic growth (Asiamah et al., 2022). Environmental damage and social issues associated with petroleum production can also have negative economic consequences (Azam et al., 2023). For instance, the cost of environmental cleanup and healthcare expenses related to pollution can drain resources that might otherwise be used for economic development.

Alternatively, there may be no discernible relationship between petroleum production and economic growth in some cases. This situation can occur when the petroleum sector is relatively small compared to the overall economy and does not play a dominant role in influencing economic conditions (Walls, 2019). In such instances, the broader economic structure and performance of other sectors may overshadow the impact of the petroleum industry.

On the empirical front, the literature on the impact of petroleum production on economic growth is relatively limited, with most studies in this area focusing primarily on broader aspects of the oil industry, such as oil price shocks, rather than specifically exploring the effects of petroleum production. However, some related studies provide insights into the broader context of the petroleum industry and its relationship with economic development.

Akinlo (2012) evaluated the significance of oil in the development of the Nigerian economy using a multivariate VAR model over the period 1960-2009. The empirical evidence from this study indicated that the oil sector is cointegrated with other non-oil sectors and can influence their growth. However, it also found adverse effects of oil on the manufacturing sector. The Granger-causality test showed bidirectional causality between oil and several sectors, indicating the interdependencies within the Nigerian economy. While this study does not specifically address the impact of petroleum production, it provides insights into the interplay between oil and various economic sectors.

Omoregie (2019) argued that Nigeria's petroleum refining capacity is a missing link in the country's GDP growth. The study pointed out that the utilisation of Nigeria's refineries had dropped significantly, leading to a refining capacity utilisation of only 14 percent in 2014, well below the global average of 90 percent. This study emphasised the importance of refining capacity and suggested that addressing this issue could help mitigate Nigeria's 'resource curse.' While not a direct exploration of the impact of refineries on economic growth, it highlights the significance of refining activities within the broader context of the oil sector.

Hafsi, Dadene, and Guennoun (2021) examined the impact of oil petroleum production on economic growth in Gulf Cooperation Council (GCC) countries. Their study found that oil production had a significant positive impact on economic growth in both the short and long-run periods. The research also identified a causal relationship between economic growth (GDP) and petroleum production, with unidirectional causality running from GDP to petroleum production. While this study primarily focuses on oil production rather than refining, it underscores the central role of the oil sector in driving economic growth in GCC countries.

Kumhof and Muir (2014) used a dynamic stochastic general equilibrium model to evaluate production and current account consequences of permanent oil supply shocks on the world economy. Their findings suggested that the effects of oil supply shocks on output growth could be significant, particularly for larger shocks and when oil acts as a critical enabler of technologies. This study highlights the potential vulnerability of economies to oil-related shocks, which could have implications for the economic growth of oil-dependent nations.

Overall, the existing empirical literature on the impact of petroleum production on economic growth is limited, with most studies focusing on broader aspects of the oil industry or oil-related shocks. However, most of the reviewed studies are consistent with the positive role oil plays in the economic growth process, irrespective of the study country under consideration or the methodology used. Although these studies provide insights into the complexities of the oil sector and its relationship with economic development, there is a necessity for more empirical research specifically examining the role of petroleum production in driving economic growth in the short and long run. Therefore, this study seeks to fill this research gap.

3. Research methodology

This study on the impact of petroleum production on the economic growth of South Africa adopted the positivist research philosophy as it emphasises the objective, empirical, and scientific investigation of phenomena. It assumes that there is an objective reality that can be observed and measured through systematic and quantitative methods. This research philosophy choice was justified because it aims to investigate the effects of petroleum production on economic growth. By employing quantitative methods and seeking empirical evidence, the positivist philosophy aligns with the study's objective of providing objective and generalisable findings that contribute to a deeper understanding of the economic dynamics of petroleum production in South Africa (Saunders et al., 2019).

This study adopted a causal research design, also known as the explanatory research design, specifically focusing on examining the short- and long-run relationships between petroleum production and economic growth in South Africa. This design allows for the investigation of cause-and-effect relationships between the variables of interest, which in this case are petroleum production and economic growth.

This study also employed a quantitative approach. The adoption of a quantitative research approach was justified for the study on the impact of petroleum production on economic growth in South Africa due to the need for objective measurement, statistical analysis, generalisability, data availability, and the assessment of impact. Quantitative research involves the systematic collection and analysis of numerical data to answer research questions. This approach is characterised by its precision and objectivity, making it suitable for studies that aim to measure relationships between variables (Kumar, 2018).

3.1. Model specification

Since the study sought to determine the short- and long-run impact of petroleum production on economic growth, a dynamic time series regression model was estimated in this study. The model consisted of GDP growth, which was the dependent variable, measuring economic growth. The main independent variable was the petroleum oil refinery, which was measured by the total barrels refined per year. To address the omission-of-variable bias, the study incorporated three control variables. Since the study focused on economic growth, core growth determinants such as gross fixed capital formation, labour force participation, and inflation were included in the growth model as control variables.

Dependent variable – Economic growth (RGDP): Economic growth is the dependent variable in this study. Todaro and Smith (2020) define economic growth as a sustained increase in a country's national output over time. Within economic literature, the measurement of economic growth encompasses various metrics, including the real GDP growth rate, the total GDP, Gross National Product (GNP), per capita GDP, per capita GNP, and a range of other indicators. In this study, the real GDP growth rate is used to measure economic growth, following Hafsi et al. (2021).

Independent variables: The following are the independent variables in the estimated model.

Petroleum production (PP): In this study, petroleum production is measured by the total barrels of crude oil refined per year. This metric provides a quantifiable indicator of the refining capacity and productivity of these facilities. A similar measure was employed by Hafsi et al. (2021) and its coefficient is expected to be positive. This positive effect can be attributed to the contribution of the petroleum sector to job creation, government revenue and enhanced economic stability and sustainability over time.

Capital (K): Capital is a core variable in the Neoclassical growth model. In this case, capital refers to the total investment in an economy used to acquire or improve physical assets like machinery and infrastructure. It boosts economic growth by enhancing productivity and technological progress (Mankiw, 2020). In this study, it was measured as a GDP ratio, with the expected impact being positive, aligning with neoclassical growth theory. Increased capital investment typically leads to higher production, efficiency, and sustained economic growth.

Labour (L): Labour is another core variable in the Neoclassical growth model. Labour refers to the workforce or human resources engaged in productive activities within an economy, including both skilled and unskilled workers (Mankiw, 2020). In this study, labour was measured by the labour force participation rate, which assesses the percentage of the working-age population actively engaged in the labour market. The coefficient for labour force participation rate is expected to have a positive sign. An increase in labour force participation implies a larger workforce, potentially leading to higher production, greater output, and positive contributions to economic growth.

Inflation (INFL): Inflation is the continual increase in the price level of goods and services in an economy over a period, resulting in a decline in the purchasing power of a currency (Todaro and Smith, 2020). This study employed the annual inflation rate, measured by changes in the Consumer Price Index (CPI), to assess price-level fluctuations. Inflation is included as a control variable in the model to account for its potential impact on economic growth. In this growth model, the coefficient of inflation is expected to have a negative sign. Excessive levels of inflation diminish the value of money, reduce consumer purchasing power and may hinder economic growth.

3.2. The auto regressive distributed lag (ARDL) model

The growth model is, therefore, specified as follows:

$$RGDPG_t = \beta_0 + \beta_1 PP_t + \beta_2 K_t + \beta_3 L_t + \beta_4 INFL_t + \mu_t \qquad (1)$$

where RGDPG is real GDP growth, PP is petroleum production, K is gross fixed capital formation, L is labour force participation and INFL is the annual inflation rate. The βs are parameters, which were estimated using regression analysis, the subscript *t* represents the period for time series data and μ is the error term.

To estimate the short- and long-run impact of petroleum production on economic growth, a dynamic time series model was estimated. Specifically, the auto regressive distributed lag (ARDL) model was estimated (Pesaran et al., 2001; Narayan and Narayan, 2004). The ARDL model was found to be the most appropriate model as it captures the dynamic aspect of a relationship between variables of interest; utilises variables that are either integrated of order zero or one or a mixture, unlike other methods such as simple Ordinary Least Squares models that utilise variables that are integrated of the same order; possesses powerful small-sample properties; and has the ability to separate the long-run and short-run effects, among its other numerous advantages (Nyasha, 2024; Nyasha and Odhiambo, 2021).

In this study, Equation 2 is estimated using the ARDL methodology developed by Pesaran and Pesaran (1997) and Pesaran *et al.* (2001). A similar approach was also followed by Hafsi et al. (2021) in their study of the dynamic impact of oil production on the economic growth of Gulf cooperation countries.
Equation 1 is re-specified in the form of a standard ARDL model as follows:

$$\Delta RGDPG_t = \beta_0 + \sum_{i=1}^{n} \beta_5 \Delta RGDPG_{t-i} + \sum_{i=0}^{n} \beta_1 \Delta PP_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta K_{t-i} + \sum_{l=0}^{n} \beta_3 \Delta L_{t-i} + \sum_{i=0}^{n} \beta_4 \Delta INFL_{t-i} + \tau_0 RGDPG_{t-1} + \tau_1 PP_{t-1} + \tau_2 K_{t-1} + \tau_3 L_{t-1} + \tau_4 INFL_{t-1} + \varepsilon_t \qquad (2)$$

where β_0 is a constant, $\beta_1, \beta_2, \beta_3, \beta_4$ and β_5 are short-run coefficients, τ_0 *to* τ_5 are long-run coefficients, *and* ε_t is a white noise residual term which caters for all the omitted variables that affect economic growth in South Africa. Further, p and q are the lag lengths for the dependent variable and independent variables, respectively. The lag lengths are automatically selected using the Akaike Information Criterion (AIC).

The Error Correction Model, which gives the short-run dynamics of the variables, is derived from Equation 2 and is specified as follows:

$$\Delta RGDPG_t = \beta_0 + \sum_{i=1}^{n} \beta_5 \Delta RGDPG_{t-i} + \sum_{i=0}^{n} \beta_1 \Delta PP_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta K_{t-i} + \sum_{l=0}^{n} \beta_3 \Delta L_{t-i} + \sum_{i=0}^{n} \beta_4 \Delta INF_{t-i} + \varsigma ECT_{t-1} + \mu_t \ldots \quad (3)$$

where ECT_{t-1} is the error correction term and ς is the error correction coefficient, which was expected to be negative and statistically significant. The error correction coefficient measures the speed of adjustment of the variables to long-run equilibrium after a shock in the short run (Gujarati, 2012). In cases where the coefficient is negative, it suggests a tendency for the variables to converge toward the equilibrium over time, indicating a correction mechanism that brings the system back to its long-term relationship following a short-run disturbance. Conversely, a positive coefficient implies divergence, suggesting that the variables move away from the long-run equilibrium after a shock in the short run. Thus, the error correction coefficient serves as a valuable indicator of the system's resilience and stability, providing crucial information for understanding the adjustment mechanisms and dynamics within the economic model under consideration.

3.3. Data collection and analysis

This study utilised secondary annual data, covering the period from 1980 to 2022. The study period from 1980 to 2022 was justified as it encompasses both the pre- and post-apartheid periods in South Africa, allowing for an examination of the impact of petroleum production on economic growth in the context of significant political and economic transitions. Additionally, this timeframe provided access to comprehensive and reliable secondary data, ensuring a robust analysis of the short and long-run relationships between refineries and economic growth. Data for petroleum production was collected from the U.S. Energy Information Administration (EIA). Data for real GDP growth, capital formation, labour force, and inflation were collected from the South African Reserve Bank (SARB) online statistical query.

A dynamic ARDL model was estimated using E-views 12 statistical software. Before estimating the ARDL model, the study conducted unit root tests to ascertain the order of integration using the Augmented Dickey-Fuller (ADF) and the Phillips Peron (PP), to make sure that there were no I (2) series. The study also conducted a multicollinearity test to ensure that there was no exact linear relationship among the explanatory variables in the regression model.

For cointegration, the ARDL Bounds Test approach was employed to test for the presence of long-run relationships among variables. This approach is applicable to different integration orders (I (0), I (1), and mutually integrated) but not for I (2) series (Nayaran and Nayaran, 2004). Rejecting the null hypothesis above the upper bound suggests cointegration, leading to the estimation of an Error Correction Model (ECM). Conversely, if the F-statistic falls below the lower bound, it implies no cointegration. During the estimation procedure, the AIC was employed as it ensures a data-driven and robust approach to lag length selection, enhancing the model's capacity to uncover meaningful short- and long-run relationships between variables.

Post-estimation tests were also done. These include the Ramsey Regression Specification Error Test (RESET) to check for model misspecification. Model validity was assessed using the F-test. Normality of residuals was examined through the Jacque-Bera (JB) test; and autocorrelation was tested using the Breusch-Godfrey (BG) LM test. In addition, the study conducted model stability tests using the cumulative sum and cumulative sum (CUSUM) of squares (CUSUMQ). Assessing the stability of the ARDL model was crucial to ensure that the estimated relationships between key variables remained consistent over time. The stability tests provide insights into whether the chosen model adequately captured the evolving economic dynamics and whether any changes in the relationships between variables should be considered. Ensuring model stability is paramount for the reliability of results, the validity of policy implications, and the robustness of the results over the extended time frame under consideration.

4. Empirical results

4.1. Unit root tests

The ADF test was utilised to test for the stationarity of the time series data used. In addition to the ADF test, the Phillips-Peron (PP) test was also employed to confirm the validity of the ADF test results. Table 2 summarises the results of the tests.

Table 2: Unit root tests

Series	ADF (Level)	PP (Level)	Differenced series	ADF (First difference)	PP (First difference)	Order of Integration
RGDPG	-5.24**	-5.23***	DRGDPG	-	-	I (0)
PP	-1.34	-1.34	DPP	-4.68**	-4.15***	I (1)
K	-2.85	-1.94	DK	-4.14	-6.41***	I (1)
L	-2.16	-2.10	DL	-6.28	-6.30***	I (1)
INF	-0.95	-2.68	DINF	-2.88	-4.63***	I (1)

*** and *** imply that the series is stationary at 5% and 1% level of significance, respectively. D stands for differenced series, and I (0) and I (1) denote integration orders zero and one, respectively.*

The results reflected in Table 2 indicate that the real GDP growth rate (RGDPG) is stationary in levels, suggesting no need for differencing [(I (0)]. In contrast, petroleum production (PP), gross fixed capital formation (K), labour force participation (L), and inflation rate (INF) required first-order differencing to achieve stationarity [I(1)]. Importantly, no series exhibited integration to order 2 [I (2)], facilitating the application and validation of the use of the ARDL bounds testing procedure in the subsequent analysis.

4.2. The bounds test for cointegration

The bounds test was employed to assess the existence or non-existence of long-run relationships among the variables. Results are summarised in the following table.

Table 3: Bounds test for cointegration

Test Statistic	Value	K
F-statistic	8.67***	4
	Critical value bounds	
Significance	Lower bound [I(0) Bound]	Upper bound [I(1) Bound]
10%	2.45	3.52
5%	2.86	4.01
1%	3.74	5.06

**** F-statistic is significant at 1% level. Critical value bounds were adapted from Pesaran et al. (2001).*

As shown in Table 3, the null hypothesis tested the absence of long-run relationships. The results reveal that the calculated F-statistic is 8.67, which exceeds the upper critical value bounds at 1% significance level. The null hypothesis of no long-run relationships is, therefore, rejected. Subsequently, both short-run and long-run models, including the ECM for short-term dynamics and the estimated coefficients for the long-term relationships, can be meaningfully established.

4.3. Multicollinearity test

A multicollinearity test was conducted to assess the strength of the linear relationships among the independent variables (PP, K, L and INF). The objective was to ascertain that there were no highly correlated independent variables ($r > 0.8$), as this could lead to serious multicollinearity issues such as indeterminate parameter estimates (Gujarati, 2012). The Pearson correlation coefficient (r) was used, and Table 4 summarises the correlation matrix, showing pairwise correlations for the variables.

Table 4: Pearson correlation matrix

	PP	K	L	INFL
PP	1.00			
K	-0.68	1.00		
L	0.54	-0.61	1.00	
INFL	-0.57	0.63	-0.66	1.00

The results show that none of the correlations exceed the 0.8 threshold. This suggests that multicollinearity concerns are not severe, and the variables can be included in the analysis without posing significant challenges associated with high collinearity.

4.4. Results of coefficient estimation

The ARDL model, represented by Equation 2, was estimated with the lag structure determined automatically using the Akaike Information Criterion (AIC) as ARDL (3, 4, 1, 4, 4). According to Narayan and Smith (2004), the AIC is preferred over other information criteria because it selects a parsimonious model if the objective is prediction. Table 5 presents the results of the long-run and short-run models estimated.

Table 5: Coefficient estimation

Panel A: Long-run model Dependent Variable: RGDPG				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	16.69	1.03	16.25	0.00
PP	0.09***	0.02	3.67	0.00
K	0.43***	0.04	9.82	0.00
L	0.004	0.003	1.20	0.25
INFL	-0.01**	0.006	-2.32	0.03
Panel B: Short-run model Dependent variable: D(RGDPG)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(RGDPG (-1))	0.34***	0.08	4.37	0.00
D(RGDPG (-2))	0.17*	0.09	1.86	0.08
D(PP)	0.04***	0.01	3.69	0.00
D(PP (-1))	0.00	0.01	0.09	0.92
D(PP (-2))	0.04**	0.01	2.70	0.01
D(PP (-3))	0.03***	0.01	3.58	0.00
D(K)	0.23***	0.02	13.69	0.00
D(L)	-0.001	0.001	-0.41	0.69
D(L (-1))	-0.001	0.001	-1.39	0.26
D(L (-2))	0.001**	0.001	2.36	0.03
D(L (-3))	0.001	0.001	1.46	0.16
D(INFL)	0.001	0.001	1.12	0.27
D(INFL (-1))	-0.001	0.001	-0.24	0.81
D(INFL (-2))	0.001**	0.001	2.33	0.03
D(INFL (-3))	-0.001	0.001	-1.55	0.14
ECM (-1)	-0.25***	0.04	-6.29	0.00
R-squared	*0.78*	*F-statistic*	*2837.78*	
Adjusted R-squared	*0.77*	*Prob(F-statistic)*	*0.00*	
S.E. of regression	*0.01*	*Akaike info criterion*	*-6.73*	
Sum squared resid	*0.00*	*Schwarz criterion*	*-5.84*	
Durbin-Watson stat	*2.74*			

****, ** and * imply that the respective coefficient is statistically significant at 1%, 5% and 10% levels of significance, respectively.*

The estimated model, as presented in Table 5, provides valuable insights into the equilibrium relationships among the variables in the study, which is found to be positive, irrespective of whether the analysis is done in the long run or in the short run. The long-run coefficient (Panel A) for petroleum production (PP) is 0.09, with a t-statistic of 3.67 (p-value = 0.00). This result implies that, in the long run, an increase in petroleum production has a positive impact on economic growth. Expanding the horizon to the long run, the study revealed a positive association between petroleum production and sustained economic growth. Thus, over an extended period, a well-managed expansion of the petroleum sector is associated with positive contributions to economic growth. Overall, the result implies that an expansion in petroleum production contributes positively to the long-term economic growth of South Africa.

In the short run, results reveal a statistically significant positive relationship between changes in petroleum production and immediate economic growth. As shown in Table 5 Panel B, short-run coefficients of petroleum production and its second and third lags ($p<.05$) are statistically significant. The results underscored the sensitivity of economic output to fluctuations in refinery activities. This implies that short-term changes in petroleum production have a swift and tangible impact on economic growth as well, reflecting the immediate responsiveness of the economy to shifts in the petroleum sector.

These long- and short-run results are consistent with theoretical predictions and empirical literature. The Solow Growth model and the Resource Based Model support the long-run results. In the Neoclassical Growth model, refining is viewed as a form of capital accumulation. The infrastructure and machinery involved in the refining process represent physical capital (Maheu et al., 2020). Additionally, the skilled workforce engaged in refining contributes to human capital. As refining capacity increases and technology improves, it enhances productivity and economic output, aligning with the Neoclassical model's emphasis on capital accumulation and technological progress.

Further, based on the Resource Based Model, petroleum production adds substantial value to the imported crude oil and alternative feedstocks, converting them into a range of high-value products such as petrol, diesel, jet fuel, and petrochemicals. This value addition contributes positively to economic growth by creating a downstream industry that supports various sectors of the economy, including transportation, manufacturing, and agriculture (Maiti et al., 2020). In addition, refineries provide employment opportunities for a significant portion of the population, with thousands of individuals directly employed in the sector, particularly in downstream activities such as retail (SAPIA, 2023). This employment generates income and stimulates consumption, further driving economic activity. The presence of refineries fosters industrialisation by supporting supply chain activities and other related industries. Theoretical and empirical literature support the short-run results too (see Kumhof and Muir, 2014; Usman et al., 2015; Omoregie, 2019; Hafsi et al., 2021; Musa, 2022).

The coefficient for gross fixed capital formation (K) is highly significant with a t-statistic irrespective of the analysis timeframe. This suggests that, in both the long and the short run, an increase in gross fixed capital formation leads to a substantial increase in economic growth. The result highlights the critical role of investment in fixed capital in fostering sustained economic growth over an extended period. This is consistent with the prediction of the Neoclassical growth model, which emphasises the important role of capital in driving economic growth of a country (Todaro and Smith, 2020).

Further, the results reveal that labour force participation (L) in the long run is statistically insignificant against expectations. This suggests that labour is not a key determinant of economic growth. This is also in line with the Neoclassical and endogenous growth models, which highlight that economic growth, in the long run, is largely driven by investment in capital and technology, and not by the amount of labour employed. Labour is only significant in the short run as in the long run, diminishing marginal returns will set in and contributions of labour to output become negative (Mankiw, 2020). However, the short-run results show the positive impact of labour on economic growth in the immediate term, as reflected by the coefficient of the second lag of D(L) (D(L -2)) that is statistically significant with a positive value of 0.001 (t-statistic = 2.36, p-value = 0.03), indicating a delayed positive impact of labour force participation on economic growth. The neoclassical growth models stress the role of labour in the short-run production function, highlighting its positive contribution to output (Mankiw, 2020).

The long-run coefficient for the inflation rate (INFL) is -0.01, with a t-statistic of -2.32 (p-value = 0.03); and one of the lagged short-run coefficients of the inflation rate (D (INFL (-2)) is statistically significant and negative (-0.001) suggesting that inflation rate, as anticipated, has a negative impact on economic growth, in both the long and short run, although the magnitude is too small. This negative and statistically significant coefficient implies an inverse relationship between inflation and long-term economic growth. However, though the impact is very small, it is significant, indicating that high and volatile inflation may hinder sustained economic growth. This emphasises the need for stable and low levels of inflation that are favourable for growth (Mankiw, 2020).

The coefficient for the first lag of the dependent variable (D (RGDPG (-1))) is 0.34 with a significant t-statistic of 4.37 (p-value = 0.00), indicating a positive and statistically significant short-term effect of the lagged economic growth on the current period's economic growth, emphasising the importance of consistency in driving economic growth.

The error correction coefficient (ECM(-1)) is -0.25 with a t-statistic of -6.29 (p-value = 0.00). This coefficient is crucial in capturing the speed of adjustment towards the long-run equilibrium. The negative sign indicates that disequilibrium in the previous period is corrected by about 25% in the current period. This implies that, in the short run, any deviation from the long-run equilibrium between economic growth and the variables, including petroleum production, is corrected by 25% in the subsequent period. A score of 0.78 was recorded for R-Square, indicating that the results of the model can be relied upon in explaining the impact petroleum refining capacity has on economic growth.

4.5 Model diagnostic tests

Various diagnostic tests were conducted to ensure the robustness and reliability of the ARDL model. The results of these tests are summarised in Table 6.

Table 6. Model diagnostics summary

Test	Test statistic	Value of the test statistic	p-value	Conclusion
Autocorrelation	F-statistic Obs*R-squared	1.92 7.55	0.18 0.12	No autocorrelation
Heteroskedasticity	Breusch-Pagan-Godfrey	22.78	0.30	No heteroskedasticity
Normality Test	Jarque-Bera	0.42	0.81	Residuals are normally distributed
Ramsey RESET	t-statistic F-statistic	0.67 0.54	0.34 0.34	The model was correctly specified
F-test	F-statistic	2837.78	p<.01	Whole model was valid

The results reported in Table 6 reveal that the estimated model passed all the diagnostic tests performed for autocorrelation, heteroskedasticity, normality, misspecification and the validity of the whole model. Overall, the diagnostic tests collectively suggest that the ARDL model was well-specified. There was no evidence of autocorrelation in the model, indicating that the residuals do not exhibit a systematic pattern over time. No heteroskedasticity in the model was found, revealing that the variance of the residuals was constant over time. The residuals were normally distributed, supporting the assumption of normality in the model. The model was correctly specified, and there was no evidence of model misspecification. The entire model was statistically significant, providing confidence in the validity of the ARDL model. In addition to the diagnostic tests, the stability of the model was assessed, focusing on the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ). The CUSUM and CUSUMQ graphs are presented in Figures 3 and 4, respectively.

Figure 3: CUSUM

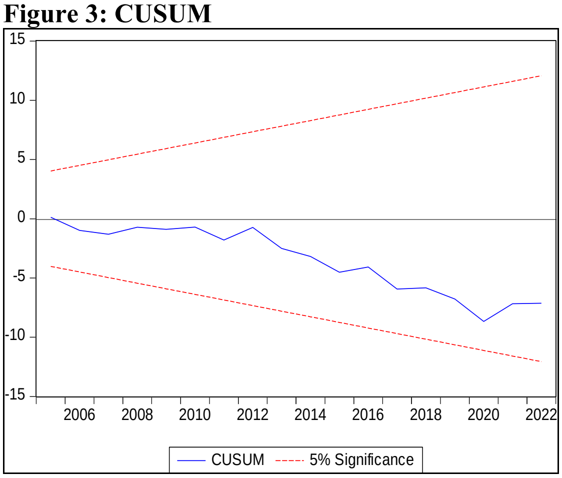
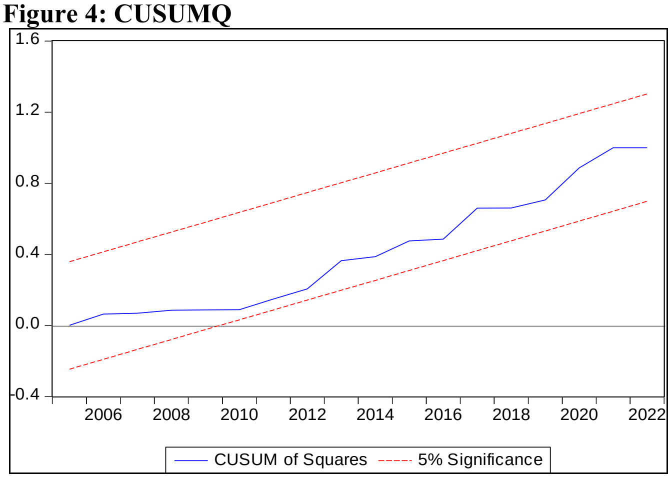


Figure 4: CUSUMQ



As shown in Figures 3 and 4, both CUSUM and CUSUMQ plots fall within the 5% significance bands, suggesting that the estimated ARDL model is stable over the study period. When the cumulative sums of residuals and squared residuals lie within the specified bands, it indicates that the coefficients in the model remain consistent and do not exhibit statistically significant deviations or structural breaks. This stability is reassuring as it implies that the identified relationships between petroleum production and South Africa's economic growth, as captured by the ARDL model, are reliable and maintain their validity over the entire period from 1980 to 2022. The absence of significant departures from stability in the CUSUM and CUSUMQ plots enhances the confidence in the robustness of the estimated model and the credibility of its implications for understanding the dynamic impact of petroleum production on the country's economic growth.

5. Conclusion

This study investigated the dynamic impact of petroleum production on the economic growth of South Africa using data for the 1980-2022 period. Although extensive research has been done on the impact of oil price shocks and oil production on economic growth in oil-producing nations, there is a notable scarcity of literature addressing the implications of petroleum production on economic growth in non-oil producing countries. Existing studies have predominantly concentrated on oil-producing countries and their economic growth dynamics, often overlooking the nuanced situation of non-oil producing nations like South Africa. This study was motivated by the need to illuminate the impact that refining capacity has on economic growth, in the case of South Africa, a non-oil producing country, as the country continues its fight against chronic low economic growth rates.

The empirical study using the ARDL model revealed that in the short run, petroleum production has a positive impact on the economic growth in South Africa. The immediate responsiveness of the economy to changes in the petroleum sector confirms that, during specific periods, an increase in refinery capacity contributes positively to economic expansion. This aligns with the notion that the petroleum sector plays a dynamic role in stimulating economic activity in the short term. The results support the idea that a well-managed and responsive petroleum sector can swiftly contribute to economic growth by generating revenue, creating employment opportunities, and stimulating consumer spending.

In the long run, the study also revealed a positive impact of petroleum production on economic growth in the study country, implying that a well-managed expansion of the petroleum sector contributes positively to sustained economic growth in South Africa. These findings are consistent with expectations and are aligned with both the theoretical and empirical literature, where refining is viewed as a form of capital accumulation, where increased infrastructure, machinery, and skilled workforce contribute to enhanced productivity and economic output over time. This suggests that, over an extended period, the positive contributions of petroleum production to the economy continue to manifest, supporting the idea that the sector plays a crucial role in shaping South Africa's long-term economic development.

Based on the results of the study and given South Africa's historical reliance on imported crude oil, the policy recommendations focus on transforming challenges into opportunities. The closure of certain refineries and reduced refining capacity underscore the need for strategic interventions to safeguard economic growth and energy self-sufficiency. Addressing the challenges faced by local refineries and strategically investing in the petroleum sector enables South Africa to enhance its economic resilience and energy security in the face of global uncertainties. To achieve this, policy makers are recommended to focus on investing in modernising and expanding refinery infrastructure; implementing policies that ensure the viability of these facilities, which may include incentives for technological upgrades, favourable regulatory frameworks, and support for research and development in the refining sector; fostering public-private partnerships in the refining sector, which can lead to improved efficiency and innovation; diversifying energy sources and promoting renewable energy; and developing develop human capital in the petroleum sector.

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