DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS (ENGLISH)
ECONOMICS PROGRAM
MASTER'S THESIS

AN EMPIRICAL RESEARCH ON THE RELATIONSHIP BETWEEN CARBON DIOXIDE EMISSIONS, FINANCIAL DEVELOPMENT AND ECONOMIC GROWTH IN SOUTH AFRICA

Rodney LANDSBERG

Supervisor
Prof. Dr. Pınar Narin EMİRHAN

2024

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İZMİR - 2024

YÜKSEK LİSANS
TEZ ONAY SAYFASI

Üniversite : Dokuz Eylül Üniversitesi
Enstitü : Sosyal Bilimler Enstitüsü
Adı ve Soyadı : RODNEY LANDSBERG
Öğrenci No : 2020801899
Tez Başlığı : An Empirical Research On The Relationship Between Carbon Dioxide Emissisons, Financial Development And Economic Growth İn South Africa

Savunma Tarihi : 14/08/2024
Danışmanı : Prof.Dr. Pınar Narin EMİRHAN

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Prof. Dr. Asuman ALTAY
Müdür

DECLARATION

I hereby declare that this Master’s Thesis titled as “An Empirical Research On the Relationship Between Carbon Dioxide Emissions, Financial Development and Economic Growth İn South Africa” has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all Materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

25.06.2024
Rodney LANDSBERG
Signature

ABSTRACT

Master's Thesis

An Empirical Research On the Relationship Between Carbon Dioxide Emissions, Financial Development and Economic Growth İn South Africa

Rodney LANDSBERG

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Graduate School of Social Sciences
Department of Economics (English)
Economics Program

This investigation examines the empirical relationship between carbon dioxide (CO_2) emissions, financial development, and economic growth in South Africa, covering the period from 1965 to 2022. The study employs a comprehensive analytical framework, including time series analysis, correlation tests, unit root tests, cointegration analysis, and Granger causality tests to explore the dynamic interactions among the variables. The results indicate significant causal relationships between economic growth and both financial development and CO_2 emissions, highlighting the influence of economic activities on environmental outcomes and financial sector expansion. The findings reveal both unidirectional and bidirectional causality among the variables, underscoring the complex interplay between economic growth, financial development, and environmental impact. Limitations of the study include data constraints specific to South Africa, the use of a single proxy for financial development, and the exclusion of external global economic factors. Despite these limitations, the study provides critical insights into the dynamics of South Africa's economy and offers valuable policy recommendations. The study concludes that sustainable economic growth in South Africa requires a balanced approach that fosters financial sector development while mitigating environmental impacts. Policymakers should focus on integrating climate change considerations into financial policies, promoting green finance initiatives, and investing in renewable energy and sustainable practices. These strategies can support economic growth, enhance financial

stability, and address environmental sustainability, contributing to long-term development goals. Future research should explore additional variables and policy interventions to further understand and mitigate the environmental impacts of economic growth without hindering financial and economic development.

Keywords: Economic Growth, Financial Development, Carbon Dioxide Emissions, South Africa, Sustainable Development, Granger Causality

ÖZET

Yüksek Lisans Tezi

Güney Afrika'da Karbondiioksit Emisyonu, Finansal Gelişme ve Ekonomik Büyüme Arasındaki İlişki Üzerine Ampirik Bir Araştırma

Rodney LANDSBERG

Dokuz Eylül Üniversitesi

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İngilizce İktisat Anabilim Dalı

İngilizce İktisat Programı

Bu araştırma, Güney Afrika'da karbondioksit (CO_2) emisyonları, finansal gelişme ve ekonomik büyüme arasındaki ampirik ilişkiyi 1965-2022 dönemi için incelemektedir. Çalışma, değişkenler arasındaki dinamik etkileşimleri araştırmak için zaman serisi analizi, korelasyon testleri, birim kök testleri, eşbütünleşme analizi ve Granger nedensellik testlerini içeren kapsamlı bir analitik çerçeve kullanmaktadır. Sonuçlar, ekonomik büyüme ile hem finansal gelişme hem de CO_2 emisyonları arasında anlamlı nedensel ilişkilere işaret ederek, ekonomik faaliyetlerin çevresel sonuçlar ve finans sektörünün genişlemesi üzerindeki etkisini vurgulamaktadır. Bulgular, ekonomik büyüme, finansal gelişme ve çevresel etki arasındaki karmaşık etkileşimin altını çizerek değişkenler arasında hem tek yönlü hem de çift yönlü nedenselliği ortaya koymaktadır. Çalışmanın en önemli kısıtı Güney Afrika'ya özgü verinin sınırlı olmasıdır. Bu kısıta rağmen, çalışma Güney Afrika ekonomisinin dinamiklerine dair kritik bilgiler sağlamakta ve değerli politika önerileri sunmaktadır. Çalışma, Güney Afrika'da sürdürülebilir ekonomik büyümenin, bir taraftan finansal sektörün gelişimini teşvik ederken, diğer taraftan çevresel etkileri azaltan dengeli bir yaklaşım gerektirdiği sonucuna varmaktadır. Politika yapıcılar, iklim değişikliği hususlarını mali politikalara entegre etmeye, çevreci finansal girişimleri teşvik etmeye ve yenilenebilir enerjiye ve sürdürülebilir uygulamalara yatırım yapmaya odaklanmalıdır. Bu stratejiler ekonomik büyümeyi destekleyebilir, finansal istikrarı artırabilir ve çevresel sürdürülebilirliği ele

alarak uzun vadeli kalkınma hedeflerine katkıda bulunabilir. Gelecekteki araştırmalar, finansal ve ekonomik büyümeyi engellemeyen daha çevreci ek değişkenleri ve politika müdahalelerini araştırmalıdır.

Anahtar Kelimeler: Ekonomik Büyüme, Finansal Kalkınma, Karbon dioksit Emisyonları, Güney Afrika, Sürdürülebilir Kalkınma, Granger Nedensellik

AN EMPIRICAL RESEARCH ON THE RELATIONSHIP BETWEEN CARBON DIOXIDE EMISSIONS, FINANCIAL DEVELOPMENT AND ECONOMIC GROWTH İN SOUTH AFRICA

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CHAPTER THREE

RESULTS AND DISCUSSION

ABBREVIATIONS

AIC	Akaike Information Criterion
ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag
BBC	British Broadcasting Corporation
CO2	Carbon Dioxide
COP	Conference of the Parties
EKC	Environmental Kuznets Curve
FD	Financial Development
FPE	Final Prediction Error
GDP	Gross domestic product
GNP	Gross national product
HQIC	Hannan-Quinn Information Criterion
IPCC	Intergovernmental Panel on Climate Change.
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary least squares
PP	Phillips-Perron
REC	Renewable energy consumption
SBIC	Schwarz Bayesian Information Criterion
SDGs	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change's
VAR	Vector Auto Regressive
VECM	Vector Error Correction Mechanism

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INTRODUCTION

The sirens for sustainable development grow louder and louder each day as multitudes of conferences, meetings, coalitions, agendas, and agreements all highlight the need to address our planet's degradation. The United Nations Framework Convention on Climate Change's (UNFCCC) Conference of the Parties (COP) meetings are targeting a goal of 1.5 degrees Celsius, as our planets heat levels grow at a staggering and critical level of 3 degrees Celsius per annum (IPCC, 2023), countless catastrophes unfold and worsen across the globe, manifesting in various forms. Floods and forest fires ravage landscapes, leaving destruction and displacement in their wake. Yet, there are also silent and indirect repercussions. Deteriorating health, exacerbated by climate change, leading to illnesses that may not make headlines but profoundly impact lives (United Nations Global Sustainable Development Report, 2023).

Interconnected to climate change, poverty and inequality continue to be the defining issues of our age. Developing countries face the brunt of these challenges. For people in developing countries, climate change leads to skyrocketing food prices, toxic air, and polluted water. It pushes communities into poverty and forces migration. The World Bank Group plays a significant role in funding climate investments in developing nations and in their report (World Bank, 2024), they defined their goal as to help countries reduce poverty while addressing climate change. Solutions include resilient infrastructure, climate-smart economies, and social protection and development need to arise from within the countries. This would aid and speed up recovery and improvement processes. The United Nations is also contributing by continuously improving and promoting the 17 Sustainable Development Goals (SDGs) established in 2015. These goals emphasize the interconnectedness of poverty eradication, health improvement, education, inequality reduction, economic growth, climate action, and environmental preservation (United Nations Global Sustainable Development Report, 2023).

The Brundtland Report, authored by the World Commission on Environment and Development (1987), also known as "Our Common Future," defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." It emphasizes responsible resource management, conservation, and economic progress while safeguarding the environment for future generations. To economists this is not a new challenge, who for some part of history, have played a crucial role in pursuing economic growth while considering the limited resources available, finding ways to enhance utility, production, and consumption without depleting resources excessively. This global conundrum motivates eager contribution, starting from familiar territories and extending our efforts further.

South Africa, as one of the core economies on the African continent, finds itself at the forefront of the global battle against climate change. According to UCT News (2024) the country has experienced firsthand the unparalleled effects of a changing climate, including extreme heatwaves, roof-breaking hail, coastal floods due to rising sea levels, and even snowfall in areas that previously had no record of such occurrences.

Despite these challenges, South Africa is in a critical position. It must simultaneously grow its economy while mitigating climate change impacts. The country actively participates in global negotiations aimed at reducing emissions that contribute to the warming of our planet. Additionally, South Africa grapples with income inequalities, stemming from a painful history of colonialism and Apartheid. To address these complex issues, research on economic growth, financial development, and climate change mitigation policies is crucial. Insights gained from such studies can pave the way for sustainable development not only in South Africa but also for other nations facing similar challenges (USAID, 2022).

Problem Statement; Economic growth refers to the increase in the production of goods and services within an economy over a specific period compared to a previous period. Traditionally, economists measure the aggregate economic growth using metrics such as gross domestic product (GDP) or gross national product (GNP). These metrics capture the aggregated market value of additional goods and services produced. Economic growth can result from various factors, including increases in capital goods, labor force, technology, and human capital. As the economy grows, average incomes rise, leading to improved material quality of life and a higher standard of living (Cornwall, 2024).

South Africa, a nation that once stood as a beacon of hope after overcoming the shackles of apartheid, now grapples with pressing economic challenges. The depreciation of public goods and services, and a dominating private sector often internationally owned have cast a shadow over the promise of a post-freedom Utopia. The need for an economy that is self-sufficient and continues to grow is paramount. At the very least, sustaining per capita consumption requirements at the basic needs level is essential (Pasara & Garidzirai, 2020).

The diverse economy of South Africa is an advantage, however, significant challenges related to economic growth are still faced. Historically, the country has struggled with high unemployment rates, income inequality, and structural constraints. The mining sector has been a cornerstone of South Africa's economy, but it faces environmental concerns due to resource extraction and land degradation. Efforts to promote sustainable economic growth involve diversifying industries, investing in infrastructure, and addressing social disparities (World Bank, 2024).

As South Africa seeks to address its economic woes, it must grapple with the delicate balance between growth and environmental sustainability. While economic expansion is crucial for meeting basic needs and improving living standards, it cannot come at the cost of irreparable harm to natural surroundings. The impact on the living habitat be it through resource extraction, pollution, or climate change requires thoughtful consideration. As these challenges are faced head-on, an economy that not only sustains per capita consumption but also safeguards the environment for generations to come must be strived for (OECD, 2021).

According to the World Bank (2023), financial development is characterized by the maturity of financial institutions, markets, and regulatory frameworks and access to financial services act as a cornerstone for economic progress. A robust financial system facilitates the efficient allocation of resources, channeling savings towards productive investments. Aydi & Aguir (2017) found that this, in turn, fuels economic growth by enhancing capital formation and entrepreneurial activity. Empirical studies have established a positive correlation between financial development and economic prosperity, particularly in developing economies. By mitigating information asymmetry and lowering transaction costs, a well-developed financial sector fosters a dynamic environment conducive to sustainable economic expansion (Emenekwe, Onyeneke, & Nwajiuba, 2022).

Banda (2022), brings to light that the distance between Sandton, a place known to be the richest square mile in Africa, is just across the road from one of the most impoverished and unbearable living settlements in the continent, Alexandra township. Figure 1. shows the in street view contrasting the two areas. According to the BBC News (2018) this is not only seen in one South African city, but is also the living norm in the tourism favored Cape town. This glaring stark divide between the rich and the poor, indicates clearly the income inequality disparity attributed to still developing financial systems that battle with immigration, education systems, depreciating public services and institutions, and a skyrocketing population (Human Sciences Research Council, 2023).

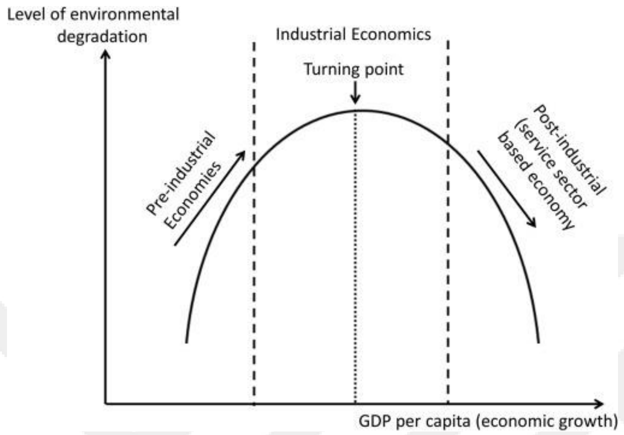
Figure 1: Images of Sandton on The Left, And Alexandra Township On The Right

Source: Greyling, 2019., The Citizen, 2024.

South Africa has a well-developed financial sector, including banking, insurance, and capital markets. However, financial inclusion remains a challenge, especially for marginalized communities. The country aims to enhance financial literacy, expand access to credit, and promote digital financial services. Sustainable financial development requires balancing economic growth with environmental and social considerations (South African Reserve Bank, 2023).

The link between several measures of environmental deterioration and per capita income is theorized to be represented by the environmental Kuznets curve (EKC). Pollution emissions rise and environmental quality falls during the early phases of economic expansion, but the pattern reverses at high income levels when per capita income reaches a certain threshold (which may vary depending on many factors) as shown in figure 2. This suggests that the relationship between per capita income and environmental damages or emissions is an inverted U (Kumar et al., 2023).

Figure 2: The Environmental Kuznets Curve



Source: Kumar et al., 2023.

While success stories like that of eThekwini municipality converting a landfill to be a nature reserve, whilst also channeling the methane and emissions produced by decomposing garbage into a World Bank award winning electricity production project. According to the United Nations Environment Programme (2018), many nations are pursuing similar initiatives to turn methane gas released by dumps into power as a result of the eThekwini Municipality in Durban's landfills producing sustainable energy. This unfortunately, only puts a dent on the main emissions driven by a powerful globally traded South African industry, locally consumed and exported coal produced electricity that has to cover the electrical needs of neighboring countries too as well as transport that is heavily reliant on diesel and petrol. Carbon emissions in the country continue to grow at an alarming rate (Prater, 2021).

South Africa is heavily reliant on mining and industrial activity. Transitioning to cleaner energy sources (such as renewables) is crucial to reduce emissions. Balancing economic development and environmental sustainability is a delicate task, especially given the country's energy challenges. South Africa faces chronic power shortages, leading to rolling blackouts. This harms productivity and economic growth. Increasing climate-related events (droughts, floods, heatwaves) disrupt agriculture, cities, and infrastructure. Poor communities are more exposed to climate risks and less able to cope with them. Supporting workers during the shift to a low-carbon economy requires reskilling and upskilling programs. South Africa's journey toward sustainable development involves balancing economic growth, financial stability, and environmental responsibility. By adopting a low-carbon, climate-resilient, and just transition, the country can address these challenges effectively (Department of Forestry, Fisheries, and the Environment, 2023).

South Africa, as a developing economy, faces the dual challenge of achieving sustainable economic growth while mitigating environmental degradation. The empirical relationship between carbon dioxide (CO2) emissions, financial development, and economic growth is a critical area of investigation for policymakers aiming to balance economic and environmental objectives. Despite numerous studies in different global contexts, the specific dynamics within South Africa remain underexplored. This study aims to examine the empirical relationship between carbon dioxide (CO2) emissions, financial development, and economic growth in South Africa, covering the period from 1965 to 2022.

This research aims to address the following key concerns. Primarily, how do carbon dioxide emissions, financial development, and economic growth interact in South Africa, and what implications do these interactions have for sustainable policy development? With the objective being that of empirically analyzing the interactions between CO2 emissions, financial development, and economic growth in South Africa over a specified period.

The study's additional objective is to identify causal relationships and potential feedback loops among these variables. What is the nature of the relationship between economic growth and CO2 emissions in South Africa? The academic investigation will additionally seek to find how financial development influences CO2 emissions and economic growth in South Africa. Does financial development facilitate investments in green technologies and sustainable practices, or does it lead to increased emissions due to industrial expansion? The research will moreover seek to provide policy recommendations that align financial development strategies with sustainable economic growth and environmental protection.

This study distinguishes itself from previous research by covering an extended period, focusing on different variables, and employing methodologies not used in some prior studies. Additionally, it examines whether the variables cause each other, exploring both bi-directional and uni-directional causality, whereas other studies have typically focused on the impact of multiple variables on a single variable.

Significance Of The Study; The knowledge of the complex link between South Africa's economic growth, financial development, and carbon emissions will be greatly improved by this research. The study closes a significant gap in the present literature by providing a thorough analysis that clarifies the interactions between these variables. The literature frequently ignores the simultaneous examination of these variables in the context of South Africa.

Due to the nation's distinct economic structure and environmental issues, it is particularly important to look at the empirical correlations between economic growth, financial development, and carbon emissions in South Africa. A sophisticated knowledge of the interplay between these factors is required given South Africa's substantial industrial base, reliance on fossil fuels for energy generation, and continuous financial development initiatives.

The findings from this study will offer valuable insights for policymakers aiming to balance economic development with environmental sustainability. By identifying the causal pathways and feedback loops between financial development, economic growth, and CO_2 emissions, the research will provide evidence-based recommendations for sustainable policy formulation. These insights will help in crafting strategies that promote financial and economic advancement while mitigating adverse environmental impacts, thus contributing to sustainable development goals in South Africa.

Scope, Limitations And Overview; This study examines the empirical relationship between carbon CO_2 emissions, financial development, and economic growth in South Africa, covering the period from 1965 to 2022. For the financial development variable, domestic credit to the private sector is used as a proxy due to the unavailability of comprehensive data for other financial development indicators.

The limitations of this study include the constraints imposed by data availability and reliability specific to South Africa, which may impact the robustness of the findings. The use of a single proxy for financial development might not capture the full complexity of financial sector dynamics. Additionally, the study does not account for all possible external factors and global economic conditions that could influence the relationships among the variables. Consequently, while the findings are pertinent to South Africa, their applicability to other developing economies with different contexts may be limited.

This thesis is organized into five chapters, each building upon the introduction to comprehensively address the research questions. Chapter 2 provides a literature review, examining existing studies on the relationships between economic growth, financial development, and CO_2 emissions, and identifying gaps that this study aims to fill. Chapter 3 outlines the research design, data sources, and analytical methods used to investigate the empirical relationships among the variables. Chapter 4 presents the results of the empirical analysis, discussing the findings in the context of South Africa's economic and environmental landscape. Chapter 5 concludes the thesis by summarizing the key findings, discussing their implications for policy and sustainable development, and providing recommendations for future research and policy actions.

CHAPTER ONE
LITERATURE REVIEW

The exploration of the correlation among economic growth, financial development and environmental pollution has been investigated in numerous studies. These inquiries vary widely in terms of econometric techniques employed, time frames studied, and geographical areas covered. This section aims to offer a concise overview of pertinent literature, emphasizing significant discoveries.

To provide a comprehensive understanding of the relationship between carbon dioxide emissions, financial development, and economic growth in South Africa, the literature review is structured into three main categories. Firstly, there are studies conducted that offer insights from a global perspective. Secondly, a review of studies conducted specifically within the context of South Africa providing a localized understanding of the phenomena. Finally, the contribution of the present study is discussed, emphasizing its significance in advancing knowledge and addressing gaps identified in the existing literature.

1.1 GLOBAL PERSPECTIVES ON THE TOPIC

This section provides an overview of empirical research conducted globally which is in relation to the relationship between carbon dioxide emissions, financial development, and economic growth. Studies in this category encompass investigations in various countries or regions beyond South Africa.

Pioneering the field, Kraft and Kraft (1978) conducted a groundbreaking analysis using United States (US) annual data from 1947 to 1974 to explore the causal relationship between gross national product (GNP) and energy consumption. Their study indicated a directional influence from economic growth to energy consumption. This insight holds relevance in understanding the interplay among economic growth and carbon emissions.

Öztürk and Acaravcı (2013) also conducted a significant and comprehensive examination of the causal relationship between financial development, trade, economic growth, energy consumption, and carbon emissions in Turkey spanning from 1960 to 2007. Employing the bounds F-test for cointegration, the study revealed a long-run relationship between per capita carbon emissions, energy consumption, real income, openness, and financial development, supporting the validity of the Environmental Kuznets Curve hypothesis in the Turkish economy. Notably, financial development showed no significant effect on per capita carbon emissions in the long run. Granger causality models further elucidated the causal links between the variables, highlighting a long-run causal relationship from energy consumption, real income, openness, and financial development to carbon emissions. Moreover, a short-run unidirectional causal relationship was observed from financial development to energy consumption and real income. The findings underscored the importance of financial reforms and efforts to reduce carbon emissions intensity in Turkey's sustainable development agenda, providing valuable insights for policymakers and researchers in other developing countries.

Mirza and Kanwal (2017), Khan et al. (2021), and Usman et al. (2022) conducted research offering insights into the intricate dynamics between economic development and environmental impact. Mirza and Kanwal (2017) conducted a dynamic causality analysis to explore the relationship between economic growth, energy consumption, and CO2 emissions in Pakistan. Utilizing Johansen-Julius co-integration test and ARDL approach, the study found evidence of bidirectional causality between energy consumption, economic growth, and CO2 emissions in both the short and long run. The results imply the importance of ensuring adequate energy supplies for sustained economic growth, suggesting a focus on increasing the share of renewable energy resources in the energy mix. Additionally, the study highlights the need for emission abatement activities to mitigate the environmental impact of CO2 emissions associated with economic growth.

Khan et al. (2021) conducted a study on the environmental impact of various factors including financial development, trade openness, economic growth, and energy consumption on carbon emissions in Bangladesh from 1980 to 2016. Utilizing the ARDL bounds testing co-integration method, their analysis revealed significant findings. They discovered that energy consumption had a notable effect on carbon emissions both in the short and long term, whereas the impact of economic development was mainly observed in the long term. Surprisingly, trade openness and financial development exhibited minimal influence on carbon emissions. In light of these results, the study recommended that the government of Bangladesh prioritizes the advancement of alternative energy sources to mitigate carbon emissions. Practical measures such as incentivizing the adoption of low-carbon technologies and imposing penalties for excessive coal consumption were suggested.

The impact of financial development, economic growth, trade openness, and energy consumption on carbon emissions in Pakistan from 1990 to 2017 was investigated by Usman et al. (2022) using the ARDL bound testing approach. They found evidence of a long-run relationship among the variables, with financial development and renewable energy contributing to improved environmental quality, while economic growth, non-renewable energy use, and trade openness led to environmental degradation. In the short run, non-renewable energy use and trade openness increased carbon emissions, while renewable energy sources improved environmental quality. Granger causality analysis revealed one-way causal relationships from economic growth, trade openness, and energy utilization to carbon emissions. The study suggested policy interventions such as promoting renewable energy adoption, introducing incentives for cleaner energy consumption, implementing carbon taxes, and increasing trade in eco-friendly products. Future research directions included considering more advanced time series methodologies for analysis.

Additionally, several studies have delved into the correlation between financial development and carbon emissions. Jiang and Ma (2019) examined the impact of financial development on carbon emissions from a global perspective. Utilizing a system generalized method of moments and data from 155 countries, they found that financial development is positively associated with carbon emissions globally and within emerging market/developing countries, but the relationship is insignificant in developed countries. They highlight the importance of considering the stage of development of a country when assessing this relationship, suggesting that the positive effect of financial development diminishes as countries develop further. The authors caution policymakers against assuming that financial development inherently leads to reduced carbon emissions and suggest prioritizing the development of the stock market over financial institutions as a means to limit carbon emissions. Their study offers valuable insights into the complex relationship between financial development and carbon emissions on a global scale, emphasizing the need for nuanced policy approaches tailored to different country contexts.

Tamazian and Rao (2010) conducted a study on the relationship between financial development and environmental degradation in transitional economies. Utilizing a system generalized method of moments (GMM) estimation and panel data from 24 transition economies spanning from 1993 to 2004, they observed that financial development plays a positive role in environmental disclosure and can potentially contribute to reducing carbon emissions. Similarly, Saidi and Mbarek (2016) explored the influence of financial development on carbon emissions across 19 emerging economies from 1990 to 2013 using a system GMM model. Their findings suggest that financial development has a long-term negative impact on carbon emissions, indicating its potential in minimizing environmental degradation.

Çetin and Ecevit (2017) conducted a comprehensive investigation into the impact of financial development on carbon emissions in Turkey from 1960 to 2011, considering economic growth, energy consumption, and trade openness. The study employed the Zivot-Andrews structural break test to assess the unit root properties of the variables and utilized the ARDL bounds test to analyze the long-run relationship among them, accounting for structural breaks. Furthermore, the Vector Error Correction Mechanism (VECM) Granger causality approach was applied to examine the direction of causality between the variables. The findings indicated a positive long-run relationship between financial development, economic growth, trade openness, and carbon emissions, supporting the finance-led environmental pollution hypothesis and the Environmental Kuznets Curve (EKC) hypothesis in Turkey. Additionally, Granger causality analysis revealed that financial development, economic growth, and trade openness Granger cause carbon emissions in the long run. The study suggests policy implications for the Turkish economy, including the encouragement of less carbon-intensive technologies through stable policy frameworks, promoting financial openness to incentivize businesses to adopt environmentally friendly technologies, and facilitating technological innovation and Research and Development (R&D) investments through the financial system to mitigate carbon emissions.

Omri et al. (2015) investigated the relationship between financial development and carbon emissions in 12 Middle East and North Africa (MENA) countries from 1990 to 2011 using a simultaneous-equation panel data model. Their study suggests that higher levels of financial system development may enhance energy conservation R&D input, leading to technological innovations and ultimately lowering carbon emissions. Moreover, Doğan and Şeker (2016) examined the long-run dynamic relationship between financial development and carbon emissions across 23 top renewable energy countries from 1985 to 2011 using dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) methods. They found evidence suggesting that financial development could reduce carbon emissions.

Tsaurai (2019) investigated the impact of financial development on carbon emissions in West African countries from 2003 to 2014 using pooled ordinary least squares (OLS), fixed effects, and random effects models. The study found that only domestic credit provided by the financial sector resulted in a significant increase in carbon emissions in West African countries. The study suggests implementing credit policies that ensure loans provided by the financial sector to domestic firms are used for acquiring environmentally friendly machinery and equipment to reduce carbon emissions.

Zaidi et al. (2019) explored the dynamic relationship of financial development and carbon emissions in the environmental Kuznets curve (EKC) framework across 17 Asia Pacific Economic Cooperation (APEC) countries from 1990 to 2016. Their analysis, employing continuously updated bias-corrected (CUP-BC) and continuously updated fully modified (CUP-FM) methods, revealed that financial development could reduce carbon emissions in both the long-run and short-run. Similarly, Zafar et al. (2019) found this conclusion to be valid for Organization for Economic Co-operation and Development (OECD) countries.

Abbasi and Riaz (2016) investigated the CO_2 emissions-financial development relationship in economies where the structural transformation of the financial sector is in its early stages. Using an augmented VAR approach, they analyzed long-run dynamics and causality direction through Granger causality and variance decomposition techniques. Results showed financial variables influencing emissions mitigation, especially in later periods of financial sector development. Per capita CO_2

emissions were co-integrated with financial indicators and GDP, with GDP per capita and stock turnover significantly impacting emissions. Economic growth and financial sector development were found to increase emissions, with stock market development alleviating liquidity constraints. In the full sample, only FDI Granger caused emissions, while in the reduced sample, private sector credit and stock turnover had significant impacts. These findings emphasize the role of financial sector maturity in achieving desirable environmental outcomes.

Moreover, numerous studies have explored the relationships between, including economic growth, financial development and carbon emissions, alongside with additional factors. Fan and Hao (2020) conducted a groundbreaking study examining the interplay among renewable energy consumption, economic growth, and foreign direct investment (FDI) in China from 2000 to 2015. Employing diverse statistical techniques, impulse response function analysis, and Granger causality tests, the study revealed a persistent equilibrium relationship among gross domestic product (GDP) per capita, FDI per capita, and renewable energy consumption per capita over the long term. Notably, while FDI had minimal short-term impact on renewable energy consumption, targeted FDI strategies coupled with a modest GDP growth slowdown significantly enhanced renewable energy utilization in the long run. These findings underscore the pivotal role of calibrated FDI policies and sustainable energy initiatives in fostering both economic development and environmental sustainability in China.

A comprehensive meta-regression analysis to scrutinize the impact of financial development on CO2 emissions, synthesizing data from 72 primary studies encompassing 275 estimation results was conducted by Gök (2020). Despite substantial heterogeneity among reported effect sizes, the analysis revealed a significant positive empirical effect of financial development on CO2 emissions, indicative of environmental degradation. The study underscored the influence of various factors, including financial indicators, estimation techniques, country/regional contexts, and time periods, on the magnitude and direction of this effect. Notably, financial development was found to exacerbate carbon emissions primarily through increased energy consumption and industrialization, with more pronounced detrimental effects observed in countries like Brazil, Greece, Nigeria, Tunisia, Turkey, and Vietnam. The findings suggest the necessity for close monitoring of financial indicators and the implementation of green trading policies, emphasizing renewable energy use, to mitigate the adverse environmental impacts of financial development.

Koondhar et al. (2021) conducted a comprehensive investigation into the relationship between carbon emissions, renewable energy consumption, forestry, and agricultural financial development in China from 1998 to 2018. Employing auto-regressive distribution lag models for correlation analysis, the study unveiled that increases in forest areas significantly decrease carbon emissions both in the short and long run, while renewable energy consumption inversely correlates with carbon emissions in the short term. Conversely, agricultural financial development exhibits a positive correlation with carbon emissions in the short term. The study further confirmed unidirectional causality running from renewable energy consumption, agricultural financial development, and forestry to carbon emissions, highlighting the imperative of transitioning from nonrenewable to renewable energies and promoting organic fertilizer consumption alongside afforestation to mitigate carbon emissions and foster environmental sustainability. The study's implications underscore the importance of governmental initiatives to incentivize investments in renewable energy, promote organic farming practices, and support afforestation efforts to address climate change and enhance food security while contributing to economic growth.

Mukhtarov et al. (2022) conducted a comprehensive analysis of the impact of financial development on renewable energy consumption in Turkey from 1980 to 2019. Utilizing VECM and ARDL techniques, the study explored the influence of financial development, economic growth, and energy prices on energy use. Results revealed a positive and statistically significant relationship between financial development and renewable energy consumption, indicating that a 1% increase in financial development leads to a 0.21% rise in renewable energy consumption. This finding highlighted the importance of financial stability, transparency, and accessibility in promoting renewable energy usage. The study suggested that understanding the role of financial development in renewable energy consumption can assist Turkey in building a sustainable energy industry and reducing reliance on imported fossil fuels.

In their study, Grabara et al. (2021) investigate the relationship between foreign direct investment (FDI), economic growth, and renewable energy consumption (REC) in Kazakhstan and Uzbekistan from 1992 to 2018. The findings reveal a two-way link between FDI and REC in both countries, with significant long-run causalities from REC and FDI. Increased electricity consumption drives the extension of renewable energy, while economic growth exhibits a negative growth hypothesis for Kazakhstan and neutrality for Uzbekistan in relation to REC. Additionally, FDI negatively impacts the share of renewable energy, possibly due to the dominance of coal, oil, and gas investments. The study emphasizes the role of policy in transitioning to sustainable energy consumption, advocating for public finance, strategic roadmaps for infrastructure development, and the stimulation of foreign direct investment in renewable energy. Moreover, it highlights the need for long-term financing and state-wide industry development programs to facilitate the transition to green energy and modernize industrial structures in Kazakhstan and Uzbekistan.

Several studies have delved into the intricate relationship between economic growth, financial development, and carbon emissions. Shahbaz et al. (2013) conducted an extensive analysis of the relationship between economic growth, energy consumption, financial development, trade openness, and CO_2 emissions in Indonesia from 1975 to 2011. Employing the ARDL bounds testing approach and VECM Granger causality technique, the study found evidence of cointegration among the variables even in the presence of structural breaks. Results indicated that economic growth and energy consumption contribute to CO_2 emissions, while financial development and trade openness mitigate them. Bidirectional causality was observed between energy consumption and CO_2 emissions, and feedback hypothesis was validated between CO_2 emissions and trade openness. Financial development was found to Granger cause energy consumption, economic growth, and trade openness. The study suggested promoting energy-efficient technologies to mitigate carbon emissions without sacrificing economic growth, and advocates for financial sector involvement in funding environmentally friendly technologies.

The impact of energy use, economic growth (EG), and financial development (FD) on CO_2 emissions in selected Association of South East Asian Nations (ASEAN) countries from 2000 to 2018 was investigated by Nawaz et al. (2020). Utilizing various econometric techniques, they found mixed orders of integration among the variables and confirmed the presence of cointegration. Employing Dynamic Ordinary Least

Squares (DOLS), Fully Modified Ordinary Least Squares (FMOLS), and Panel Mean Group (PMG) estimators, the study revealed a positive effect of economic growth, energy consumption, and financial development on CO2 emissions. This suggests that an increase in financial development leads to higher energy use, subsequently resulting in increased CO2 emissions in the ASEAN countries. The study emphasized the need for policy interventions to address climate challenges and predicted future economic indicators post-oil era. Given the rising sea levels and environmental damage, ASEAN nations are urged to reduce carbon emissions through a policy mix and invest significantly in research and development of clean energy technologies to meet renewable energy targets and combat climate change effectively.

Jian et al. (2019) examined the nexus between economic growth, financial development, energy consumption, and CO2 emissions in China from 1982 to 2017. Using Johansen cointegration and vector error correction modeling (VECM), the study found a long-term cointegration relationship among these variables. Granger causality tests revealed a short-term positive effect of CO2 emissions on energy consumption, economic growth, and financial development, while economic growth and financial development were identified as Granger causes for energy consumption. Impulse response analysis indicated a positive two-way causal relationship between CO2 emissions and energy consumption, with financial development promoting CO2 emissions in the short term. However, economic growth was found to curb CO2 emissions in the long run. Policy recommendations included promoting financial innovation, optimizing energy structure, improving energy efficiency, encouraging renewable energy, and implementing market-based measures such as carbon trading to foster sustainable development in China.

Al-mulali and Sab (2012) conducted a study on thirty Sub Saharan African countries to examine the impact of energy consumption and CO2 emissions on GDP growth and financial development. Using a panel model from 1980 to 2008, the results indicated that energy consumption significantly contributed to both economic growth and financial development, albeit with increased pollution. The study recommended strategies such as enhancing energy efficiency, implementing energy savings projects, and increasing investment in energy infrastructure to achieve sustainable financial development and GDP growth. The findings emphasized the need for these countries to prioritize energy productivity enhancement and increase investment in energy projects to fully harness their energy potential.

Emenekwe et al. (2021) conducted a comprehensive analysis of the relationship between financial development (FD), economic growth, and carbon CO2 emissions across 37 Sub-Saharan African (SSA) countries from 2000 to 2016. Utilizing second-generation analytical techniques, the study revealed that overall FD significantly reduces CO2 emissions in the region, aligning with the environmental Kuznets curve (EKC) hypothesis. Specifically, a 1-unit increase in the overall FD index led to a 2.867% reduction in CO2 emissions in the long run. Furthermore, the study identified a bi-directional causality between FD and CO2 emissions. While the financial market index (including access and efficiency dimensions) contributed to CO2 emission reduction, financial institution development showed no significant impact. The findings conveyed the importance of prioritizing financial market access and efficiency to maximize CO2 emission reduction potential, while also advocating for policies to promote investment in environmentally friendly projects. The study's policy implications extended beyond SSA countries to other developing regions, emphasizing the need for tailor suited approaches considering various dimensions of financial development and their differential effects on carbon emissions.

Li et al. (2021) conducted an empirical study on the relationship between CO2 emissions, financial development, and economic growth in Brazil, Russia, India, China, and South Africa. (BRICS) countries over the past 40 years. Utilizing cointegration tests and quantile regression methods, they found a clear correlation between the variables in China and South Africa, indicating a two-way relationship between CO2 emissions, financial development, and economic growth in these countries. Additionally, the study revealed that at the 0.6th quartile, South Africa’s financial development had a negative impact on CO2 emissions, while Brazil’s CO2 emissions had a negative impact on financial development. Furthermore, India’s financial development showed the strongest impact on CO2 emissions in the low quantile, suggesting an improvement in environmental emissions with financial development. The findings presented the need for BRICS countries to focus on sustainable economic development and consider the relationship between financial development and emission-reduction policies when formulating environmental policies.

1.2 STUDIES ON SOUTH AFRICA

This section reviews existing literature specifically focusing on South Africa regarding the relationship between carbon dioxide emissions, financial development, and economic growth. It synthesizes findings from studies conducted within the South African context, highlighting unique factors and dynamics relevant to the country.

Bah and Azam (2017) examine the causal relationship between electricity consumption, economic growth, and CO2 emissions in South Africa from 1971 to 2012. Employing the Autoregressive Distributed Lag (ARDL) bounds test and Toda and Yamamoto augmented Granger causality test, the study confirms the existence of cointegration among the variables and finds no causality between electricity consumption and economic growth, supporting the neutrality hypothesis. However, it identifies unidirectional causality from CO2 emissions to electricity consumption and from financial development to CO2 emissions. The study conveyed the need for increased investment in the electricity sector to ensure reliability of supply and advocates for tapping into South Africa's renewable energy potential to address environmental concerns and promote sustainable economic growth.

The study by Atsu et al. (2021) investigated the relationship between Information and Communication Technology (ICT), energy consumption, financial development, and CO2 in South Africa from 1970 to 2019, with a focus on controlling for financial development effects. Employing various estimators, including ARDL, DOLS, and FMOLS, the findings reveal that ICT and fossil fuel consumption exacerbate CO2 emissions, while renewable energy consumption and financial development mitigate them. Specifically, a 1% increase in ICT activities leads to a 0.565% rise in CO2 emissions in the long term, with 93.20% of any temporary shock to this relationship corrected over time. The study highlights South Africa's advanced ICT infrastructure and significant carbon emissions contribution globally, prompting the examination of ICT's role in environmental mitigation. Furthermore, it discusses South Africa's unique position as the largest economy in sub-Saharan Africa, heavily reliant on fossil fuels, and emphasizes the importance of financial development in promoting green technologies.

Odhiambo's (2012) study investigated the causal relationship between CO2 emissions and economic growth in South Africa, employing the ARDL-Bounds testing approach and incorporating energy consumption in a trivariate model from 1970 to 2007. The findings revealed a distinct unidirectional causal flow from economic growth to CO2 emissions in South Africa, with energy consumption Granger-causing both CO2 emissions and economic growth. Despite South Africa's high carbon dioxide emissions, the country's status as a "Non-Annex 1 Country" under the Kyoto protocol exempts it from emission reduction targets. Nevertheless, South Africa is pursuing policies to mitigate emissions and explore renewable energy sources. The study underscores the importance of energy conservation policies and renewable energy exploration to reduce carbon emissions without compromising output growth.

Shahbaz et al. (2013) investigated the impact of financial development, economic growth, coal consumption, and trade openness on CO2 emissions in South Africa from 1965 to 2008. Using the ARDL bounds testing approach and error correction method, the study establishes a long-run relationship among the variables, confirming that economic growth escalates energy emissions while financial development mitigates them. Coal consumption significantly contributes to environmental degradation, whereas trade openness improves environmental quality. Additionally, the study identifies the existence of an environmental Kuznets curve, suggesting that South Africa can sustain economic growth while controlling environmental degradation through efficient energy use. The findings underscored South Africa's unique position with high economic growth, substantial energy-related emissions, and robust financial infrastructure. Notably, the study did reveal the crucial role of financial development in reducing energy pollutants, indicating the potential for financial reforms to enhance environmental quality. Furthermore, policies promoting trade openness and financial openness could attract foreign direct investment in research and development, leading to technological innovations that mitigate environmental degradation.

1.3 CONTRIBUTION OF THE PRESENT STUDY

This section outlines the contribution of this paper to the existing body of literature. It discusses the significance of this research in extending understanding and provides insights into the dissimilarity of the research topic. Building upon prior research in the field, this study extends the analysis to encompass a broader data period and employs advanced econometric techniques to deepen our understanding of the relationships between economic growth, financial development, and carbon emissions in South Africa.

The current study aims to investigate the long-term empirical relationship between economic growth, financial development, and carbon emissions. Specifically, it focuses on analyzing the relationship using a time series approach from 1965 to 2022. The study employs the Auto-Regressive Distributed Lag (ARDL) Model through the analysis of correlation, cointegration, Granger causality and diagnostics.

While existing literature often explores the relationships between economic growth, financial development, and emissions across various countries or regions, this thesis uniquely narrows its scope to South Africa. Additionally, while the core variables examined; economic growth, financial development, and emissions may align with those in other studies, this research extends beyond merely assessing direct relationships. By exploring the bidirectional causal links between economic growth, financial development, and emissions, this study provides a more comprehensive understanding of the complex interplay between these factors within the South African context.

In contrast to Bah and Azam (2017) study, which examines the causal relationship between electricity consumption, economic growth, and CO2 emissions in South Africa from 1971 to 2012, this research focuses specifically on the relationship between carbon dioxide emissions, financial development, and economic growth in South Africa over the extended period of 1965 to 2022.

Bah and Azam (2017) employed the ARDL bounds test and Toda and Yamamoto augmented Granger causality test to explore causality among electricity consumption, economic growth, financial development, and CO2 emissions, this study emphasizes financial development rather than electrical consumption. This paper utilizes methodologies similar to Bah and Azam (2017) but applies them to a different set of variables, emphasizing carbon emissions, financial development, and economic growth.

Unlike the research by Atsu et al. (2021), which looks at the relationship between ICT, energy consumption, financial development, and CO2 emissions in South Africa between 1970 and 2019, this investigation focuses on the relationship between CO2 emissions, financial development, and economic growth in the context of South Africa. Whereas Atsu et al. use a wider variety of variables, including energy consumption and information and communications technology, in their analysis.

There are differences in this scholarly inquiry considered are financial development and economic growth as CO2 emissions predictors, delving beyond the analysis of ICT and energy usage to offer a more focused look at the factors that influence CO2 emissions in South Africa from an economical and financial activity perspective. This makes it possible to get a more detailed knowledge of the precise mechanisms by which economic growth and financial development affect environmental outcomes in the South African context, providing insights that are specifically suited to the opportunities and difficulties that this particular setting presents.

In contrast to Odhiambo (2012) who focused on the causal relationship between CO2 emissions and economic growth in South Africa. Odhiambo (2012) primarily incorporates energy consumption in a trivariate model. This current analysis however, deviates firstly by delving into a broader scope by examining the interplay between carbon dioxide emissions, financial development, and economic growth in the same context. Secondly, Odhiambo (2012), covers the 1970 and 2007 period whereas this study entails data from 1965 to 2022.

Thirdly, this research further differs in that it extends the analysis to include the role of financial development alongside economic growth in influencing carbon emissions. By incorporating financial development, the analysis aims to provide a comprehensive understanding of the drivers of carbon emissions in South Africa, considering both economic and financial dimensions. This broader perspective offers insights into how financial sector development interacts with economic growth to shape carbon emissions patterns, thereby contributing to a more nuanced understanding of the factors driving environmental degradation in South Africa.

Differing from the study done by Shahbaz et al. (2013b), which primarily focused on the period up to 2008 and utilized specific methodologies, this research extends the analysis to include data up to 2022 and employs a combination of ARDL, Granger causality tests, and Wald coefficient tests to offer a more comprehensive examination of the complex interplay between economic growth, financial development, and carbon emissions in South Africa.

This research endeavor also exhibits differences in the scope, methodology, and analytical approach. Firstly, the methodological and analytical approaches differ between the two studies. While Shahbaz et al. (2013b) employs the ARDL bounds testing approach, error correction method (ECM), and unit root tests, this piece of research adds Granger causality and Wald coefficient tests to investigate causal relationships among variables. These additional techniques offer a more sophisticated analysis, allowing for a deeper understanding of the complex interdependencies between economic growth, financial development, and environmental impact.

Secondly, Shahbaz et al. (2013b) exclusively examined the relationships of economic growth to CO2 emissions, financial development (FD) to emissions, coal consumption to emissions, and trade openness to emissions. This indicates a focus solely on testing the effects of these variables on emissions. In contrast, this paper expands this scope by investigating the relationships of economic growth to emissions, financial development to emissions, and additionally explores the interactions between economic growth and financial development. Specifically, examined in this research work is the relationships of economic growth to financial development, financial development to economic growth, emissions to financial development, and emissions to economic growth. This broader approach allows for a more comprehensive understanding of the dynamics between these factors.

Overall, this study enhances the literature by extending the data period, employing advanced econometric techniques, and examining both unidirectional and bidirectional causality among GDP, financial development, and CO2 emissions. These methodological advancements and analytical insights contribute to a more comprehensive understanding of the relationships driving sustainable development in South Africa, distinguishing the study from prior research in the field.

CHAPTER TWO
DATA AND METHODOLOGY

The aim of this chapter is to detail the data sources, variables, and methodology employed in the study to investigate the relationship between Carbon Dioxide Emissions, Financial Development and Economic Growth İn South Africa. This includes a comprehensive description of the time period under consideration, the chosen variables, their measurements, and the methodology utilized, primarily focusing on the Auto-Regressive Distributed Lag (ARDL) model. Additionally, this chapter elucidates the rationale behind the selection of the ARDL model, its implementation process, and associated tests such as correlation analysis, stationarity tests, and Granger causality analysis. Through this exposition, the chapter seeks to provide a robust foundation for subsequent analyses and interpretation of results in the pursuit of understanding the interplay between economic development, financial dynamics, and environmental sustainability in the South African context.

2.1 DATA DESCRIPTION

This section aims to outline the methodology employed in this study, focusing on the selected time period and variables, including GDP per capita, domestic credit to the private sector (FD) as a proxy for financial development, and per capita carbon dioxide emissions (CO2). This section provides a clear understanding of the data sources, transformations, and rationale behind the chosen approach.

2.1.1 Time Period

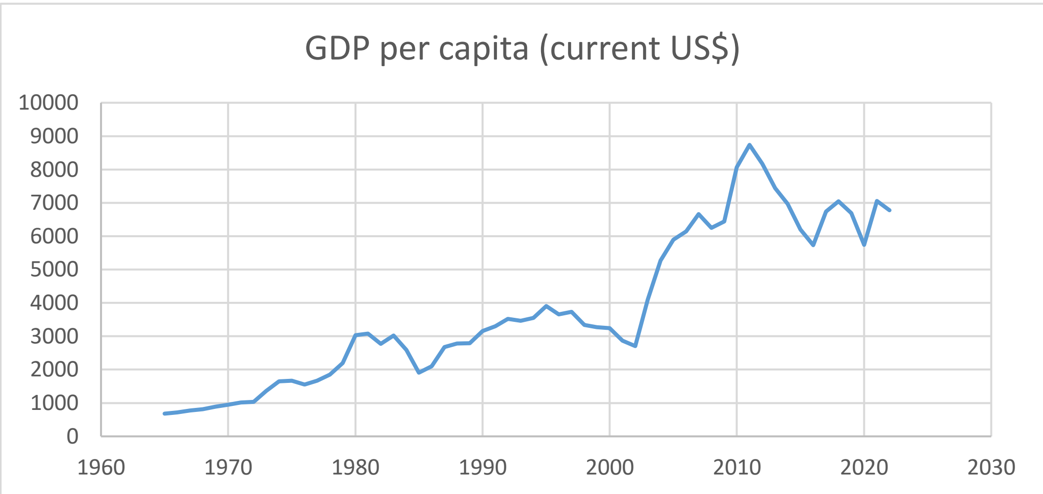
This study employs a time series approach from the period of 1965 to 2022. Since there were no more current data available for the variables, this specific time period was selected as the necessary data was available. According to Enders (2014), a time series is a collection of consecutive observations of a given variable made at regular intervals over an extended period of time. The most popular frequency ranges for time series are yearly, quarterly, monthly, weekly, and daily. Economic time series data frequently have distinctive characteristics, such as a distinct trend, a high degree of shock persistence, increased volatility with time, and a meandering pattern that shares co-movements with other series.

2.1.2 Variables

The considered variables in the study are: GDP per capita (GDP), domestic credit to the private sector as a proxy for financial development denoted as FD, and per capita carbon dioxide emissions (CO2). To adjust for variations in variables resulting from alterations in population composition, the variables' per capita basis for GDP and CO2 were obtained.

GDP per capita is the gross domestic product divided by midyear population. GDP is the most widely used measure of a country’s economic activity and growth. The GDP data is retrieved from the World Development Indicators of World Bank database and is expressed in current US$. It provides a thorough summary of economic performance in relation to each individual. This data is essential in order to evaluate the productivity and economic well-being of the South African population. Figure 3 shows the variable on a graph (World Bank Open Data, 2023).

Figure 3: Gross Domestic Product per Capita



Source: World Bank Open Data, 2023.

Domestic credit to private sector data was obtained from the World Bank database under the World Development Indicators and is expressed as a percentage of GDP. Domestic credit to the private sector denotes the financial support extended to private enterprises by financial entities. This assistance encompasses activities such as providing loans, acquiring non-equity securities, offering trade credits, and managing other accounts receivable, all of which establish a basis for repayment. In certain instances, these financial claims may encompass credit extended to public enterprises. The entities involved in these financial transactions comprise monetary authorities, deposit money banks, and other financial corporations, including those not accepting transferable deposits but incurring liabilities such as time and savings deposits. Examples of such financial entities encompass finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies (World Bank Open Data, 2023).

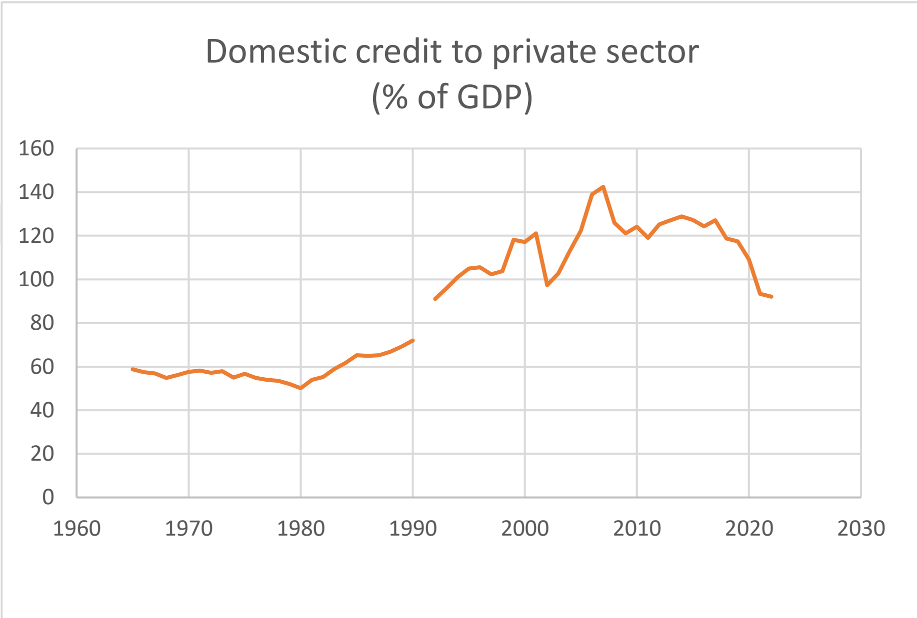
This metric reflects the multifaceted nature of financial interactions involving monetary authorities, deposit money banks, and various other financial entities, providing a comprehensive view on the financial landscape's development and dynamics. Since it encompasses financial resources directed to private enterprises, including loans, non-equity securities, trade credits, and other receivables, domestic credit to the private sector is employed as a proxy when examining financial development within the context of this study.

For the year 1991, the dataset on domestic credit to the private sector contains an absent entry. Bah and Azam (2017) addressed the missing observation by employing the linear interpolation method. Figure 4 shows the domestic credit to the private sector data set retrieved from the World Development Indicators and Figure 5 conveys the linear interpolated domestic credit to the private sector data variable.

Carbon emissions per capita (CO2 per capita) data was taken from the worldwide carbon project. The emissions of an average individual in a nation or area are represented in tonnes per person and are computed by dividing the total carbon dioxide (CO2) emissions by the population.

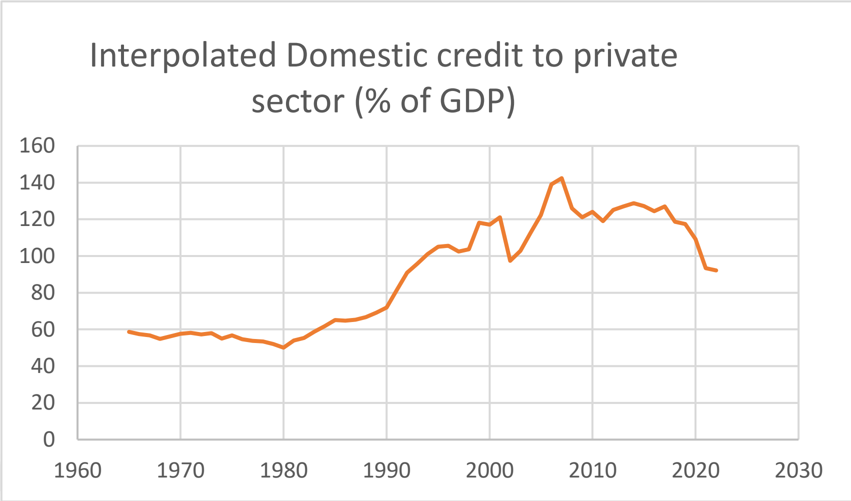
The variable represents the amount of CO2 released both directly from industrial operations like the manufacturing of steel and cement, as well as from the combustion of fossil fuels. Emissions from coal, oil, gas, flaring, cement, steel, and other industrial activities are included in the CO_2 per capita calculation. Deforestation, changes in land use, soils, and vegetation are not included in the variable. These numbers do not account for exchanged commodities because they show production based emissions.

Figure 4: Domestic credit to private sector (% of GDP)



Source: World Bank Open Data, 2023.

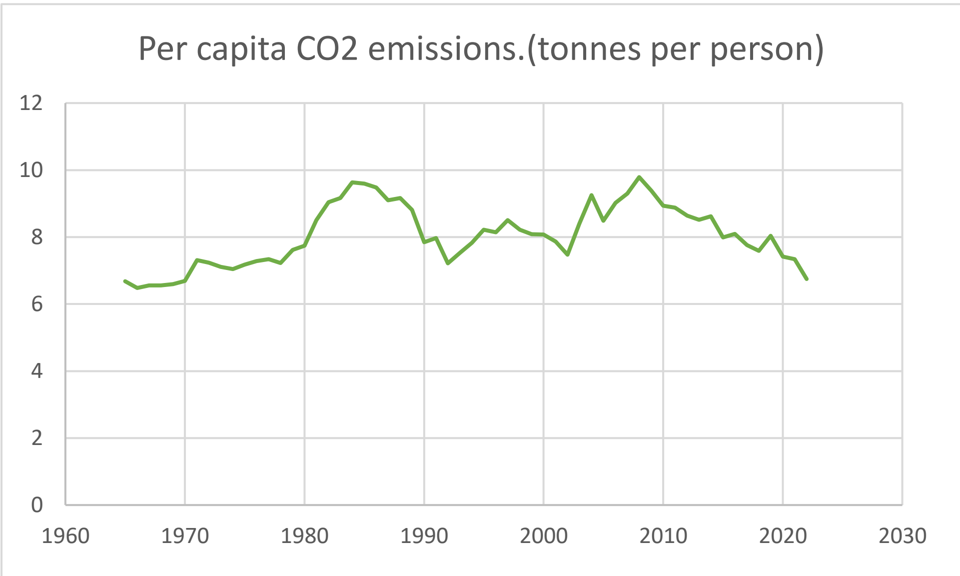
Figure 5: Interpolated Domestic credit to private sector (% of GDP)



Source: World Bank Open Data, 2023.

A common method for comparing nations' contributions to climate change is to use annual emissions estimates. However, this measure frequently takes global population disparities into account as well. Figure illustrates per capita emissions on a chart, to provide an understanding of the typical South Africa's carbon footprint.

Figure 6: Per capita CO2 Emissions In Tonnes Per Person



Source: World Bank Open Data, 2023.

Every variable is converted into its natural logarithm form. This adjustment serves to mitigate fluctuations in the data series, facilitating the measurement of approximate growth rates through the consideration of logarithmic differences. They are denoted as lnGDP for the natural log of GDP, lnFD for the natural log of the interpolated domestic credit to the private sector as a proxy for Financial Development and lnCO2 as the natural log of carbon emissions respectfully.

2.2 METHODOLOGY

This section aims to clarify the methods used in this research, with a specific focus on the Auto-Regressive Distributed Lag (ARDL) model. The main analytical method for evaluating possible long-term correlations between variables, such as financial development and economic growth, is the ARDL model. This part also tries to outline the Granger causality analysis, cointegration analysis, correlation analysis, and stationarity analysis that were carried out during the investigation.

2.2.1 Auto-Regressive Distributed Lag (ARDL)

An ordinary least squares (OLS) based model that may be used for both non-stationary and mixed order of integration time series is the autoregressive distributed lag (ARDL) model. The Autoregressive Distributed Lag (ARDL) limits test is a technique used to evaluate whether long-term relationships exist between variables. Cointegration analysis is frequently used in conjunction with this test. If cointegration is present, the number of cointegrating relationships can be evaluated using the ARDL limits test (Pesaran, Hasem, & Pesaran, 1997).

According to Shrestha and Bhatta (2018), this model can be considered because data from time series may be related to its prior values in some way. The time series model's autoregressive (AR) feature shows that each variable's current value is based on its historical value as well as a few adjusting factors. These adjustment factors are calculated using the relationship between the present and historical values.

This paper employs the ARDL model and presents the findings. The study explores the relationship between financial development and the economic growth and its effect on carbon emissions in South Africa. The study gives an explanation and convey the diagnostics of the ARDL model within the above mentioned relationship.

According to Gujarati (2019), when following the ARDL model the model should be correctly specified. Additionally, correlation, stationarity, cointegration and model diagnostics should be tested. The tables of correlation show how the variables are related to one another. The time series are either stationary or can be changed to become stationary. This stationarity is determined using the enhanced Dickey-Fuller unit root test, which was validated by the Philips Perron unit root test.

The model's specifications based on the cointegration findings and lag distribution, helps develop the ARDL model. The specification also indicates which variables are independent and dependent. To determine the long-term connections between variables. In this paper the bounds test for cointegration is employed. Using diagnostic tests for problems like heteroscedasticity and autocorrelation, the model's quality of fit is evaluated.

2.2.2 Correlation and Stationary Tests

The use of correlation analysis is one way to gauge the relationship between variables. The Pearson correlation coefficient is used in this investigation. The statistical link between the variables will be shown by the coefficient.

A time series' stationarity is evaluated using unit root tests. The concept of stationarity indicates that the distribution form is unaffected by changes in time. When unit roots within the series are found, non-stationarity is assumed. To determine whether unit roots are present, a number of tests are used, as recommended by Elliott et al. (1996).

Kwiatkowski et al. (1992a, 1992b) imply that the choice to accept or reject a unit root depends on the informativeness of economic time series or the restricted efficacy of typical unit root tests versus relevant alternatives. An essential first step in analysis is to determine if a time series is stationary. However, the presence of a trend component makes the series non-stationary in many observed series.

The initial phase of causality analysis involves conducting stationary tests to ascertain the integration levels of variables, ensuring they are either integrated at level value I(0) or in their first differences I(1) and not at their second difference I(2). This research utilizes both the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron test to validate the dependability of outcomes.

The ADF test is specified as:

$$\Delta x_t \ = \alpha + \beta_t + \delta x_{t-1} + \sum_{i=1}^{k} y_i \, \Delta x_{t-1} \ + \varepsilon_t$$

(2.1)

The variable under test is x, the differenced operator is Δ, the white noise residual is ε_t , and the parameters, $\{ \beta, \delta, y_i \}$ are all represented in the equation above (Asteriou & Hall, 2006).

The ADF test and the Phillips-Perron (PP) test, on the other hand, differ significantly. The ADF test relies on statistically independent error terms with constant variance, whereas the PP test makes less stringent assumptions about the error distribution. It provides a robust alternative for testing stationarity (Asteriou & Hall, 2006).

The PP test regression equation is as follows:

$$\Delta y_{t-1} \ = \ \alpha_t + \delta y_{t-1} + \varepsilon_t$$

(2.12)

When a time series exhibits a unit root issue however its first difference has no unit root, this suggests that the first differences of the time series may be the solution of the unit root problem. According to MacDonald (2015), the sequence of changes from one period to the next is called the first difference in a time series. For instance, if the value of the time series Y at period t is indicated by Y_t , then the first difference of Y at time t will be $Y_t - Y_{t-1}$. To deliver findings, a variety of econometric analysis techniques for time series are employed. In this study the Augmented Dickey-Fuller test will be used to formally test the stationarity, this will be confirmed by the Phillips-Perron test which is also a formal unit root test.

For both the ADF and the PP tests the following hypothesis is adopted:

H0: Variables are non-stationary

H1: Variables are stationary.

2.2.3 Test for Cointegration

The Bounds test of cointegration, also known as the ARDL and developed by Pesaran, Shin, and Smith (2001), will be used to assess cointegration in this study. There are numerous notable advantages associated with employing the ARDL approach in comparison to alternative cointegration tests.

First, the variables can be integrated at order zero (I(0)), order one (I(1)), or a mix of both. In either case, the ARDL approach still works. Second, in contrast to the Johansen cointegration test, it is especially appropriate for small sample sizes. Thirdly, the ARDL approach offers unbiased long-run estimates even in cases where some of the variables are endogenous (Pesaran, Shin, and Smith, 2001).

To perform the bounds test for cointegration the conditional ARDL (p, q1, q2) is specified as follows:

ARDL Equation 1:

$$\begin{aligned}\Delta lnGDP_t \; = \alpha_{10} + \beta_{11} lnGDP_{t-1} + \beta_{12} lnFD_{t-1} + \beta_{13} lnCO2_{t-1} \\ + \sum_{i=1}^{p} A_{11} \Delta lnGDP_{t-i} + \sum_{i=1}^{q1} A_{12} \Delta\, lnFD_{t-i} + \sum_{i=1}^{q2} A_{13} \Delta lnCO2_{t-i} \\ + e_{1t}\end{aligned} \tag{2.13}$$

ARDL Equation 2:

$$\begin{aligned}\Delta lnFD_t \; = \alpha_{20} + \beta_{21} lnGDP_{t-1} + \beta_{22} lnFD_{t-1} + \beta_{23} lnCO2_{t-1} \\ + \sum_{i=1}^{p} A_{21} \Delta lnGDP_{t-i} + \sum_{i=1}^{q1} A_{22} \Delta\, lnFD_{t-i} + \sum_{i=1}^{q2} A_{23} \Delta lnCO2_{t-i} \\ + e_{2t}\end{aligned} \tag{2.14}$$

ARDL Equation 3:

$$\Delta lnCO2_t = \alpha_{30} + \beta_{31} lnGDP_{t-1} + \beta_{32} lnFD_{t-1} + \beta_{33} lnCO2_{t-1} + \sum_{i=1}^{p} A_{31} \Delta lnGDP_{t-i} + \sum_{i=1}^{q1} A_{32} \Delta\, lnFD_{t-i} + \sum_{i=1}^{q2} A_{33} \Delta lnCO2_{t-i} + e_{3t} \quad (2.15)$$

In equations 2.13, 2.14, and 2.15, GDP is the Gross Domestic Product per individual in South Africa expressed in current US dollars. FD is the domestic credit to the private sector which is used as a proxy for financial development. Baha & Azam (2017) used domestic credit to the private sector as a proxy for financial development. CO2 is the Carbon dioxide emissions per capita (in US tons) for South Africa. A_{11}, A_{12}, A_{13}, A_{21}, A_{22}, A_{23}, A_{31}, A_{32}, A_{33} are the short run coefficients and β_{11}, β_{12}, β_{13}, β_{21}, β_{22}, β_{23}, β_{31}, β_{32}, β_{33} are the Long Run Coefficients. The first differenced operators are represented by Δ , the constant terms are α_{30}, α_{30}, α_{30}. The error terms are e_{1t} , e_{2t} , e_{3t} .

After specifying the Conditional ARDL testing the lagged variables for joint significance is the next step. This will be tested in the equations (2.13, 2.14 and 2.15) using the F-test. The F-test will then be compared to the critical values once it has been calculated. Narayan's (2005) critical values, which are created especially for small sample sizes, are used in this study.

When the estimated F-statistic is less than the lower bound critical value the null hypothesis is accepted and suggests that there is no cointegration. On the other hand, if the upper bound is exceeded, cointegration between the variables is indicated and the null hypothesis is rejected. On the other hand, if the F-statistic lies between the ranges marked by the lower and higher limits, then cointegration is not assured (Narayan, 2005).

Hypothesis:

H0: $\beta_{11} = \beta_{12} = \beta_{13} = \beta_{21} = \beta_{22} = \beta_{23} = \beta_{31} = \beta_{32} = \beta_{33} = 0$: No Cointegration

H1: $\beta_{11} = \beta_{12} = \beta_{13} = \beta_{21} = \beta_{22} = \beta_{23} = \beta_{31} = \beta_{32} = \beta_{33} \neq 0$: Cointegration

2.2.4 Granger Causality Analysis

Granger causality tests are used to examine whether the past values of one variable help predict another variable, indicating a potential causal relationship. The test is based on the idea that if variable X Granger-causes variable Y, past values of X should contain information that helps predict Y. The Granger causality test is applied to indicate if one variable's past values provide significant predictive power for another variable. This analysis helps discern whether a causal relationship exists between the variables and the directionality of causation (Granger, 1969).

Granger causality analysis is employed in this study to explore the temporal precedence and potential causal relationships among variables. This study, investigates the presence of Granger causality among carbon dioxide emissions, financial development, and economic growth in South Africa. The results of the Granger causality tests will be presented, indicating the presence or absence of causal relationships between carbon dioxide emissions, financial development, and economic growth in South Africa.

Specifically explored is the directional causality between financial development and economic growth, assessing whether one variable's past values predict changes in the other variable. Additionally, the examination of whether past values of carbon dioxide emissions Granger-cause changes in financial development indicators, and vice versa. Furthermore, the analysis investigates whether past emissions levels Granger-cause changes in economic growth, and vice versa.

The findings from the Granger causality analysis will provide insights into the dynamic interactions among carbon dioxide emissions, financial development, and economic growth in South Africa. The empirical findings and interpretations will be conveyed to depict the relationships between environmental sustainability, financial sector development, and economic prosperity in the context of South Africa.

Wooldridge (2019) outlines that in the Granger Causality analysis the Vector Auto Regressive (VAR) short run model should be adequately specified, the optimal lag determined, the causality tests conducted and finally the diagnostics such as normality, stability and serial correlation tests performed.

The short run VAR Models are specified as follows:

VAR Equation 1:

$$lnGDP_t = \alpha_{11} + \sum_{i=1}^{k} \beta_i lnGDP_{t-1} + \sum_{j=1}^{k} \emptyset_j \, lnFD_{t-j} + \sum_{m=1}^{k} \varphi_m \, lnCO2_{t-m} + u_{1t} \tag{2.16}$$

VAR Equation 2:

$$lnFD_t = \alpha_{12} + \sum_{i=1}^{k} \beta_i lnGDP_{t-1} + \sum_{j=1}^{k} \emptyset_j \, lnFD_{t-j} + \sum_{m=1}^{k} \varphi_m \, lnCO2_{t-m} + u_{2t} \tag{2.17}$$

VAR Equation 3:

$$lnCO2_t = \alpha_{13} + \sum_{i=1}^{k} \beta_i lnGDP_{t-1} + \sum_{j=1}^{k} \emptyset_j \, lnFD_{t-j} + \sum_{m=1}^{k} \varphi_m \, lnCO2_{t-m} + u_{3t} \tag{2.18}$$

Determining the optimal number of lags for the VAR model is conducted following an examination of the AIC criteria, the optimal number is then selected. In the causality testing the null hypothesis implies no Granger causality, while the alternative hypothesis suggests the existence of Granger causality between the variables.

The study employs a modified Wald test to determine whether the null hypothesis should be accepted or rejected. If the p-value is less than 0.05, the null hypothesis that there is no causal relationship should be rejected; if the p-value is more than 0.05, the null hypothesis should be accepted (Wooldridge, 2019).

CHAPTER THREE
RESULTS AND DISCUSSION

This chapter aims to provide a comprehensive presentation and interpretation of the empirical results obtained from the investigation into the relationship between carbon dioxide emissions, financial development, and economic growth in South Africa. Through detailed analysis of summary statistics, time series graphs, correlation tables, unit root tests for stationarity, ARDL cointegration tests, Granger causality tests, and diagnostic tests, the chapter seeks to convey the complex dynamics and interdependencies among these key variables.

This chapter also seeks to establish commonalities, discrepancies, and possible points of convergence or divergence between the acquired results and those documented in pertinent literature. The chapter intends to add to the continuing academic conversation on the connection between carbon emissions, financial development, and economic growth by comparing the results of this study with previous studies.

3.1 SUMMARY STATISTICS

The statistics in Table 1 provide insights into the summary of the distributional characteristics of the variables lnGDP, lnFD, and lnCO2. The total observations of each variable are 58.

The mean values for lnGDP, lnFD, and lnCO2 are 8.033871, 4.430164, and 2.078053. These positive mean values suggest that, on average, the natural logarithms of GDP, FD, and CO2 emissions are positive. The median values are 8.087878, 4.530097, and 2.080947. These values represent the middle data points in each variable's distribution, this shows that about half of the observations fall below these values and another half fall above.

Table 1: Summary Statistics

Series	lnGDP	lnFD	lnCO2
Mean	8.033871	4.430164	2.078053
Median	8.087878	4.530097	2.080947
Maximum	9.075327	4.958795	2.281281
Minimum	6.523755	3.9137	1.868698
Std. Dev.	0.7075859	0.3499516	0.1134841
Skewness	-0.5065757	-0.0749349	-0.0752495
Kurtosis	2.34972	1.328042	2.035399
Variance	0.5006778	0.1224661	0.0128786
Observations	58	58	58

Source: Created by the author.

The maximum values for lnGDP, lnFD, and lnCO2 are 9.075327, 4.958795, and 2.281281. These values represent the highest observed values for each variable in the dataset. The minimum values are 6.523755, 3.913728, and 1.868698. These values represent the lowest observed values for each variable in the dataset. Furthermore, the maximum and minimum values provide an understanding of the range of variation within each variable.

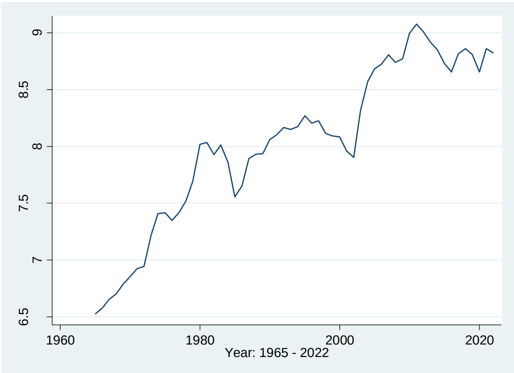
The Skewness of all the variables is negative. These negative skewness values suggest that the distributions of the variables are skewed to the left, with a longer tail on the left side. The kurtosis values suggest that the distributions are somewhat leptokurtic, with heavier tails compared to a normal distribution, indicating that there may be more occurrences of lower values compared to higher values. Additionally, the leptokurtic nature of the distributions implies a higher likelihood of extreme values or outliers, which could signal periods of economic volatility or environmental events.

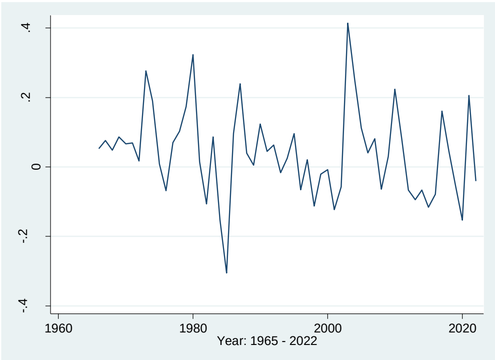
The positive mean and median values for lnGDP suggest that, on average, South Africa has experienced positive economic growth over the observed period. The range of variation from minimum to maximum values indicates the extent of economic fluctuation within the dataset. The positive mean and median values for lnFD indicate a general trend of growth and development in the financial sector. This suggests that financial institutions and markets in South Africa have been expanding, potentially facilitating economic growth and investment. The positive mean and median values for lnCO2 highlight a consistent level of carbon emissions over time. However, the relatively lower standard deviation and skewness indicate a more stable distribution compared to GDP and financial development, suggesting less variability in carbon emissions.

3.2 TIME SERIES GRAPHS

Figure 7 illustrates an overall upward trend in GDP per capita over time, however, with noticeable fluctuations. This suggests a general increase in economic prosperity, but the presence of fluctuations implies periods of both growth and potential economic challenges. Figure 8 showcases a similar upward trend in financial development, indicating growth and expansion in the financial sector. However, significant fluctuations suggest periods of instability or shifts in financial policy and regulation.

Figure 7: Gross Domestic Product in log Form and first Differences

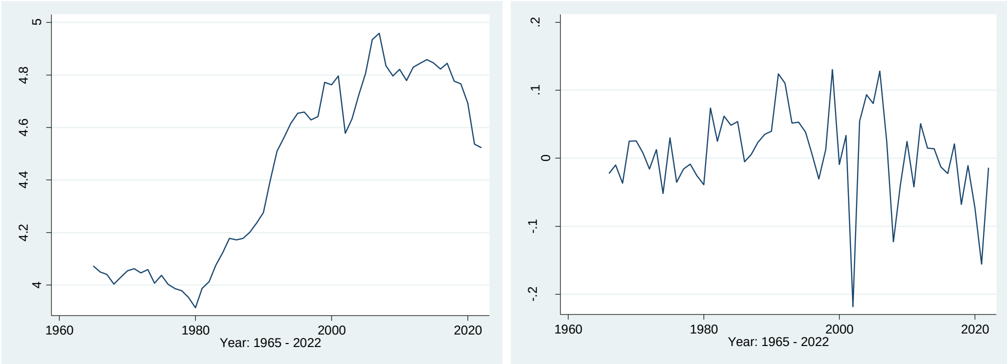




Source: Created by the author.

Note: Taking GDP per capita as A, and GDP per capita 1st differences as B.

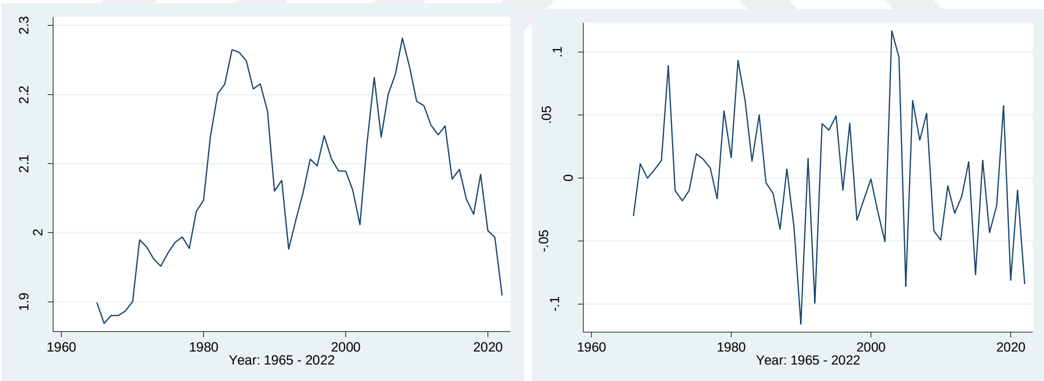
Figure 8: Financial Development in its Log form and First Differences



Source: Created by the author.

Note: Taking Financial Development as A and Financial Development 1st differences as B.

Figure 9: Per Capita CO2 Emissions In Log And First Difference Forms



Source: Created by the author.

Note: Taking Per capita CO2 emissions as A and Per capita CO2 emissions 1st differences as B.

Contrary to the clear trends observed in GDP per capita and financial development, Figure 9 shows per capita CO2 emissions with no discernible upward or downward trend. This lack of trend suggests a complex relationship between economic activity and environmental impact, influenced by various factors such as the South African energy policies, technological advancements, and industrial practices.

The time series analysis reveals that none of the variables exhibit constant mean and variance, indicating non-stationarity. However, visual inspection of the level forms of the data series does not meet this criterion. Figures 7, 8, and 9 illustrate the first differences of GDP per capita, financial development, and CO2 emissions, respectively. These plots appear to exhibit stationary behavior, indicating that the variability in the data may be more consistent over time. Nonetheless, formal unit root tests are necessary to confirm the order of integration and ascertain the stationarity of the variables.

3.3 CORRELATION BETWEEN THE VARIABLES

Table 2 shows the correlation between the variables Year, $lnGDP$, $lnFD$,and $lnCO2$. The correlation coefficient between the year and lnGDP is 0.9393, year and lnFD is 0.8908 and year and lnCO2 is 0.4169.

Table 2: Correlation Table

	year	**lnGDP**	**lnFD**	**lnCO2**
year	1.0000			
lnGDP	0.9393	1.0000		
lnFD	0.8908	0.8273	1.0000	
lnCO2	0.4169	0.5817	0.4097	1.0000

Source: Created by the author.

This indicates a strong linear relationship between the year and the natural logarithm of Gross Domestic Product (lnGDP), the year and the natural logarithm of Financial Development (lnFD). However, a positive weaker linear relationship between the natural logarithm of CO2 emissions and the year is shown.

lnGDP and lnFD have a strong positive correlation (0.8273). This shows a strong linear relationship between the natural logarithm of GDP and the natural logarithm of Financial Development (lnFD). lnGDP and lnCO2 also have a strong positive correlation (0.5817). This implies a strong linear relationship between the natural logarithm of Gross Domestic Product and the natural logarithm of Carbon Dioxide emissions (lnCO2).

The correlation between lnCO2 and lnFD is positive but weaker (0.4097), suggesting a weaker linear relationship between the natural logarithm of CO2 emissions and the natural logarithm of Financial Development (lnFD).

The strong positive correlations between the year and both lnGDP and lnFD suggest that over time, South Africa has experienced significant economic growth and financial development. This indicates a positive trajectory for the economy, potentially reflecting improvements in productivity, investment, and overall economic performance.

The weaker correlation between the year and lnCO2 emissions implies that while economic growth has occurred, it has not been strongly associated with proportional increases in carbon emissions. This could indicate efforts to decouple economic growth from environmental degradation, reflecting potential advancements in energy efficiency, renewable energy adoption, or environmental regulations within South Africa.

Several studies have reported a positive correlation between economic growth and carbon dioxide emissions. For instance, Zhu et al. (2019) identified a significant positive correlation between GDP and CO2 emissions in their analysis of Chinese provinces. However, some studies have suggested a decoupling of economic growth from carbon emissions. For example, Liu et al. (2014) noted a decreasing trend in the carbon intensity of economic growth in China, indicating a potential shift towards greener economic activities. In contrast, this study found a positive correlation between GDP and CO2 emissions in South Africa.

3.4 UNIT ROOT TESTS FOR STATIONARITY

3.4.1 Augmented Dickey-Fuller (ADF) test

Table 3.4.1 shows the Results of Augmented Dickey-Fuller test of the variables, lnGDP, lnFD, and lnCO2. The absolute level value of the t-statistic (-2.8) of the log of the gross domestic product is lower than all the critical absolute values (10% critical value of -3.176), therefore H0: cannot be rejected.

Table 3: Results of Augmented Dickey-Fuller test

	Constant		
Variable	**level**	**1st diff**	**conclusion**
lnGDP	-2.814	-6.048	I(1)
lnFD	-0.872	-4.177	I(1)
lnCO2	-1.105	-4.734	I(1)

Source: Created by the author.

This means that the log of GDP per capita is non stationary. Furthermore, the absolute 1st difference value of the t-statistic (-6.048) of the log of GDP is higher than all the critical absolute values (1% critical value of -4.139), thus the H0: Variables are non-stationary, can be rejected. This means the log of GDP per capita is stationary at the first difference. The log of GDP has no unit root at order I(1).

The stationarity of lnGDP at the first difference suggests that changes in GDP per capita over time exhibit stable behavior. This stability indicates that economic growth in South Africa, as measured by GDP per capita, tends to evolve smoothly without erratic fluctuations.

The log of Financial Development has a t-statistic absolute level value of -0.8, which is less than all of the critical absolute values (10% critical value of -3.176). Therefore, H0 cannot be rejected. As a result, the Financial Development log at the level value is non-stationary. However, since the t-statistic's absolute first difference value of -4.177 is greater than all critical absolute values (with a 1% critical value of -4.139), H0 is thus rejected. This indicates that for the first difference, the log of GDP per capita is stationary. The log of FD has no unit root at order I(1).

The stationarity of lnFD at the first difference indicates that financial development within the South African economy follows a stable trajectory over time. This stability suggests that the evolution of financial markets, access to credit, and overall financial intermediation functions smoothly without significant disruptions. It implies that the financial sector in South Africa is resilient and capable of supporting economic growth and development by providing necessary financial services to businesses and individuals.

The log of CO2 has an absolute t-statistic level value of (-1.105), which is lower than all the critical absolute values (10% critical value of -3.176), because of this H0 cannot be rejected. The log of GDP per capita is non-stationary at its level condition. On the other hand, the absolute 1st difference value of the t-statistic (-4.734) of the log of CO2 is higher than all the critical absolute values (1% critical value of -4.139), hence H0 can be rejected. The log of CO2 per capita is stationary at the first difference. The log of CO2 has no unit root at order I(1).

The stationarity of lnCO2 at the first difference signifies that changes in carbon dioxide emissions per capita exhibit stable patterns over time. This stability suggests that the drivers of carbon emissions, such as industrial activities, energy consumption, and transportation, evolve predictably within the South African context.

All the variables lnGDP, lnFD and lnCO2 are stationary and there is no unit root at order I(1). Overall, the stationarity of these key variables indicates that the South African economy experiences relatively stable and predictable trends in economic growth, financial development, and carbon emissions.

3.4.2 Phillip-Perron (PP) test for unit root.

Table 4 displays the level and first difference results of the Phillip-Perron test. The Phillip-Perron test (PP) for unit root confirms the results obtained from the augmented Dickey-Fuller test, that the variables are stationary in their first differences. The variables lnGDP, lnFD and lnCO2 have no unit root at order I(1).

Table 4: Results of the Phillip-Perron (PP) test For Unit Root

	Constant		
Variable	**level**	**1st diff**	**conclusion**
lnGDP	-2.28	-5.68	I(1)
lnFD	-0.803	-5.866	I(1)
lnCO2	-1.189	-7.632	I(1)

Source: Created by the author.

The results confirm that the key variables: lnGDP, lnFD, and lnCO2, exhibit stable behaviors over time after differencing. This stability suggests that changes in gross domestic product (GDP), financial development, and carbon dioxide emissions per capita within the South African economy follow predictable patterns, facilitating reliable analysis and forecasting.

3.5 COINTEGRATION TESTS

3.5.1 ARDL Bounds test for Cointegration

Table 5 portrays the results of the ARDL bounds test for cointegration, indicating the optimal lags, the F-statistic, the critical limits as well as the decision. In equation 1 (EQ1), in Table 4.5.1, the log of GDP takes lag 2, the log of FD has 1 lag and the log of CO2 has the optimal lag number 0. The F-statistic value of 12.485 is greater than critical value 4.1 at I(1), this means that at order I(1) the F-statistic for Equation 1, is above the lower bound critical values at 1%, 5% and 10% significant levels. Accordingly, the null hypothesis of no cointegration is rejected and we conclude that there is evidence of cointegration.

Table 5: ARDL Bounds test for Cointegration results

Model	F-Stat	Optimal Lag	I (0) - I (1) Bounds At (%)			Decision
			1%	5%	10%	
EQ1 (GDP/FD,CO2)	12.485	(2,1,0)	3.17 - 4.14	3.79 - 4.85	5.15 - 6.36	Cointegration
EQ2 (FD/GDP,CO2)	11.854	(1,0,0)	3.17 - 4.14	3.79 - 4.85	5.15 - 6.36	Cointegration
EQ3 (CO2/GDP,FD)	18.433	(1,0,0)	3.17 - 4.14	3.79 - 4.85	5.15 - 6.36	Cointegration

Source: Created by the author.

In equation 1 (EQ1), the optimal lag structure suggests that changes in lnGDP, lnFD, and lnCO2 are interrelated over time. The calculated F-statistic of 12.485 exceeds the critical value at order I(1), indicating strong evidence of cointegration. This suggests that economic growth (lnGDP), financial development (lnFD), and carbon emissions (lnCO2) are jointly determined in the long run, with each variable influencing the others.

The results of the ARDL bounds test for equation 2 (EQ2) shows that the log of FD has an optimal lag of lag 1, the log of GDP's optimal lag is of lag 0 and the log of CO2 takes lag 0. Since the F-statistic of 11.854 is higher than the crucial value of 4.1 at I(1). The F-statistic for EQ2 is therefore above the lower bound critical values for the 1%, 5%, and 10% significant levels at order I(1). As a result, we conclude that there is evidence of cointegration and reject the null hypothesis that there is no cointegration.

The equation 3 (EQ3) ARDL bounds test for cointegration results indicate that the optimal lag of the natural logarithm of CO2 is lag 1, the log of GDP has an optimal lag of lag 0 and the log of FD takes lag 0. The H0: No Cointegration is rejected because the F-statistic of 18.433 is more than the critical value of 4.1 at I(1). As a result, at the 1%, 5%, and 10% significant levels at order I(1), the F-statistic for Eq. (3) is above the lower bound critical values. Consequently, we reject the null hypothesis that cointegration does not exist and conclude that cointegration is supported by the data.

Equation 2 (EQ2) and equation 3 (EQ3) also exhibit evidence of cointegration, with F-statistics of 11.854 and 18.433 respectively surpassing the critical value at order I(1). These results further reinforce the notion that lnGDP, lnFD, and lnCO2 are cointegrated, implying stable long-term relationships among these variables. The cointegration results suggest that economic growth, financial development, and carbon emissions in South Africa are not independent but rather integrated processes. Changes in one variable are likely to influence the others in the long run.

3.5.2 Serial Correlation and Heteroskedasticity tests

Table 6shows the Cointegration test diagnostics, it gives the results of the Durbin-Watson test, the Breusch-Godfrey's LM test as well as the White's IM test for Heteroskedasticity.

Table 6: Serial Correlation And Heteroskedasticity Test Results

Model	DW d-stat	BG LM test	C&T IM-Test	Autocorrelation	Heteroskedasticity
EQ1 (GDP/FD,CO2)	1.87728	Prob>Chi2 0.0928	Prob>Chi2 0.5057	no	no
EQ2 (FD/GDP,CO2)	2.052896	Prob>Chi2 0.6845	Prob>Chi2 0.9338	no	no
EQ3 (CO2/GDP,FD)	1.976782	Prob>Chi2 0.6651	Prob>Chi2 0.0543	no	no

Source: Created by the author.

In equation 1 (EQ1), The Durbin-Watson d-statistic (6, 55) = 1.87728 shows that there is very weak or no serial correlation. This is confirmed by the Breusch-Godfrey LM test with a p-value of 0.0928, it is larger than the conventional significance level of 0.05. Therefore, we cannot reject the null hypothesis of no autocorrelation. The p-value (0.5057) obtained from the Cameron & Trivedi's decomposition of IM-test, is greater than the conventional significance level (0.05), suggesting that there is no strong evidence to reject the null hypothesis of homoscedasticity. The p-value is relatively large, suggesting that the residuals do not exhibit significant heteroskedasticity.

Equation 2 (EQ2) shows according to the Durbin-Watson d-statistic (4, 56) = 2.052896, that there is either no serial correlation at all or very little of it. The Breusch-Godfrey LM test, which has a p-value of 0.6845, larger than the typical significance level of 0.05, confirms this. As a result, the null hypothesis that there is no autocorrelation cannot be rejected. The Cameron & Trivedi's decomposition of IM-test p-value (0.9338) is higher than the traditional significance level (0.05), indicating that there is insufficient data to rule out the homoscedasticity null hypothesis. Given the comparatively large p-value, suggesting that there is no indication of heteroskedasticity in the residuals.

In equation 3 (EQ3) the Durbin-Watson d-statistic (4, 56) = 1.976782 indicates that there is either very little or no serial correlation. This is confirmed by the Breusch-Godfrey LM test, which has a p-value of 0.6651, which is higher than the usual significance level of 0.05. Therefore, it is not possible to reject the null hypothesis that there is no autocorrelation. Since the IM-test's p-value (0.0543) is greater than the conventional significance threshold (0.05), it cannot be concluded that the homoscedasticity null hypothesis is not supported by the available data. Considering the relatively high p-value, it appears that the residuals do not show any signs of heteroskedasticity.

The absence of significant serial correlation and heteroskedasticity in the residuals of all equations enhances the reliability of the models' estimations. Researchers and policymakers can have confidence in utilizing the results derived from these models for designing and implementing economic, financial, and environmental policies in South Africa. The coefficients of the models can be interpreted with greater confidence, knowing that the statistical assumptions underlying the models hold, and the estimated effects are reliable.

3.6 GRANGER CAUSALITY

3.6.1 Optimal Lag

Table 3.6.1: shows the Optimal lag test results of the FPE, AIC, HQIC and SBIC criterions. Based on these criteria, In the long run, the lag order 8 has the lowest AIC and HQIC values -6.42, -5.33 respectfully.

Additionally, the LR test for lag order 8 is statistically significant. Therefore, in this case, the lag order of 8 is employed for the VAR model as it provides the best trade-off between model fit and complexity according to these information criteria.

Table 7: Optimal lag test results

Lag	**LR**	**df**	**p**
8	25.497*	9	0.002
AIC	**FPE**	**HQIC**	**SBIC**
-6.42009	4.40E-07	-5.32793	-3.55206

Source: Created by the author.

The optimal lag test results, selecting lag order 8 for the VAR model, reveal significant long-term relationships among lnGDP, lnFD, and lnCO2 in South Africa. This suggests lasting effects of GDP, financial development, and carbon emissions on each other, emphasizing their interconnectedness. By striking a balance between model fit and complexity, lag order 8 captures essential dynamics without unnecessary complexity.

3.6.2 VAR Estimation

Table 3.6.2 shows the summary results of the VAR Estimation. In equation 1, the coefficient of 1.1011 suggests that a one-unit increase in lnGDP in the previous period leads to a 1.1011 unit increase in lnGDP in the current period, holding other variables constant.

Table 8: VAR Estimation results summary

VAR	Lags (AIC)	Lowest p-values	Variables		
			lnGDP	lnFD	lnCO2
EQ1(GDP/FD,CO2)	(1,4,8)	(0.00, 0.004, 0.068)	1.101096	1.038382	0.6294862
EQ2(FD/GDP,CO2)	(7,1,6)	(0.004, 0.00, 0.00)	-0.3682189	1.095509	0.8064176
EQ3(CO2/GDP,FD)	(1,7,1)	(0.049, 0.116, 0.00)	0.1314643	0.3092583	0.7354178

Source: Created by the author.

The coefficients for the variables with lags 2 to 8, are negative or close to zero, indicating weaker or negligible effects of past values of lnGDP on the current value of lnGDP. The coefficient 1.038382 for lnFD at lag 4 suggests that a one unit increase in the previous period leads to an increase of 1.038382 units of lnGDP in the current period, holding other variables constant. This is significant at a 95% confidence interval with a p-value of 0.004. For for lnCO2, the coefficient is significant at a 10% confidence level, with a coeffiecient of 0.6294862 and a p-value of 0.068. Suggesting that a one unit increasein lnCO2 in the previous period leads to an increase of 0.6294862 units in lnGDP in the current period, holding other variables constant.

The positive coefficient for lnGDP suggests that increases in GDP tend to lead to further GDP growth, although with diminishing returns over time. The significant coefficient for lnFD implies that improvements in financial development positively influence GDP, supporting economic growth. However, the coefficient for lnCO2, although positive, is not statistically significant at conventional levels, indicating a weaker impact of carbon emissions on GDP.

Equation 2, shows that the coefficient for lnGDP at lag 7 (L7) is statistically significant (p = 0.004). At lag 7, the coefficient of -0.3682 suggests that a one-unit increase in lnGDP seven periods ago leads to a decrease of 0.3682 units in lnFD in the current period, holding other variables constant. The coefficient for lnFD at lag 1 (L1) is highly significant ($p < 0.001$). At lag 1, the coefficient of 1.0955 indicates that a one-unit increase in lnFD in the previous period leads to an increase of 1.0955 units in lnFD in the current period, holding other variables constant. The coefficient for lnCO2 at lag 6 (L6) is highly significant ($p < 0.001$). At lag 6, the coefficient of 0.8064 suggests that a one-unit increase in lnCO2 six periods ago leads to an increase of 0.8064 units in lnFD in the current period, holding other variables constant.

Equation 2 highlights a bidirectional relationship between lnFD and lnGDP, with both variables exerting significant influences on each other. This emphasises the importance of a robust financial sector for fostering economic expansion. Additionally, the positive coefficient for lnCO2 suggests that past carbon emissions contribute to financial development, potentially reflecting investments in carbon-intensive industries.

For the relationship between lnCO2 and its lagged variables (lnGDP, lnFD) as indicated by equation 3, the coefficient for lnGDP at lag 1 (L1) is significant at a 5% confidence level ($p = 0.049$). At lag 1, the coefficient of 0.1315 suggests that a one-unit increase in lnGDP in the previous period leads to a 0.1315 unit increase in lnCO2 in the current period, holding other variables constant. The coefficient for lnFD at lag 7 (L7) is not significant ($p = 0.116$). Therefore indicating no significant effect of lagged values of lnFD on lnCO2. The coefficient for lnCO2 at lag 1 (L1) is highly significant ($p < 0.001$). At lag 1, the coefficient of 0.7354 indicates that a one-unit increase in lnCO2 in the previous period leads to a 0.7354 unit increase in lnCO2 in the current period, holding other variables constant. The positive coefficient for lnGDP suggests that economic growth contributes to increased carbon emissions, reflecting the energy-intensive nature of economic activities.

Similar findings have been reported by studies such as (Pesaran, Shin, & Smith, 2001) and (Shrestha & Bhatta, 2018), which also observed diminishing returns of past GDP values on current GDP growth over time. Furthermore, the positive impact of financial development on economic growth aligns with the conclusions drawn by Bah & Azam (2017).

3.6.3 Granger Wald Causality Test

The Table 3.6.3 displays the results of Granger causality Wald tests for different equations and excluded variables. In Equation 1, with GDP as the dependent variable, the p-value of 0.000 for lnFD is significant, indicating that past values of lnFD Granger-cause lnGDP. This shows a significant uni-directional Granger causality from lnFD to lnGDP, with a chi-squared statistic of 34.731 and 8 degrees of freedom. Similarly, the p-value of 0.020 for lnCO2 is significant, implying that past values of lnCO2 Granger-cause lnGDP, presenting a significant uni-directional Granger causality from lnCO2 to lnGDP, with a chi-squared statistic of 18.153 and 8 degrees of freedom. Additionally, the conjointly obtained significant p-value of 0.000 for lnFD and lnCO2 suggests that past values of both lnFD and lnCO2 collectively Granger-cause lnGDP, with a chi-squared statistic of 41.748 and 16 degrees of freedom. These findings suggest that changes in lnFD and lnCO2 are predictive of variations in lnGDP over time. These relationships when considering only equation 1, are uni-directional, indicating that lnGDP is influenced by lnFD and lnCO2, and not vice versa.

The significant uni-directional Granger causality from lnFD to lnGDP indicates that past values of financial development in South Africa have predictive power for future changes in GDP. This suggests that improvements or declines in financial development, such as changes in banking services, access to credit, or efficiency of financial markets, may impact the country's economic output over time. The significant uni-directional Granger causality from lnCO2 to lnGDP suggests that past levels of carbon dioxide emissions in South Africa are predictive of future changes in GDP. This implies that environmental factors, such as pollution levels or energy production methods, may influence economic activity in the form of Industrial activity, mining activity, coal burning for electricity consumption, cement and steel production, transportation and other emission producing activities in the country. The joint significant Granger causality of lnFD and lnCO2 on lnGDP suggests that both financial development and carbon dioxide emissions collectively have predictive power for South Africa's GDP.

Table 9: Granger Wald Causality Test results

Equation	Excluded	Chi2	df	Prob>Chi2
lnGDP	lnFD	34.731	8	0.000
lnGDP	lnCO2	18.153	8	0.020
lnGDP	ALL	41.748	16	0.000
lnFD	lnGDP	17.511	8	0.025
lnFD	lnCO2	28.376	8	0.000
lnFD	ALL	42.59	16	0.000
lnCO2	lnGDP	10.521	8	0.230
lnCO2	lnFD	11.596	8	0.170
lnCO2	ALL	15.749	16	0.471

Source: Created by the author.

From Equation 2 taking the log of FD as dependent variable, The test outputs a significant 0.025 p-value for lnGDP. indicating that past values of lnGDP Granger-cause lnFD. This shows a significant uni-directional Granger causality from lnGDP to lnFD, with a chi-squared statistic of 17.511 and 8 degrees of freedom. Similarly, the p-value of 0.000 for lnCO2 is significant, implying that past values of lnCO2 Granger-cause lnFD, presenting a significant uni-directional Granger causality from lnCO2 to lnFD, with a chi-squared statistic of 28.376 and 8 degrees of freedom. Additionally, the conjointly obtained significant p-value of 0.000 for lnGDP and lnCO2 suggests that past values of both lnGDP and lnCO2 collectively Granger-cause lnFD, with a chi-squared statistic of 42.590 and 16 degrees of freedom. These findings suggest that changes in lnGDP and lnCO2 are predictive of variations in lnFD over time. However, it's important to note that when considering only equation 2, these relationships are uni-directional, indicating that lnFD is influenced by lnGDP and lnCO2.

Furthermore, the significant Granger causality from GDP to FD implying that economic growth, as represented by GDP, influences financial development, the significant Granger causality from carbon dioxide emissions to financial development, suggests that environmental factors, such as carbon emissions, can influence the development of financial systems. The conjointly obtained significance of both GDP and carbon dioxide emissions collectively Granger causing changes in financial development (lnFD) underscores the combined influence of economic growth and environmental factors on financial development in South Africa.

In Equation 3, with Carbon Dioxide Emissions (lnCO2) as the dependent variable. For lnGDP as the excluded variable, the chi-squared statistic is 10.521 with 8 degrees of freedom, resulting in a p-value of 0.230. This shows an insignificant relationship, indicating that past values of lnGDP do not significantly Granger-cause changes in lnCO2. In regards to lnFD as the excluded variable, the chi-squared statistic is 11.596 with 8 degrees of freedom, resulting in a p-value of 0.170. Similarly, this presents an insignificant relationship, indicating that past values of lnFD do not significantly Granger-cause changes in lnCO2. Considering all excluded variables together, the chi-squared statistic is 15.749 with 16 degrees of freedom, resulting in a p-value of 0.471. This also suggests an insignificant relationship, meaning that the collective influence of all excluded variables, including lnGDP and lnFD, does not significantly Granger-cause changes in lnCO2.

The insignificant relationship between lnGDP and lnCO2 suggests that historical trends in GDP may not be strong predictors of changes in carbon dioxide emissions. This could indicate that economic growth alone may not be a reliable indicator of carbon emissions, suggesting that factors other than GDP may have a more significant influence on carbon emissions in the country. Likewise, the insignificance between lnFD and lnCO2 suggests that historical trends in financial development may not be strong predictors of changes in carbon dioxide emissions in South Africa. This could imply that the level of financial development, including aspects such as access to credit, investment opportunities, and banking services, may not have a significant impact on carbon emissions in the country. The insignificant relationship when considering all excluded variables collectively reinforces the notion that the combined influence of GDP, financial development, and potentially other variables does not significantly predict variations in carbon dioxide emissions in South Africa.

Overall, the p-value of 0.000 for lnGDP in the equation with lnFD as the dependent variable indicates a significant uni-directional causality from lnGDP to lnFD. The p-value of 0.025 for lnFD in the equation with lnGDP as the dependent variable presents a significant uni-directional causality from lnFD to lnGDP. These results suggest bidirectional causality between lnGDP and lnFD. The p-value of 0.020 for lnCO2 in the equation with lnGDP as the dependent variable suggests significant uni-directional causality from lnCO2 to lnGDP. However, the p-value of 0.230 for lnGDP in the equation with lnCO2 as the dependent variable implies insignificant causality from lnGDP to lnCO2. These results convey a uni-directional causality from lnCO2 to lnGDP, but not in the opposite direction. The p-value of 0.000 for lnCO2 in the equation with lnFD as the dependent variable suggests a significant uni-directional causality from lnCO2 to lnFD. Similarly, the p-value of 0.170 for lnFD in the equation with lnCO2 as the dependent variable indicates insignificant causality from lnFD to lnCO2. These results suggest uni-directional causality from lnCO2 to lnFD, but not in the opposite direction.

In the context of South Africa, the results of the Granger causality tests suggest intricate relationships between GDP, financial development, and carbon dioxide emissions. The bidirectional causality between lnGDP and lnFD implies a dynamic relationship where changes in financial development can affect GDP, and vice versa. This suggests that improvements or declines in financial systems, such as banking services, access to credit, or investment opportunities, may impact economic growth in South Africa, while economic growth can also influence the development of financial institutions and markets.

The uni-directional causality from lnCO2 to lnGDP indicates that past levels of carbon dioxide emissions influence GDP in South Africa. This shows that environmental factors, such as pollution levels or energy production methods, can impact economic activity. However, there is no significant causality from GDP to carbon dioxide emissions, indicating that economic growth may not necessarily lead to changes in carbon emissions in the short term.

The causality from lnCO2 to lnFD brings forth that past levels of carbon dioxide emissions have an effect on financial development in South Africa. This relationship could be as a result of environmental regulations affecting financial markets, investor preferences for sustainable investments, or the economic impacts of climate change. However, there is no significant causality from financial development to carbon dioxide emissions, indicating that changes in financial systems may not directly influence carbon emissions.

Policymakers need to consider these relationships when designing strategies for sustainable development, economic growth, and environmental protection. Efforts to promote financial development and economic growth should be aligned with policies aimed at reducing carbon emissions and mitigating climate change impacts.

3.6.4 Wald Coefficient test

The table 3.6.4 shows the results of the Wald coefficient causality tests for different equations and excluded variables. In equation 1, the null hypothesis that the lagged value of lnFD (lnFD at lag 1) does not Granger-cause lnGDP is rejected ($p < 0.001$).

Similarly, the null hypotheses for lnFD at lags 2 through 8 are also rejected, indicating that past values of lnFD significantly Granger-cause changes in lnGDP. Furthermore, the null hypothesis that the lagged value of lnCO2 (lnCO2 at lag 1) does not Granger-cause lnGDP is rejected ($p = 0.0201$). Likewise, the null hypotheses for lnCO2 not Granger-causing lnGDP at lags 2 through 8 are also rejected, indicating that past values of lnCO2 significantly Granger-cause changes in lnGDP. The results confirm the Granger Wald Causality Test results, indicating that past values of both lnFD and lnCO2 significantly Granger-cause changes in lnGDP. This suggests that fluctuations both financial development and carbon dioxide emissions exert a notable influence on the gross domestic product of South Africa.

Table 10: Wald Coefficient Causality Test results

Equation	Coefficient	L1 - L8	Chi2	Prob>Chi2
(EQ1) lnGDP	lnFD	0	34.73	0.000
	lnCO2	0	18.15	0.020
(EQ2) lnFD	lnGDP	0	17.51	0.025
	lnCO2	0	28.38	0.000
(EQ3) lnCO2	lnGDP	0	10.52	0.230
	lnFD	0	11.6	0.170

Source: Created by the author.

Equation 2 shows that the null hypothesis that the lagged value of lnGDP (lnGDP at lag 1) does not Granger-cause lnFD is rejected ($p = 0.0252$). Hence, the null hypotheses for lnGDP not Granger causing lnFD at lags 2 through 8 are also rejected, indicating that past values of lnGDP significantly Granger-cause changes in lnFD. The null hypotheses for lnCO2 not Granger causing lnFD at lags 1 through 8 are also rejected, indicating that past values of lnCO2 significantly Granger-cause changes in lnFD.

This reveals that past values of both lnGDP and lnCO2 significantly Granger-cause changes in lnFD. This implies that developments in financial development follow changes in GDP and carbon emissions. Thus, improvements or setbacks in the economic growth and environmental management may have an effect on financial sector outcomes in South Africa.

In equation 3, the null hypothesis that the lagged values of lnGDP do not Granger-cause lnCO2 is not rejected ($p = 0.2303$). Equally, the null hypotheses for lnFD at lags 1 through 8 are also not rejected ($p = 0.170$), indicating that past values of lnFD and lnGDP do not significantly Granger-cause changes in lnCO2.

There is no significant evidence to suggest that past values of lnGDP or lnFD Granger-cause changes in lnCO2. This suggests that while GDP and financial development may influence carbon emissions indirectly through other channels, the causal relationship between these variables and CO2 emissions in South Africa may be weaker or influenced by additional factors beyond the scope of this analysis.

The positive association between financial development and economic growth is a well-established phenomenon. This study's findings support numerous prior studies highlighting the critical role of financial development in fostering economic growth. Similarly, Demirgüç-Kunt and Levine (2008) found evidence supporting the positive impact of financial intermediaries on economic growth, consistent with the results of this study.

3.6.5 Diagnostics

The Table 3.6.5 shows the results of the Lagrange-multiplier test for different autocorrelation. The p-values are relatively large (0.76517 and 0.66533, respectively).

Table 11: Autocorrelation Test Results

Autocorrelation			
Lag	Chi2	df	Prob>Chi2
1	5.7448	9	0.76517
2	6.7288	9	0.66533

Source: Created by the author.

This implies that there is not enough evidence to reject the null hypothesis of no autocorrelation. These results suggest that, based on the Lagrange-multiplier test, there is no strong indication of autocorrelation in the residuals at lag orders 1 and 2. In the context of the South African economy, this implies that the model adequately captures the temporal dependencies in the data, ensuring the reliability of the estimated coefficients over time.

The table 3.6.6 shows the results of the Jarque-Bera, skewness and kurtosis test for normality. The Jarque-Bera test has p-values which are all relatively large, suggesting that there is no strong evidence to reject the null hypothesis of normality for the residuals. For the skewness and kurtosis tests, the p-values are also relatively large, indicating that there is no strong evidence to reject the null hypotheses of zero skewness and kurtosis.

Table 12: Normality Tests Results

Equation	Jarque-Bera Prob>Chi2	Skewness Prob>Chi2	Kurtosis Prob>Chi2
lnGDP	0.84358	0.93194	0.56395
lnFD	0.69041	0.55138	0.53436
lnCO2	0.36106	0.15664	0.86012
ALL	0.79382	0.49952	0.86137

Source: Created by the author.

This means that based on the results of these statistical tests, there is no clear indication that the residuals deviate significantly from a normal distribution, are skewed, or exhibit excess kurtosis. The model is therefore normally distributed. This implies that the assumptions underlying the statistical tests and estimations are met, enhancing the robustness of the model's results in analyzing the South African economy.

The stability of the model was tested using the Eigenvalue stability condition test. The result as shown in the Appendix, was that all the eigenvalues lie inside the unit circle. Indicating that the VAR satisfies stability condition. The VAR Model is stable. This stability validates the model's predictions and policy implications in the context of the South African economy, hence bolstering its usefulness influencing economic decision-making and policy formation.

CONCLUSION

This chapter aims to synthesize the key findings of the study regarding the relationships between economic growth, financial development, and carbon emissions in South Africa. This section will provide a cohesive summary of the results obtained. Additionally, it will abridge the implications of these findings for understanding the complex dynamics of the South African economy and expand on informing policy decisions aimed at promoting sustainable economic growth, financial development and environmental stewardship.

Moreover, this chapter will, in the context of South Africa, discuss the implications of the empirical findings for policymakers, researchers, and practitioners. By exploring the causal relationships and interplays between carbon emissions, financial development, and economic growth, this chapter aims to shed light on the sustainability challenges facing South Africa and offer practical recommendations for promoting environmentally sustainable economic growth and development strategies tailored to the country's unique context.

Time series graphs illustrated upward trends in GDP per capita and financial development over time, with notable fluctuations, suggesting periods of both growth and instability, indicating overall economic growth and expansion in the financial sector. Contrarily, per capita CO2 emissions displayed no discernible trend, highlighting the complex relationship between economic activity and environmental impact.

Significant F-statistic values indicate evidence of cointegration among GDP, financial development, and CO2 emissions, implying long-term relationships among these variables. The cointegration analysis provided evidence of long-term relationships among the variables, suggesting the presence of stable equilibrium dynamics.

Granger causality tests revealed significant causal relationships between GDP and financial development, as well as between CO2 emissions, GDP and financial development. Highlighting the influence of economic growth on the financial sector expansion, environmental impact influencing economic growth and financial system improvements.

Indicated is a bidirectional relationship where past values of lnFD Granger cause changes in lnGDP, and vice versa. This implies a feedback loop between economic growth and financial development, each influencing the other. Additionally, a unidirectional relationship is shown, where past values of lnCO2 Granger cause changes in lnGDP, suggesting that increased carbon emissions contributes to economic expansion. Also revealed as well is a unidirectional relationship where past values of lnCO2 Granger cause changes in lnFD, indicating that increasing carbon emissions influence developments in financial development.

Overall, the results suggest both bidirectional causality among lnGDP, lnFD, and unidirectional causality from lnCO2 to lnGDP and lnFD, highlighting the complex interplay between economic growth, financial development, and environmental impact. While carbon emissions appear to drive financial development and economic growth, there are also feedback loops between these variables, indicating a dynamic relationship.

The findings of this study have important implications for policymakers, economists, and environmentalists alike. Understanding the intricate relationships between economic growth, financial development, and environmental sustainability is crucial for crafting effective policies that promote balanced and sustainable development.

Given the bidirectional causality between lnGDP and lnFD, policymakers should focus on promoting sustainable economic growth while simultaneously fostering a conducive environment for financial sector development. This can be achieved through policies that encourage investment, entrepreneurship, and innovation while ensuring financial stability and inclusivity.

The significant uni-directional causality from lnCO2 to lnGDP, brings forth the need for comprehensive environmental regulations and economic policies to mitigate carbon emissions while sustaining economic growth. This could involve implementing carbon pricing mechanisms, incentivizing renewable energy investments, and promoting energy efficiency measures across industries.

The causality from lnCO2 to lnFD, suggests that policymakers could integrate climate change considerations into financial sector policies and strategies. This may involve incorporating environmental risk assessments into financial decision-making processes, promoting green finance initiatives, and encouraging sustainable investment practices among financial institutions.

Policies should focus on sustainable economic growth by investing in infrastructure, innovation, and education to foster a resilient financial sector. Prioritize implementing measures like adopting clean energy technologies, enhancing energy efficiency, and promoting sustainable practices to mitigate the environmental consequences on economic growth. Enhance the resilience and stability of the financial sector through regulatory reforms, risk management frameworks, and financial inclusion initiatives that support sustainability while ensuring financial stability.

Given the complex interplay between economic growth, financial development, and environmental impact, there is a need to prioritize investments in renewable energy infrastructure and green technologies. This can create new opportunities for economic growth, job creation, and technological innovation while reducing carbon emissions and environmental degradation.

Enhancing institutional capacity and public awareness on sustainable development issues is crucial. Policymakers should prioritize education and training programs to build the skills and knowledge necessary for implementing and monitoring sustainable development initiatives effectively. This can empower stakeholders to make informed decisions and actively participate in shaping a sustainable future for South Africa.

It is crucial to set up strong monitoring and evaluation systems in order to keep track of how well policies that support sustainable development are working. Frequent evaluations of social, economic, and environmental indicators can aid in identifying new issues, assessing the effectiveness of policies, and directing future decision-making.

The complicated interactions between South Africa's environmental sustainability, financial development, and economic growth are the focus of these policy recommendations. Policymakers can endeavor to attain sustainable and inclusive development results for the nation by embracing a comprehensive strategy that incorporates economic, environmental, and social factors.

In conclusion, this study contributes to the understanding of the complex interplay between economic indicators, financial development, and environmental sustainability. By employing rigorous time series analysis techniques, light has been shed on the dynamics and relationships among these variables in the context of South Africa. It is hoped that these findings will inform policy discussions and contribute to the pursuit of sustainable and inclusive economic development.

Future research could delve deeper into the mechanisms driving the observed relationships and explore additional variables that may influence the dynamics of economic growth, financial development, and carbon emissions. Furthermore, examining the effectiveness of policy interventions aimed at mitigating environmental impact without hindering economic growth would be valuable for informing evidence based policymaking.

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APPENDIX

Appendix 1: Eigenvalue Stability Condition

Eigenvalue	Modulus
-7.355e-16 + .9550209*i*	.955021
-7.355e-16 - .9550209*i*	.955021
.6753017 + .6753017*i*	.955021
.6753017 - .6753017*i*	.955021
-.6753017 + .6753017*i*	.955021
-.6753017 - .6753017*i*	.955021
-.9550209	.955021
.9550209	.955021
-.2336716 + .7002871*i*	.738244
-.2336716 - .7002871*i*	.738244
.2336716 + .7002871*i*	.738244
.2336716 - .7002871*i*	.738244
-.329947 + .6604085*i*	.738244
-.329947 - .6604085*i*	.738244
.7002871 + .2336716*i*	.738244
.7002871 - .2336716*i*	.738244
.6604085 + .329947*i*	.738244
.6604085 - .329947*i*	.738244
-.7002871 + .2336716*i*	.738244
-.7002871 - .2336716*i*	.738244
-.6604085 + .329947*i*	.738244
-.6604085 - .329947*i*	.738244
.329947 + .6604085*i*	.738244
.329947 - .6604085*i*	.738244

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.