



School of Commerce

College of Law and Management Studies

**The South African firms' relationship between carbon emissions and
corporate financial performance**

By

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Submitted in fulfilment of the requirements for the degree of Masters of Accountancy in the
School of Commerce, University of KwaZulu-Natal.

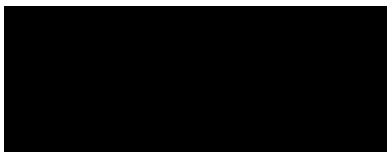
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ABSTRACT

Over the last decades, the primary objective of the business was to purely to generate profit for shareholders. However, this paradigm is shifting due to growing pressures from stakeholders and regulators on companies to manage their carbon emissions and adopt a triple bottom-line framework that balances economic objectives with social and environmental objectives. In line with this, the study examines the relationship between financial performance and carbon emissions for 17 JSE-listed industrial metal and mining companies over the period 2018 to 2022. Applying panel data analysis, financial performance measures (return on assets, Tobin's Q, and return on equity) were used as dependent variables. As a carbon emissions measure, carbon intensity was used as an independent variable, with leverage, firm growth and size identified as control variables. The findings indicate that entities that significantly emit carbon generally have weaker financial performance, as evidenced by the negative relationship. This implies that companies that engage in carbon emissions reduction activities can increase their financial performance. The study offers valuable insight for companies, governments, and policymakers and contributes to the existing literature. Future studies are encouraged to include different studies, extend the time frame and apply different financial performance indicators.

Keywords

Financial performance, greenhouse gas emissions, carbon emissions, and JSE-listed industrial metal and mining companies.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
CBT	Carbon Tax
CDP	Consumer Domestic Product
CEO	Chief Executive Officer
CPI	Consumer Price Index
CO ₂	Carbon Dioxide
EPS	Earnings Per Share
ETS	Emissions Trading Scheme
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ROA	Return on Assets
ROE	Return on Equity
ROI	Return on Investment
RONW	Return on Net Worth
ROS	Return on Sales
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1: Introduction

1.1 Introduction

Traditionally, shareholders opened businesses with the primary objective of creating wealth for themselves through profit maximisation. However, nowadays, there has been a notable shift in corporate objectives towards sustainable value creation as reflected in the triple bottom line, a framework emphasising environmental, social and economic requirements (Artiach, Lee, Nelson, and Walker, 2010). This shift has been mainly caused by the amplified awareness of issues such as climate change and greenhouse gas emissions (GHG) (Ganda and Milondzo, 2018). Corporations are expected to manage their environmental impact as regulatory and stakeholder pressures intensify. Consequently, companies and scholars are now assessing how firms' environmental behaviour, specifically carbon emissions, impacts their financial performance. A key metric used to measure carbon emissions is the carbon intensity, which is the amount of GHG emissions per revenue (Busch and Hoffmann, 2011). In line with this context, this study investigates the relationship between financial performance and carbon emissions for South African JSE-listed industrial metal and mining companies.

1.2 Background to the Study

Social and environmental issues, including GHG emissions, air and water pollution, climate change, natural resource base, and high unemployment, have recently received increased attention from governments, societies, and policymakers internationally (Saygin and ÖNk, 2023; Sibanda and Ndlela, 2020). Among all these environmental issues, climate change has received significant attention as a critical global issue that requires special attention due to its environmental and social impact (Saygin and ÖNk, 2023). Despite mitigating efforts, human survival is still threatened by rising sea levels, melting glaciers, and intense and erratic rainfall (Ganda and Milondzo, 2018; Naidoo, Sukdeo, and Zuma, 2020; Zhang, Wang, Yin, and Su, 2012).

Historically, Developed economies have mainly been significant carbon emitters due to their substantial use of coal, fossil fuels, and the industrial revolution (Huisinsh, Zhang, Moore, Qiao, and Li, 2015). However, developing economies like South Africa, India, Brazil, China, and Russia are now also emitting at a higher rate (Huisinsh et al., 2015). These economies are experiencing growth in gross domestic product (GDP) owing to improved economic activities and higher productivity. South Africa, in particular, is one of the world's most significant GHG

emitters and one of the leading carbon emitters in Africa, resulting in significant carbon emissions (Ganda and Milondzo, 2018; Sibanda and Ndlela, 2020). The country has one of the largest economies in Africa, with substantial economic and industrial power. Approximately 80% of the country's energy is derived from fossil fuels, which contributes significantly to the country's total carbon emissions (Ganda and Milondzo, 2018).

Central to this context is the industrial metal and mining industry, a cornerstone of the South African economy, as it is one of the largest industries and one of the most significant GDP contributors. In 2022, the industry grew by 10,5% to reach \$ 180,729,9 Million (Market-Line, 2023). The industry is, however, also one of the most carbon-intensive industries due to its energy-intensive processes, further increasing the environmental concerns.

International and local companies and governments have passed new policies to reduce carbon emissions to ensure that negative consequences on the environment do not grow even further. Internationally, governments have implemented policies like energy or carbon taxes (CBT), voluntary initiatives, and emissions trading schemes (ETS). Locally, the South African government has implemented a CBT on carbon emissions based on fuel input emissions and the polluter pays principle (Alton, Arndt, Davies, Hartley, Makrelov, Thurlow, and Ubogu, 2014). These policies have fostered sustainable practices; however, their financial implications remain unknown, particularly whether the carbon reduction improves financial performance or imposes further costs.

Companies and stakeholders are still unsure of the practices in place to reduce carbon emissions and the effects that these practices may have on the company's financial performance, despite the policies in place. This knowledge gap, together with the limited existing studies on the South African region and inconclusive international findings, creates an urgent need to investigate the relationship between carbon emission and financial performance. This study will bridge the region-based void by focusing on the South African JSE-listed industrial metal and mining entities.

The research uses a quantitative approach, applying primary financial measures, return on equity (ROE) and return on assets (ROA) as accounting-based measures of efficiency and profitability. Additionally, to complement these, Tobin's Q was also applied as a financial measure to capture the investor's perception of firm value (Busch and Hoffmann, 2011). Applying both internal and external measures allows for a more comprehensive understanding of financial performance. Carbon intensity was applied as an independent variable. Multiple

regression techniques will be used to examine the data. 17 JSE-listed industrial metal and mining companies were sampled for the analysis. Secondary data for these companies from 2018 to 2022 were drawn from Bloomberg and the companies' websites.

1.3 Problem Statement

In South Africa, the introduction of CBT and the triple bottom line has heightened the stakeholders' awareness of the companies' environmental accountability (Artiach et al., 2010). However, a critical knowledge gap persists as companies and stakeholders still lack knowledge and understanding of how carbon emissions affect financial performance. This inconsistency is compounded by existing literature providing mixed and inconclusive findings on this relationship. Further, the limited research in the South African context, specifically in the carbon-intensive industrial metal and mining industry, indicates the need for further investigation of the relationship. To address these gaps, this study investigates the nature and specific impact of carbon emissions on key financial performance measures, ROA, ROE and Tobin's Q for JSE-listed industrial metal and mining industry.

1.4 Objectives of the Study

Focusing on the JSE-listed industrial metal and mining South African companies, this study's objectives include the following.

1. To investigate, using the panel regression on 2018 to 2022 data, the nature of the relationship between financial performance (ROE, Tobin's Q and ROA) and carbon emissions in JSE-listed industrial metal and mining companies.
2. To examine the specific impact of carbon emission on financial performance measures, ROE, ROA and Tobin's Q for these companies.

1.5 Research Questions

Focusing on JSE-listed industrial metal and mining South African companies, the research questions are:

1. What is the nature (positive, negative or neutral) of the relationship between financial performance and carbon emissions?
2. How do carbon emissions impact ROA, ROE and Tobin's Q for these firms?

1.6 Significance of the Study

Currently, there is a growing research interest focusing on the environment and sustainability, specifically on carbon emissions and the related impact on the firms' financials. However, little to no focus has been paid to the South African region and companies. This study aims to bridge that void and contribute to the knowledge on climate change, financial performance, and GHG emissions, in the South African context with the main focus on the industrial metal and mining industry. Further, the result may inform companies, policymakers and regulators about managing carbon emissions.

1.7 Delimitations (Scope) of the Study

The delimitations of this study are:

- Time frame: This study only covers a five-year period, which is from 2018 to 2022
- Geography of the study: This study only focuses on South Africa. This country faces significant climate change challenges and has a high carbon-intensive economy primarily owing to high dependence on mining, metal and coal-based manufacturing. Developing countries like South Africa receive less attention in this research area. Focusing on the country bridges that gap.
- Industry and companies: This study focuses on JSE-listed industrial metal and mining industry. The industrial metal and mining industry is one of the biggest carbon emitters in the country and one of the most critical sectors in the economy. Further, the JSE-listed companies are big companies expected to adopt and comply with environmental and sustainability commitments. Hence, they are most likely to publish their environmental and financial data.

1.8 Assumptions

This study does not make any predetermined assumptions about the direction or the nature of the relationship. Further, the analysis is purely based on statistical findings and empirical data.

1.9 Study Limitations

This study's limitations include the following:

- The focus is only on JSE-listed industrial metal and mining companies from 2018 to 2022. During this period, only 17 companies disclosed their complete carbon emission data. Hence, utilising a limited number of entities is a constraint for this study.
- The financial measures used, namely ROA, Tobin's Q, and ROE, are imperfect. They are subjected to management manipulation.
- There is not enough updated data on carbon emissions post-2022, limiting the study from applying the most relevant data. As public disclosure is voluntary, companies tend to avoid their environmental performance disclosures.

1.10 Summary/Organisation of the Study

The dissertation is structured as follows: Chapter 2 reviews the existing empirical and theoretical literature. Chapter 3 focuses on the research methodology by presenting and discussing the tools and methods employed to collect and analyse the data. Chapter 4 presents, analyses and discusses the findings. Lastly, Chapter 5 concludes the study, proposes recommendations and suggestions for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter establishes the theoretical and empirical foundation for the study. It begins by outlining the relevant theories, including institutional, stakeholder and legitimacy theories. These theories offer valuable insight into why or not corporations engage in environmentally friendly practices. It then discusses the critical elements and concepts related to the study, such as financial performance measures, carbon emissions, and the related carbon emissions policies. Lastly, the chapter offers a critical assessment of the existing empirical studies on the relationship between the firms' financial performance and carbon emissions

2.2 Theoretical Framework

Scholars have developed and used various theories to explain financial performance and carbon emissions. While there is no one-size-fits-all theory, the relationship between an entity's financial performance and carbon emissions is mostly understood through the lenses of stakeholders' theory, institutional theory and legitimacy theory (Ganda and Milondzo, 2018; Rokhmawati, Sathye, and Sathye, 2015; Sakin and Kefe, 2024).

2.2.1 Institutional Theory

Institutional theory primarily focuses on an entity's decisions that are heavily influenced by social framework issues rather than those that are purely rational financial decisions (Chu, Xu, Lai, and Collins, 2018). The theory concentrates primarily on how social influences shape organisational decisions and actions. It assumes that entities operate in a social framework of accepted assumptions, values, and norms about what establishes acceptable and appropriate commercial behaviours (Carpenter and Feroz, 2001). Within this context, the development paradigm refers to a shift from traditional profit maximisation models toward sustainable development frameworks that encompass economic growth with environmental and social considerations like carbon emission reduction for long-term benefit (Huisinigh et al., 2015). Sustainability in this paradigm balances the social equity, environmental stewardship, and economic viability. This alignment motivates the present study's focus on assessing the impact of carbon emissions on financial performance within South Africa's carbon-intensive industrial metal and mining industry (Artiach et al., 2010). It reflects the evolving expectations placed on

companies to align with sustainability-related practices, such as reducing carbon emissions to maintain or gain legitimacy within the community.

Every company faces pressures from customers, regulators (legal) and the economic side of view. The increased legal compliance with environmental obligations (legal pressure), increased competition due to globalisation, resulting in cost reduction and profitability focus (economic pressure), and increased customer expectations (consumer pressure) have forced companies to consider the environment. Hence, Institutional theory details why and how entities are influenced by the environment in which they function and identifies the stakeholders that impact the business decisions.

There are three institutional pressures, namely coercive, normative and mimetic, that entities have to consider in their decisions (DiMaggio and Powell, 1983). Mimetic pressures are defined as the entity's effort to mimic the actions of its successful industry competitor to imitate its successful path (Lin and Sheu, 2012). Competitors' growth and success in adopting and implementing environmentally friendly innovations may cause companies to imitate them.

According to Chu et al. (2018), normative pressures prompt entities to conform to be regarded as legitimate and to have legitimate actions. This can arise from standards and values that stakeholders promote externally. For example, customers' expectations of an entity being environmentally friendly exert normative pressure on the entity to implement green practices. Hence, these customers' expectations create a situation for companies to act on these environmental pressures proactively.

Coercive pressure results from the influence employed by governing bodies or individuals in a position of power (Lin and Sheu, 2012). For example, a company's actions may be influenced by government agencies through regulatory policies. According to Chu et al. (2018), regulatory pressures are commonly assessed as coercive pressures in the literature. Different governments have intervened and implemented different regulations to respond to carbon emissions, such as CBT. With this, entities feel the pressure from the government to either pay penalties or comply with the implemented regulations.

Various stakeholders' increased focus on the environment has made it essential for companies to provide or produce environmentally friendly services or goods. Accordingly, entities seek to improve their efforts to minimise their negative environmental impact while meeting their stakeholders' needs; consequently, pressures from various stakeholders prompt entities to

behave in a certain way. Hence, this theory supports this study by indicating how the broader social framework issues influence the companies' financial performance.

2.2.2 Stakeholder Theory

Stakeholder theory involves identifying individuals who are either affected or can affect a company's achievement of its goals as stakeholders (Kaplan and Norton, 1992). The entity's stakeholders generally include customers, employees, shareholders, suppliers, creditors, government bodies, and public interest groups. Different stakeholders have different interests in the company; for example, shareholders are primarily interested in profit (dividends), and customers are mainly interested in the services or goods provided by the entity.

The company must consider every stakeholder's needs. Not considering the interests of every stakeholder in the company makes it difficult for a company to meet its vision, mission, and goals (Jensen, 2010; Rokhmawati, Gunardi, and Rossi, 2017). This is because costs are bound to increase once adverse reactions from the company's stakeholders occur and because stakeholders are the main drivers of entity wealth (Rokhmawati et al., 2017).

Numerous scholars have used this theory to understand the stakeholders and entities' relationship and their relationship outcomes. Specifically, many scholars have used the theory to assess entities' environmental pressures and impact (Cordeiro and Tewari, 2015). The stakeholder theory differs from the traditional view that the business's aim is to serve the shareholders by maximising their value. The theory suggests that companies must consider all stakeholders' interests in making business decisions when they want to be more successful (Rokhmawati et al., 2015; Rusli, Augustine, Murwaningsari, and Breliastiti, 2019).

The theory suggests that entities form part of the social structure they affect. Accordingly, entities' actions and decisions should respond to what stakeholders require. Stakeholder theory supports this study as it highlights that responding to the stakeholders' needs by reducing their carbon emissions or taking care of the environment is a significant strategic decision to build and maintain a good stakeholder relationship.

2.2.3 Legitimacy Theory

Legitimacy explains why entities choose specific actions and how those actions are perceived by various stakeholders (Dowling and Pfeffer, 1975). The theory provides that entities are

accountable to stakeholders and are part of the broader system to which they want to be seen as operating appropriately (Ellram, Tate, and Saunders, 2022). Hence, this leads to entities performing activities like disclosing voluntary information that makes them appear legitimate.

This theory considers society's expectations, emphasising that the ongoing survival of the company can be heavily impacted if it fails to meet the expectations and needs of the society in which it operates. Rather than describing companies' behaviour (which is normative), legitimacy theory seeks to explain or describe companies' behaviour (Dowling and Pfeffer, 1975). Therefore, it can be said that legitimacy is met by the entity when it demonstrates that its activities and actions align with social values.

Three criteria are primarily used to assess the legitimacy of one action versus the other: cognitive, moral and pragmatic (Suchman, 1995). Pragmatic legitimacy's main aim is to meet the external stakeholders' expectations and to be perceived as appropriate. In contrast, cognitive legitimacy is based on the perspective that an entity's behaviours are legitimate and cannot be challenged (Ellram et al., 2022). Pragmatic legitimacy actions are focused on the entity receiving anything tangible, which is usually financial gain.

Moral legitimacy questions whether an action is "the right thing to do" and is regarded as a stakeholder's normative perception (Ellram et al., 2022). Different entities can answer the question differently, so differentiating self-interest and moral legitimacy is impossible. For example, an entity can aim to reduce carbon emissions because it improves its reputation and trusts that it is the right thing to do. This theory supports this study as companies may engage in carbon emission reduction projects to be perceived by the various stakeholders as legitimate. This might or might not have a differing impact on the companies' financial performance.

2.2.4 Summary of the Theoretical Framework

Stakeholder theory, legitimacy and institutional theory provide a valuable insight into how different corporations can manage their emissions and the potential impact this might have on financial performance. All three of these theories fully support this study.

2.3 Carbon Emissions

Recently, various kinds of environmental issues have been gaining attention internationally. These issues include ozone depletion, deforestation, acid rain, waste issues, global warming,

and biodiversity. Each issue has a different characteristic, resulting in different stakeholders emphasising a particular issue. Most stakeholders have regarded global warming as the most essential environmental issue (Iwata and Okada, 2011; Wang, Li, and Zhang, 2021). Because of its damaging impact, it is perceived as one of the biggest threats to human survival and the main result of carbon emissions.

According to Huisinigh, Zhang, Moore, Qiao and Li (2015), global warming negatively impacts the environment and human lives by reducing growth rates globally, mainly in developing countries, i.e. South Africa, due to extreme weather. Further, increasing mosquitoes as a result of warming, leading to high rates of people infected with malaria and decreases crop yields.

Increases in international production capacity have caused a corresponding increase in carbon emissions. These carbon emissions result in numerous negative externalities, which cause severe social and natural issues, such as air pollution (Van Emous, Krušinskas, and Westerman, 2021). These negative externalities will only intensify due to increased carbon emissions and human recklessness (Yu, Wang, Li, and Shi, 2016). One of the most significant externalities is climate change.

Climate change refers to a change in climate due to human activities, like burning fossil fuels, high consumption, waste, deforestation, and agriculture (Huisinigh et al., 2015; Wang et al., 2021). It is a significant concern for human and environmental life. It results in multiple issues, such as societal, technological, global warming, and economic and ecological imbalances. It further threatens to undermine years of economic and social development and affect several human rights, such as the right to shelter, food, life, and health (Segger, 2016).

There are six main gas components or GHG emissions, namely, hydrofluorocarbons, nitrous oxide, sulphur hexafluoride, methane, carbon dioxide and perfluorocarbons (Huisinigh et al., 2015). Carbon dioxide is among these gases, one considered prominent and one that many scholars have taken an interest in. These emissions are divided into three different scopes, scope 1, 2 and 3. Scope 1 includes all the GHG attributed directly to the corporation's practices, from direct combustion of furnaces, fossil fuels in boilers, production processes, and power generation (Sakin and Kefe, 2024). Scope 2 includes indirect GHG from purchased energy, such as steam, heat, and electricity (Busch and Hoffmann, 2011; Ganda and Milondzo, 2018). Both emissions scopes (Scope 1 and 2) reflect the company's resource use efficiency. According to Lewandowski (2017), Scope 3 emissions are not significant cost drivers as they are not subject to governing constraints. It includes indirect carbon emissions from other

ancillary sources, like emissions from goods the entity sells and the transportation of employees.

In South Africa, carbon dioxide is the leading emission contributor, as in 2022 it contributed 81.9% of the total emissions (Department of Forestry Fisheries and the Environment [DFFE], 2024). Most of these carbon dioxide emissions were from the Energy, Industrial and Agriculture industries, with average contributions of 92.3%, 7.2% and 0.5% respectively (DFFE, 2024). Internationally, growth in carbon emissions is mostly from industry, energy supply and transport sectors (Huisingh et al., 2015). This aligns with South Africa's data, as according to the DFFE (2024), the energy sector (including transport and energy sectors), which Eskom mainly drives, contributed to 86% of all emissions in 2022. This was followed by the Agriculture industry, which contributed 11% of all emissions. Third was the Industrial sector, which contributed 6.4% of all emissions. Out of the 6.4% industrial sector's contribution, the metal and mineral industries were the most significant contributors, contributing 51.2% and 19.8% respectively.

Due to the varying operations of the different industries, some industries pollute more than others. Those sectors that pollute more are called dirty sectors, and others that pollute less are called clean sectors. According to Ganda and Milondzo (2018), dirty sectors are those sectors that have high GHG per output unit. Clean sectors are those sectors that have low emissions per output unit. Dirty sectors include energy, materials, industrial, and pharmaceutical. Clean sectors include health care, telecommunications, customer staples, customer discretionary, and financials (Ganda and Milondzo, 2018; Mani and Wheeler, 1998) .

The industrial metal and mining industry is one of the dirtiest sectors, as its processes are largely energy-intensive. The industrial metal and mining sector emissions include direct and indirect carbon emissions. According to Liu, Ji, Lü, Wang, Zhi, Pei, and Quan (2021), direct emissions are the emissions from energy consumption of mining activities and processes. Meanwhile, indirect emissions result from fuel consumption during the detonation of explosives, electricity production, and mining operations.

2.4 Carbon Emissions Policies

Currently, companies produce more to meet the increasing demands and profit targets, which means more carbon is emitted. However, with the introduction of different carbon emission policies and increasing stakeholders' awareness of the environment, companies are now

looking at implementing clean production measures. These measures aim to increase production, lower carbon emissions, improve environmental compliance and flexibility in production. Various stakeholders are affected when companies commence an emissions reduction process and energy-saving production. Hence, every stakeholder, especially employees, must be involved more effectively to reduce emissions and save energy (Yang and Zhang, 2017).

To maximise profit, companies have increased carbon emitted and have created a negative externality for the environment and communities. If left unchecked, these negative carbon emissions externalities can have irreversible issues for the ecosystem and humans (Ding, Chen, and Wang, 2020). It is essential that measures are in place to ensure that these externalities are not far-spread and that the responsible parties internalise them. Many actions worldwide have been undertaken to stabilise or minimise carbon emissions.

These measures include the Paris Agreement, the Kyoto Protocol, and the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement is an international climate change accord that contains countries' policy obligations. It enshrines top-down and bottom-up approaches to international climate governance (Segger, 2016). The agreement intends to improve the international response to climate change pressures in the sustainable development context.

In comparison, the UNFCCC is the central framework for international efforts to avoid climate change dangers (Segger, 2016). The UNFCCC does not provide binding enforcement mechanisms and GHG emission limits. However, it provides a framework for further instruments and protocol negotiations. On the other side is the Kyoto Protocol, which was introduced in 2005. The Protocol is based on the premise that to save the planet, GHG emissions should be reduced (Sibanda and Ndlela, 2020).

In line with these measures, many incentives are recommended to reduce carbon emissions. For example, incentives include carbon pricing, fossil fuels subsidies, renewable energy low-cost auctions and energy efficiency standards (Tsai, 2020). Internationally, carbon pricing is the most popular incentive. It is based on charging carbon emitters, including offset mechanisms, ETS, CBT, etc. ETS and CBT are the two main strategies that different governments and countries have adopted to reduce these carbon emissions (Elkins and Baker, 2001; Ganda and Milondzo, 2018). According to Elkins and Baker (2001), ETS determines

specific levels of emissions targets through allowances in trade, while CBT aims to reduce GHG by using a direct price mechanism.

2.4.1 Emissions Trading Schemes (ETS)

Carbon trading is a carbon pricing technique under carbon cap-and-trade to reduce and regulate carbon emissions (Tsai, 2020). It requires companies to accept the cost of abating emissions or purchase a polluting permit. According to Jingxian and Wenjie (2023), an ETS is a market-based incentive, a financial policy measure for environmental sustainability and a constraint to ensure that the double carbon goal is satisfied promptly. The double carbon refers to the effort to attain carbon neutrality and a carbon peak. This is the goal adopted by, for example, China, to reduce carbon emissions.

Implementing an ETS allows entities to receive financial gain by selling excess carbon allowances. The sale is made on the market, creating the carbon trading market. The country's respective government sets a carbon emission cap that limits the levels of carbon that companies can emit. The emissions cap amount, called permits or carbon allowance, is then allocated to each installation via auction or freely. Companies that manage to reduce carbon emissions can sell permits to other companies that have failed to reduce carbon emissions (Tsai, 2020).

Several countries like China, Switzerland, New Zealand, Kazakhstan, the EU, and Australia, as well as New York, Maryland, Maine, California, and Delaware in the United States, have implemented ETS (Huisingh et al., 2015). According to Chan, Li, and Zhang (2013), due to the South African energy sector's oligopolistic structure, the ETS is unlikely to be effective, as the scheme is supposed to be competitive. For example, the South African energy industry is mostly dominated by Eskom. On the other hand, CBT is a better option in South Africa, as it can reduce carbon emissions, lead to low-carbon and cleaner technologies, and improve energy efficiency (Elkins and Baker, 2001).

Scholars believe an ETS is better for responding to environmental stress. This is because the ETS is a market-based instrument with high flexibility and is cost-effective (Zhang, Zhang, and Zhang, 2024). According to Xiao, Li, Zhu, Xie, Hu, and Huang (2021), the ETS improves the companies' total factor productivity and also promotes the companies' profitability and operating capacity.

2.4.2 Carbon Tax (CBT)

Among government regulations worldwide, CBT is essential for managing carbon emissions. CBT has been implemented in countries like South Africa, Ireland, Great Britain, Sweden and Finland (Ding et al., 2020). It is a carbon pricing technique and a pollution tax. It is tax-charged on energy sources that emit carbon (Tsai, 2020). The CBT concept is based on the premise that the regulators can adjust external pollution through taxes.

According to Tsai (2020), the CBT objective is to decrease the unfavourable and harmful levels of carbon emissions, particularly carbon dioxide. Hence, decelerating the negative impact of climate change on humans and the environment. CBT encourages entities to find efficient and effective solutions to deliver and produce their services and goods. It is generally determined by the carbon emitted (quantity) and the CBT rate. Irrespective of the fact that CBT is viewed as the most effective way to decrease carbon emissions, it has some disadvantages, such as introducing more costs for the company.

To decrease carbon emissions, the South African government voluntarily announced in the 2009 Copenhagen Climate Change Conference that South Africa would reduce GHG locally. The goal was to lower the existing level of emissions by 34% in 2020 and 42% in 2025 (Alton et al., 2014). CBT was implemented in South Africa on the 1st of June 2019 to reduce GHG emissions in an affordable, cost-effective, and sustainable manner

The CBT was implemented in South Africa to ensure that customers and companies consider climate change's externalities (negative costs) in their future investments, consumption, and production decisions (De Jager, 2018). The tax is based on the polluter pays principle. This means that companies (polluters) pay tax on the amount (quantity) of carbon emitted in a period (De Jager, 2018). In South Africa, CBT is imposed on companies operating facilities that emit a combined capacity above or equal to the CBT threshold. The CBT initial rate was set at R120 per tonne (Nong, 2020). This rate was increased by the consumer price index (CPI) +2% per annum until the 31st of December 2022, and then further increased by CPI only.

In addition to the CBT, South Africa has other policies that impact carbon pricing. These policies are environmental-related taxes implemented at the local and national government levels. Examples include product taxes, aviation taxes, vehicle taxes and transport fuels. Further to this, specifically to reduce coal burning, South Africa's long-term goal is to improve the production of renewable energy sources. To ensure this goal is met, and as decarbonisation

assistance, the Just Energy Transition Partnership provided \$8.5 million to the country in 2021 (Market-Line, 2023). In South Africa, the tax is collected and administered by SARS.

2.5 Financial Performance

Financial performance is the company's overall financial well-being and status over a specific accounting period (Busch and Hoffmann, 2011). It further refers to the company's financial outcome from operating business activities (Ooi, Goh, Yeap, and Loo, 2018). In other words, financial performance assesses the viability of the entity and its ability to meet its economic goals. Hence, financial performance analysis is essential for the entity's decision-making process (Babalola and Abiola, 2013).

The entity's financial performance is analysed by using various financial performance measures. The most common measures are balanced scorecards and financial ratios (Kaplan and Norton, 1992; Lewellen, 2004). A balanced scorecard is generally employed to measure not only the financial performance but also the overall company's performance. A balanced scorecard focuses stakeholders' attention on different measures and includes different functional activities.

The balanced scorecard is based on the cause-and-effect association between non-financial and financial measures (Lubis, Torong, and Muda, 2016). According to Lubis et al. (2016), the main advantage of the balanced scorecard is that it focuses on financial measures and includes non-financial measures. Managers only have to focus on 15-20 key performance measures. This may save time, but it can also result in incorrect measurement, as the chosen indicators may not be appropriate.

The other widely used method to measure financial performance is the application of financial indicators, commonly known as financial ratios. Financial ratios show the relationship between two variables. They are widely used for comparison purposes to obtain information about different companies' performances (Babalola and Abiola, 2013). Computation of financial ratios may be pretty straightforward, but interpreting them may be challenging. Although the computation of ratios may be necessary, scholars and practitioners assert that interpreting these ratios is crucial. Therefore, if it is wrong, regardless of whether the calculation is correct, the whole analysis is wrong, thereby resulting in incorrect decisions (Lewellen, 2004).

Some researchers and practitioners use accounting-based measures, while others use market-based measures (Alexander and Buchholz, 1978; Ooi et al., 2018; Tsoutsoura, 2004). These two measures represent different perceptions of correctly evaluating a company's financial performance. Each measure has biases and implications (Hillman and Keim, 2001; McGuire, Sundgren, and Schneeweis, 1988). Using different measures often makes it hard to compare companies and sectors and the outcomes of other studies (Hillman and Keim, 2001). McGuire et al. (1988) state that accounting-based measures primarily focus on the company's earnings or returns in response to the entity's accounting policies.

McGuire et al. (1988) further state that accounting-based measures have many limitations, including using historical data and being based on or affected by different accounting policies and estimates. While these measures are based on historical data, the market-based measures are based on future information. The data used for accounting-based measures are subject to manipulation by management. Some scholars view market-based measures to be an appropriate indication of the company's intangible value (Haniffa and Cooke, 2005; Prado-Lorenzo, Rodríguez-Domínguez, Gallego-Álvarez, and García-Sánchez, 2009).

Market-based measures are generally affected by economy- or market-wide forces, such as inflation and recession (McGuire et al., 1988). They are not affected by the different accounting policies as accounting-based measures, and they often represent the shareholders' evaluation of the company's ability to generate economic earnings (McGuire et al., 1988).

Inadequately designed performance measures can lead to dysfunctional behaviour (Orlitzky, Schmidt, and Rynes, 2003). Dysfunctional behaviour occurs when employees, in particular managers, want to achieve their inner motives rather than achieve the company's goals (Balthazard, Cooke, and Potter, 2006). The Enron Corporation and the most recent Steinhoff scandals are the best indications of dysfunctional behaviour by managers (MacKenzie, Garavan, and Carbery, 2011). Such behaviour is usually driven by the company's remuneration structures, such as rewarding employees with bonuses based on revenue or net profit. It is the most significant disadvantage of accounting-based measures, as the measures are exposed to management manipulation.

2.6 Empirical Literature

Existing studies done on this relationship have yielded inconclusive and mixed results. Some literature finds that the relationship is negative, suggesting that lowering emissions can enhance the company's financial performance. Conversely, other studies find a positive relationship, indicating that an increase in carbon emissions results in better profitability, and vice versa. Other studies find no clear relationship, while the last findings suggest that the relationship may only materialise in the long term.

2.6.1 Negative Relationship

Much academic literature suggests that companies with good environmental performance, demonstrated by low carbon emissions, have superior financial performance. In line with these findings, in the broader African context, Le and Nguyen-Phung (2024) used comprehensive data from companies in Africa from 2005 to 2021 to investigate the impact of a company's GHG emissions on ROA and ROE. Their research found that GHG emissions negatively impact ROA and ROE. Further, post-Paris Agreement implementation, an increase in ROA and ROE is associated with a decreased GHG emissions. However, the study focuses on the continental level and may overlook the national-level variations, suggesting the need for a country-specific analysis like the present study that focuses on South Africa.

A South African study by Hou, Tran, Msefula, and Dlamini (2025) found a negative nexus between financial performance and GHG emissions, reinforcing the national relevance. Another South African study by Ganda and Milondzo (2018) applied multiple regression techniques to analyse the impact of carbon emissions on 63 South African entities' financial performance. The return on investment (ROI), return on sales (ROS), and ROE were used as financial measures. Scopes 1 and 2, and their sum, were used as carbon emission measures. The study also found a negative relationship, suggesting that companies that enforce carbon emission reduction initiatives can control financial performance effectively. However, this study's limited timeframe of one year reduced the robustness of the study, suggesting the need for panel approaches like this study. These South African studies provide an essential foundation, suggesting a negative relationship within the country's context.

Jangid and Sharma (2025) sampled 1,539 non-financial corporations in the Asia-Pacific region and found that carbon emission reduction positively affects both market and accounting-based

measures of financial performance. In the same region, Bharali Saikia and Maji (2024) sampled 100 Indian companies and came to the same conclusion, strengthening the evidence of developing economies.

In their other study, Maji and Saikia (2024) investigated the impact of GHG emissions on the US and Indian entities' financial performance and found a negative nexus. These findings aligned with their other study, indicating the necessity for companies and their executives to lower GHG emissions to increase financial performance. The study emphasised the “win-win” ideology, whereby firms' financial performance increases while there is a decrease in carbon emissions.

Ghose, Makan, and Kabra (2023) investigated the impact of carbon productivity on a corporation's financial performance among 66 Indian listed companies from 2019 to 2020 and 2015 to 2016. Carbon productivity is the sales amount per unit of GHG emissions (Nishitani and Kokubu, 2012). A random effect model with the Hausman and Breusch-Pagan tests was used to investigate the impact. Findings indicated a positive carbon productivity impact on financial performance, suggesting that entities may obtain a competitive edge by reducing carbon emissions.

Another study by Makan and Kabra (2021) applied the panel regression method to 36 Indian listed companies. Financial performance and carbon emissions were measured by the market-to-book ratio and carbon productivity, respectively. Findings aligned with their other study, showing a positive association between carbon reduction and financial performance, complementing the “win-win” ideology.

Daud, Meutia, and Yuniarti (2023) examined the eco-efficiency effect on the Indonesian companies' financial performance. The financial performance and eco-efficiency were measured by the financial indicators, namely ROS, ROA, ROE and emission intensity, respectively. The study used data from 2019 to 2021 to capture the eco-efficiency effect. Findings indicated that financial performance is positively impacted by eco-efficiency. This study suffers from a limited perspective, as it only applied accounting-based financial indicators. Similarly, Meng, Gou, and Chen (2023) noted that better carbon performance positively affects China's companies' financial performance.

Using 184 firm-year observations from 23 Indian companies across 13 different sectors, Kumar and Firoz (2018) applied panel data analysis. Total assets, company age, leverage, industry,

beta, ownership, cross-border listing, and BVTM served as control variables, with carbon intensity as the independent variable. Results indicated that carbon emissions negatively impact firm financial performance, specifically Earnings Per Share (EPS) and Return on Net Worth (RONW). This study offered a valuable cross-sector evidence.

In the European continent context, Hewagama, Rainsbury, and Zudana (2025) focused on New Zealand-listed companies. They noted that firm performance (Tobin's Q) is negatively associated with carbon emissions. Similarly, Issa (2024) used 1740 observations of UK-listed firms to answer whether initiatives to reduce emissions enhance financial performance. The study employed various techniques, such as system generalised and ordinary least squares methods. Results revealed a significant negative nexus between carbon emissions and financial performance.

Sakalsız and Özçelik (2024) investigated the relationship between Turkey's companies' financial performance and carbon emissions from 2017 to 2021. Applying the random effect, the study concluded that carbon emissions negatively affect ROE and ROA. However, no statistical effect was noted between carbon emissions and Tobin's Q. Another study on the Turkish context by Sakin and Kefe (2024) concluded that higher carbon emissions negatively impact ROE and ROA among 31 listed entities sampled over the 2017 to 2020 period.

Perdichizzi, Buchetti, Cicchiello, and Dal Maso (2024) found that market valuations are negatively associated with higher carbon emissions for European firms. Liu, Zhou, Yang, Hoepner, and Kakabadse (2023) also concluded that organisational performance and carbon emissions are negatively associated for 100 UK-listed firms from the carbon-sensitive industries over the 2010 to 2017 period.

Homroy (2023) explored how the gender composition of chief executive officers (CEO's) children (i.e. the presence of daughters) as an identification variable. The results found that UK firms managed by CEOs with daughters demonstrate stronger environmental awareness and improved profitability through carbon emission reduction. The study used an innovative approach, focusing on CEOs' children as an identification approach; however, it suffers from UK bias. In the Central-Eastern Europe, Nichita, Nechita, Manea, Irimescu, and Manea (2021) confirmed that managing the GHG emission yields increased ROS (financial performance). The study benefits from being concise, as only the ROS was used as the dependent variable, but the evidence is limited to only the chemical industry.

Studies by Secinaro, Brescia, Calandra, and Saiti (2020), and Tzouvanas, Kizys, Chatziantoniou, and Sagitova (2020) analysed data from European companies. Both their results revealed that entities with good environmental performance generally have good profitability. Cucchiella, Gastaldi, and Miliacca (2017) found that adopting appropriate GHG emissions and implementing the environmental management system could improve the entity's profitability. This suggests that firm-wide adoption and implementation of practices to mitigate climate change increases profit by lowering production costs and reducing environmental risk. This may be due to the combination of enhanced productivity and demand.

In the American context, Houqe, Opare, Zahir-ul-Hassan, and Ahmed (2022) found that companies suffer financially primarily due to the market's negative reaction to increased carbon emissions. Castilho and Barakat (2022) reported that adopting climate change mitigating strategies yields improved financial outcomes for entities on the Brazilian stock exchange. Lucas and Noordewier (2016) confirmed that companies that engage in pollution control and environmental management practices see a positive effect on their profitability.

At an international level, Salvi, Martielli, Battisti, Forliano, and Kumar (2025) examined 118 global companies from 2018 to 2022 and found that carbon emissions have negative consequences on financial performance. Similarly, Ibishova, Misund, and Tveterås (2024) leveraged a 14,866-observation dataset from 35 industries, 36 countries, and 2768 companies over 2002-2022. The results also indicated that reducing carbon emissions improves financial performance (measured by ROE and ROA).

Sitompul, Suroso, Sumarwan, and Zulbainarni (2023) used a systematic literature review to examine the relationship between entities' financial performance and carbon management approaches. The review covered multiple countries and industries. The result indicated that 9% of the articles demonstrated mixed results, while 59% exhibited positive findings. These findings reflect that, more often than not, reducing carbon emissions yields positive outcomes for financial performance. Loohuis (2022) confirmed that The result indicated that increased carbon emissions result in decreased financial performance over time among 830 sampled global entities.

A Meta-analysis was applied by Galama and Scholtens (2021) to examine the nexus between financial performance and GHG emissions. Their study included 34 studies with 74 effect sizes for 1997-2019 from different countries. The study found that entities with good financial

performance have lower carbon emissions. Similarly, another study on multiple countries with emerging economies found that lower profitability, as measured by Tobin's Q and ROA, is associated with higher carbon emissions (Miah, Hasan, and Usman, 2021).

To better understand the nexus between financial performance and green innovations, Yi, Zeng, Chen, and Shi (2021) used meta-analysis to analyse the relationship. With a sample of 80 studies and 20,503 observations, this study found a negative relationship, suggesting that green innovation results in better financial performance. Findings also showed a significant relationship in countries with limited corruption. Van Emous et al. (2021) applied the panel data analysis (fixed effect OLS regression model) on cross-country data. The findings indicated that ROS, ROE and ROA increased due to decreased carbon emissions.

Trinks, Mulder, and Scholtens (2020) sampled 1572 international companies from 2009-2017 to investigate the effect of carbon efficiency on companies' financial performance. The result found that good financial performance is associated with good carbon efficiency. Gallego-Álvarez, Segura, and Martínez-Ferrero (2015) applied panel data analysis on 89 international entities from 2006 to 2009. Their results found that emitting less positively impacts entities' financial performance, suggesting that entities can improve their environmental behaviour to achieve improved financial performance.

These findings, collectively, suggest that companies that actively respond to their stakeholders' needs to lower carbon emissions improve their competitive advantage and reputation, resulting in increased financial performance. Thus, they support legitimacy and stakeholder theory in that companies benefit from responding to stakeholder pressures by reducing carbon emissions and increasing their financial performance. Entities that can't meet the environmental needs of lowering carbon emissions may face a reduced demand from environmentally friendly customers. This suggests that stakeholders, especially investors, value the companies' efforts towards emissions reductions. Furthermore, the decline in financial performance may be due to excessive penalties from non-compliance with environmental laws like the CBT and increased compliance costs with environmental regulations. However, some of these studies were limited to short time frames as they used only one year in their data set.

2.6.1 Positive Relationship

In contrast, some scholars find that carbon emissions positively affect companies' financial outcomes. These scholars suggest that proactively investing in carbon emission reduction is detrimental to the company's financial performance. For example, Chomachaei and Golmohammadi (2025) assessed the impact of CBT, a central GHG reduction regulation, on US firm performance. The result revealed that the CBT negatively impacts the entity's financial performance. These findings are robust for policy focus (CBT). Similarly, Adu, Flynn, and Grey (2023) found that financial performance and carbon performance (reduced carbon emissions) are negatively related. This suggests that an increase in carbon emissions is associated with an increase in financial performance.

Senna and de Araujo Moxotó (2025) found that, on average, Brazilian companies with better financial performance have higher CO₂ emissions (positive correlation). Findings are relevant for developing economies. Vaicondam, Mustafa, Roslan, Ming, and Ramayah (2025) reached the same conclusion, suggesting that Malaysian companies that do not actively engage in GHG emissions reductions may still have increased financial performance.

The findings of Li, Huang, Wen, Li, Yan, Skitmore, Shi, and Lai (2025) show a positive association between carbon emissions and financial indicators like Tobin's Q (long-term indicator) and operating profit (short-term indicator). Using both market and accounting-based measures, the study benefits from a multi-metric scope. Similarly, a study valuable for South African relevance by Hou et al. (2025) found that high GHG emissions correspond with high Tobin's Q for South African firms. This suggests that emissions reductions result in a decline in financial performance, specifically the Tobin's Q.

Busch, Bassen, Lewandowski, and Sump (2022) assessed the sensitivity and robustness of Delmas, Nairn-Birch, and Lim (2015) results by extending and replicating the study. The identical research design was applied, but a different time frame was used. The initial study found that the relationship changes from positive in the short term to negative in the long term. The study found that these initial findings of a positive relationship between short-term financial performance and carbon emissions are robust. However, the initial negative association between long-term financial performance and carbon emissions is not robust. Although the study evidence is limited to only the European region, it is insightful for replication.

Wang, Li, and Gao (2014) found a positive correlation between the entity's financial performance and GHG for Australian public companies. Mao, Zhang, and Li (2017) analysed the firms' performances and external and internal low-carbon integration relationships using businesses in China. The study found that reduced carbon emissions negatively impact financial performance while improving environmental performance. This suggests that as companies comply with environmental regulations, the operating costs increase, reducing the profit.

Furthermore, Fujii, Iwata, Kaneko, and Managi (2013) used the ROA of Japanese manufacturing firms as an economic performance indicator and dependent variable to assess the association between CO₂ emissions and economic performance. Results found a positive correlation, indicating that reducing carbon emissions is not always a good idea to improve profitability. This suggests that there is a monetary cost to carbon emission reduction. These findings support institutional theory as regulatory pressures, like CBT, are seen as an additional cost that reduces financial performance.

2.6.3 Unclear/No Relationship

In addition to the above, some scholars concluded that there is no clear relationship. In line with this viewpoint, Hewagama et al. (2025) examined the effect of GHG emissions on the firm performance of New Zealand-listed entities. Findings showed no carbon emission impact on the entity's performance (ROE and ROA). According to Chan et al. (2013), carbon ETS positively impact the power sector's revenue and material costs. However, the carbon ETS does not affect the steel, iron, and cement industries. The study used a panel of 10 European countries with a sample of 5873 companies during 2001-2009.

Another European study by Dragomir (2012) scrutinised the environmental disclosures of the top five sampled gas and oil European entities using their sustainability reports. It found that European companies' environmental data were unrelated to their financial performance. Elsayed and Paton (2005) used the performance of UK entities (Tobin's Q, ROS and ROA) as the dependent variables to analyse the environmental impact on financial performance. The entity's environmental performance is the independent variable. Their study's findings suggest that the impact of environmental performance on firm performance is neutral.

Several Asian studies also found that there is no clear relationship. Park, Khue, and Lee (2024) used data from Korean-listed companies from 2011 to 2017. They discovered that ETS increased profitability slightly. However, it significantly reduced the firm's value. Zhang et al. (2012) applied a regression analysis to verify the nexus between economic performance and CO2 emissions reduction practices for 85 steel and iron companies in China. Results indicated that there is no clear impact of reducing CO2 emissions on economic performance.

An American study assessed whether large companies in the S&P 500 index, adopting eco-friendly practices, are better off financially. Petitjean (2019) used a panel dataset from 2005 to 2017 and found that emission reduction practices are not associated with financial performance. Similarly, another US study used 500 S&P firms in 6 different sectors for the 2012-2013 period and found that there was no clear relationship between environmental and operational efficiencies (Yu et al., 2016).

Sæther and Skjerven (2023) applied the panel data analysis on 80 international energy sector companies, with data from 2014 to 2021. The findings revealed no statistically significant relationship. Similarly, Damert, Paul, and Baumgartner (2017) analysed the influence of different international businesses' climate change responses on economic performance and found no clear relationship between economic performance and carbon reduction practices was indicated by the findings. Consistent with these results, Salahuddin, Alam, and Ozturk (2016) found that the economic growth generated by the company has no impact on short-term or long-term carbon emissions.

2.6.4 Non-Linear Relationship

Lastly, some scholars believe that carbon emission reduction may take time to impact financial performance, but it can affect it in the long run. Most of these scholars believe that investing in the environment leads to higher costs in the short term. In contrast, returns regarding consumer satisfaction and productivity improvement may be noted later. Further, companies must spend heavily on environmental costs. This can be through initiatives like providing environmentally friendly services or goods.

Broadstock, Collins, Hunt, and Vergos (2018) used 350 UK FTSE-listed companies to explore the relationship between business performance and GHG emissions. The study used Tobin's Q

and ROE as performance measures and dependent variables. The findings indicated that the relationship is non-linear, suggesting that both performance and emissions levels decrease in the long run.

Yang and Zhang (2017) found a U-shaped nexus between profitability and carbon constraints of sizeable thermal power entities, where profitability decreases in the early stages. The decrease in profitability is primarily due to high upfront research and development costs. Thereafter, with reduced carbon emissions, profitability increases as the costs become part of the operations.

The study of Ghisetti and Rennings (2014) used German companies and the merging of the 2009 and 2011 Mannheim Innovation Panel. Findings indicated that in the short term, when environmental regulations are external restrictions, “going green” does not pay. However, it does pay in the long run when the compliance and understanding of the environmental regulations have improved.

2.6.5 Summary of Empirical Literature

Based on the preceding, the empirical literature indicates no consistent finding regarding the relationship. Findings vary as studies also differ in methodology adopted; for example, different studies use different financial indicators, and some measure carbon emissions differently. Further, different studies use different geographies, time frames, industries, and companies.

There is also a visible lack of academic literature focused on the developing economies, especially the South African region. This study’s objectives of investigating the carbon emissions and financial performance, and assessing the impact of carbon emissions on multiple financial performance measures among JSE-listed industrial metal and mining companies from 2018 to 2022, address these gaps. With this, the study does not set any hypotheses.

2.7 Summary

The reviewed literature indicates that the association between financial performance and carbon emissions has continued to be of great interest to scholars. However, the existing literature does not provide one clear, and unanimous result. Some studies found a negative

relationship (Ganda and Milondzo, 2018), while others found a positive or insignificant relationship (Adu et al., 2023; Busch et al., 2022). These inconsistencies in results are due to numerous reasons, such as using different periods, countries, industries, methodologies and performance measures.

While there is extensive existing global evidence, there is limited research in the South African context, particularly in the carbon-intensive industrial metal and mining sector. This is despite the importance of the sector as one of the largest GDP contributors in the country, and it being one of the country's largest carbon emitters. This study thus addresses this gap by examining the relationship between JSE-listed industrial metal and mining companies' financial performance (ROA, ROE and Tobin's Q) and carbon emission (carbon intensity) for the period 2018 to 2022. By synthesising the institutional, legitimacy and stakeholder theories with empirical literature review inconsistencies, the review highlights the potential "win-win" via carbon reductions and improved financial performance. The following chapter presents and discusses the methodology used to investigate this relationship.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This study took a quantitative approach to examine and study the impact that carbon emissions have on the financial performance of South African industrial metal and mining firms. This was done by examining the impact of the intensity of carbon emissions on companies' financial performance ratios/indicators. The financial measures were ROA, Tobin's Q, and ROE. Multiple regression techniques (Panel data analysis) were used to examine the relationship. Further, e-views was used as the statistical software to analyse the data.

3.2. Research Philosophy

This study adopts the positivist philosophy, which supports the use of quantitative methods to test the statistical relationship between variables by applying quantifiable and objective data (Antwi and Hamza, 2015). Positivist philosophy is appropriate as the study seeks to examine a measurable relationship between carbon emission and financial performance using secondary data, through the panel regression method.

3.3 Population and Sample Selection

According to Acharya, Prakash, Saxena, and Nigam (2013), a sample is used when one cannot use the entire population. It can thus be defined as a subset selected to represent the whole population. This study's target population comprises all JSE-listed industrial metal and mining companies between 2018 and 2022. The public disclosure of carbon emissions and GHG data usually takes time, and limited data is available for the period before 2018 and after 2022. Therefore, this 5-year (2018 to 2022) timeframe is selected. Delisted companies and companies with incomplete data during this period are excluded to maintain data consistency.

The financial performance and carbon emissions relationship fluctuates across industries. Every industry emits at a different level, making carbon emissions industry-dependent. Industry differences arise because high-emitting industries are often more subject to regulations. The industrial metal and mining sector pollutes a lot and utilises vast amounts of energy during processing and extraction, making it relevant to the study. To eliminate any industry bias, the focus is only on JSE-listed entities in the industrial metal and mining sector. Further, Tobin's Q, one of our dependent variables, considers the entity's market value and hence requires the company to be listed.

Out of all industrial metal and mining JSE-listed companies, only 17 disclosed their complete carbon emissions data and financial information for 2018 to 2022. Consequently, the final sample includes 17 companies. Both financial performance and carbon emissions data were extracted from the Bloomberg ESG database and corroborated using the companies' annual and integrated reports.

The major issue in selecting and using a sample is sample representativeness. Suggesting that the results may not be generalised as they may not represent the entire population (Gallego-Álvarez et al., 2015). The analysis result may not, however, be invalidated because the results are assumed valid for entities with the same features as those sampled. The data employed in the analysis were collected primarily from Bloomberg and were collected based on availability. The findings may not be generalised, but they may not be invalidated as the sampled companies are in the same industry and all are listed.

3.4 Research Approach and Design

Research design is the researcher's overall strategy to integrate different components of the study in a coherent manner that addresses the research objectives. Three main approaches can be adopted in an academic research: quantitative, qualitative, and mixed methods. Qualitative research focuses on words rather than quantifying and analysing data. Quantitative research, on the other hand, encompasses gathering data and quantifying it for statistical treatment and testing relationships between variables to evaluate specific research objective (Apuke, 2017; Queirós, Faria, and Almeida, 2017).

The mixed approach is a mix of quantitative and qualitative methods. For this study's purposes, a quantitative research design was adopted to examine the companies' financial performance and carbon emissions. Quantitative methods were adopted as they are more appropriate for assessing causality using statistical tools. This approach has been used by previous scholars who also analysed the association between the firm's financial outcomes and emissions (Ganda and Milondzo, 2018; Sakin and Kefe, 2024; Wang et al., 2014). A panel-data structure is adopted as it improves efficiency and robustness because it allows examination of variations across companies and over time, aligning with the study's objectives (Hsiao, 2007).

3.5 Data Types and Sources

This study used secondary data that is readily available in the public domain. Companies' carbon emissions and financial performance information were primarily obtained from the Bloomberg ESG database. Bloomberg is a credible source, as a study by Broadstock et al. (2018) also used it to conduct the research. Where data could not be obtained from Bloomberg, supplementary data were obtained from the company's website on annual and audited integrated reports. Additionally, credible and reputable search engines like Google Scholar, Emerald, and EBSCO were used to conduct the literature review research.

The firm's financial performance and carbon emissions were used as the dependent and independent variables for the study. Further, firm size, growth and leverage were used as the control variables. The table below presents a summary of the variables' units of measurement. The details of each variable unit of measure are explained fully above.

3.6 Model Specification

This study adapted the multiple regression analysis model Ganda and Milondzo (2018) recommended. However, this model was tailored to test the relationship for JSE-listed industrial metal and mining companies. It was used in a panel data analysis of over 5 years rather than a 1-year analysis by Ganda and Milondzo (2018). Further, the capital intensity control variable was removed from the model primarily due to the unavailability of data.

Multiple regression can accommodate various correlated variables, providing a flexible framework for data analytics. Multiple regression is ideal for this study as several variables were used in the data analysis. Panel data analysis observations involve cross-sectional and time series dimensions, indicated by i and t , respectively. Panel data allow the control of unobservable and missing variables, capturing more accurate predictions and gathering more accurate inferences (Hsiao, 2007). Further panel data assist in assessing the company's performance over a period.

Panel data is considered a superior analytical method because it uses variation in time and cross-sectional dimensions (Delmas, Nairn-Birch, and Lim, 2015). Hence, the 5-year panel data analysis from 2018 to 2022 was used. The analysis is computed using a random or fixed effect estimation model and differs from a regular cross-section or regular time series regression. The random effects method is better than the fixed effects method in the absence of

a correlation between model variables and fixed effects, as it allows more efficient coefficient estimation.

The random effects model is based on the assumption that variables are non-random and are not correlated with any other explanatory (independent) variables (Gallego-Álvarez et al., 2015). Furthermore, in comparison to the fixed effect model, the random effect model is more efficient. However, it is slightly less consistent than the fixed effect model. Random effect *p-value* results are better than fixed effect due to the model's efficiency. This means that a random effect should be used if there is statistical reasoning, as statistically, the use of the fixed effect model is reasonable because of the consistent results. The study used the Hausman test and the LR test (likelihood ratio) to identify the most suitable model between the fixed effect and random effect for each financial performance measure (dependent variable).

The final model specification is as follows:

$$\begin{aligned} \text{Financial Performance}_{i,t} &= \beta_0 + \beta_1 (\text{Firm Size}_{i,t}) + \beta_2 (\text{Growth}_{i,t}) + \beta_3 (\text{Leverage}_{i,t}) \\ &+ \beta_4 (\text{Total Carbon Emission Intensity}_{i,t}) + \varepsilon_{i,t} \end{aligned}$$

Where:

- i denotes the company;
- β_0 is the intercept (estimated parameters);
- $t=1, 2, \dots, t$ indicates time;
- $\varepsilon_{i,t}$ is the random error;
- Financial performance = Tobin's Q, ROE, and ROA;
- Total Carbon Emissions intensity = TCE intensity

3.7 Justification of Variables

The sub-section below details and justifies the variables selected and included in the model. Further, explaining how the explanatory variables used in the models predict the dependent variable. Each variable was selected based on the empirical evidence and theoretical significance. The sub-section is divided into independent, dependent and control variables.

3.7.1 Independent Variables

Evidence from existing studies indicates that researchers used various scopes of emissions for their analysis. Some studies only used scope one emissions (Chen and Silva Gao, 2012). Other studies used the sum of scope 1 and 2 emissions (Houqe et al., 2022; Misani and Pogutz, 2015). The last group of scholars used the 1st and 2nd scopes of emissions separately (Ganda and Milondzo, 2018). Few companies in South Africa report scope three emissions, as there is a lack of framework or guidance for disclosing scope three emissions. Thus, scope three was excluded from the study analysis.

According to Misani and Pogutz (2015), to efficiently measure the entities' carbon emissions, only scopes 1 and 2 are suitable. This study thus used the sum of scope 1 and 2 emissions to measure carbon emissions effectively. This allowed the study to account for all the essential changes in the company operations, as well as the innovations and investments that affect carbon emissions. Misani and Pogutz (2015) also focused on the sum of the two scopes. Further, to align with existing literature, the intensity of carbon emissions is measured as the sum of scope 1 and 2 emissions to total revenue (Lewandowski, 2017; Misani and Pogutz, 2015).

3.7.2 Dependent Variables

This study used the company's financial performance as the dependent variable. Existing literature commonly uses market or accounting-based financial performance measures as its dependent variables (Delmas et al., 2015). Hence, to align with the existing literature, the dependent variables used in this study were market and accounting-based financial performance indicators. It is important to note that these methods are not substitutes. However, these measures complement each other. Market-based measures are considered long-term, while accounting measures focus primarily on the short term. Further, these measures are essential in measuring the companies' financial success.

To ensure that this study considers both methods, Tobin's Q, ROA, and ROE were applied as dependent variables. All three measures have been used previously in the environment, specifically carbon emissions and sustainability studies (Gallego-Álvarez et al., 2015; Ganda and Milondzo, 2018; Lewandowski, 2017; Misani and Pogutz, 2015; Sakin and Kefe, 2024).

Tobin's Q was utilised as the market-based measure, with ROA and ROE as accounting-based measures (Delmas et al., 2015).

ROA measures the entity's profitability in relation to the total assets employed by dividing the company's net profit by the total assets (Elsayed and Paton, 2005). Essentially, ROA highlights the earnings generated from capital invested. The ratio provides information to shareholders, managers, analysts, and other stakeholders about the company's management efficiency in utilising the company's assets to generate profit or returns. According to Busch and Hoffmann (2011), ROA is a robust variable for statistically gathering significant results.

The ROA is most suitable for operating efficiency measurement and reflects the company's medium-long-term financial strength. ROA can vary for different companies and industries depending on various factors. Listed companies' ROA can also vary significantly from that of unlisted companies. Therefore, as a comparative measure, it is better to compare the ROA to the entity's previous one and also compare it to the ROA of a similar company. Based on this, this study only used the JSE-listed industrial metal and mining companies to avoid industry bias.

ROE is a measure that is commonly used to measure liquidity, solvency, efficiency, and shareholders' return (Busch and Hoffmann, 2011). It is computed as the net profit to the company's equity (Ganda and Milondzo, 2018). Equity would include share premium, ordinary share capital, and reserves. The reason behind using ROE as a performance measurement is that it primarily provides more reliable information and results than EPS.

Lastly, according to Delmas et al. (2015), Tobin's Q is the entity's market value to the replacement cost of its assets. Tobin's Q reflects intangibles not captured by ROE and ROA (accounting-based measures) by considering the company's market value. For our research purposes, Tobin's Q ratio equals the sum of market capitalisation (MVE), preferred equity (PE) and total liabilities (TL), to total assets (TA) (Delmas et al., 2015).

$$\text{Tobin's Q} = \frac{MVE + PE + TL}{TA}$$

3.7.3 Control Variables

This research includes numerous control variables that align with existing work. The chosen control variables were selected because they are more likely to assist in examining and assessing the relationship. Financial risk (Leverage), firm size, and growth are the control variables used for this research.

Leverage measures the company's risk, which includes the risk that could impact the entity's market value. To measure the entities' financial risk, the total debt to total assets ratio was used (Welch, 2011). A company's risk tolerance affects its ability to engage in carbon emissions management (Busch and Hoffmann, 2011). Growth was computed as the change in the company's sales over two accounting periods (King and Lenox, 2001). Companies with more growth may be more willing to undertake carbon emission reduction projects to ensure continued growth.

According to Artiach et al. (2010), the entity's size increases economies of scale for the entity as well as the entity's visibility to different stakeholders. This study measured a firm's size as the natural logarithms of the total company's assets (King and Lenox, 2001; Sakin and Kefe, 2024). This is because, in the industrial metal and mining sector, size is mostly considered by the total assets in the balance sheet. A natural logarithm is used to measure and transform this control variable to avoid skewed distributions. Big listed companies may demonstrate a more responsible behaviour to be seen as legitimate and to please environmentally friendly stakeholders (Busch and Hoffmann, 2011).

This study initially tried to include capital intensity as the control variable. Relevant studies controlled for capital intensity, measured as capital expenditure divided by total assets (Delmas et al., 2015; Ganda and Milondzo, 2018). When performing further assessment, the capital intensity was removed as the control variable, primarily due to the unavailability of data. This exclusion was required to ensure the completeness and integrity of the dataset.

TABLE 1: VARIABLES, UNITS OF MEASUREMENT SUMMARY

Control Variable	Measurement	Supporting literature
Leverage	Total debt/Total assets	Le and Nguyen-Phung (2024)
Firm Size	Total Asset natural logarithm	King and Lenox (2001)
Growth	Change in sales over two years	Sakin and Kefe (2024)
Independent Variable		
carbon emissions intensity	The sum of scope 1 and 2 emissions to total revenue	Misani and Pogutz (2015)
Dependent Variable		
Tobin's Q	$\frac{MVE + PE + TL}{TA}$	Delmas et al. (2015)
ROE	Net profit/equity	Sakin and Kefe (2024)
ROA	Net profit/Total Asset.	Elsayed and Paton (2005)

3.8 Estimation Procedure

To determine the most suitable model for each financial performance measure (dependent variable), the LR test (likelihood ratio) and the Hausman test were computed. These tests were applied to all three financial performance measures, namely Tobin's Q, ROE, and ROA, to determine whether to use the random effect, pooled least squares, or fixed effect model. According to Gallego-Álvarez, Segura, and Martínez-Ferrero (2015), the normality assumption may be redundant when obtaining multiple regression analysis results. Hence, this study did not assess the normality of the distribution of the variables. The results are presented in the table below.

TABLE 2: DETERMINING THE MODEL TO BE USED FOR FINANCIAL PERFORMANCE MEASURES

	Test statistics	<i>P</i> value	Result
ROA			
LR ratio	4.505342	0.0000	A panel model (random effects) is the most appropriate.
Hausman	23.187534	0.0001	The fixed model is more suitable.
ROE			
LR ratio	6.130205	0.0000	A panel model (random effects) is the most appropriate.
Hausman	24.089832	0.0001	The fixed model is more suitable.
Tobin's Q			
LR ratio	9.906314	0.0000	A panel model (random effects) is the most appropriate.
Hausman	3.069430	0.5463	The random model is more suitable.

In multiple regression (Panel data analysis), variables include unit and time dimensions. According to Sakin and Kefe (2024), the model has to be estimated according to the unit and time effect as either one or a two-way model. Hence, the likelihood ratio test (LR test) has been computed in Table 2 above. The likelihood ratio (LR test) was used to test whether the random effects or the classical model is the most appropriate. As per Table 2, LR test statistical values for ROA, ROE and Tobin's Q were 4.505342, 6.130205 and 9.906314, respectively. The LR test probability values (*P*-value) for the dependent variables were all less than 10% ($p < 0.01$). Hence, the H_0 hypothesis, which states that every unit effect equals zero, was rejected for all dependent variables because $p < 0.01$. This means the random effect model is more appropriate than classical models.

The Hausman test determines the most suitable model between the random and fixed effect models. This test assesses the null hypothesis of the absence of correlation between individual variables and individual effects. The rejection of the null hypothesis suggests that a lower efficiency degree is obtained in the estimation results using a fixed-effect model. The Hausman

test null hypothesis provides that the appropriate model is the random effect, whereas the alternative hypothesis suggests that the fixed effect is the better model.

The above table (Table 2) shows that the statistical Hausman test values were 3.069430, 23.187534, and 24.089832 for Tobin's Q, ROA, and ROE, respectively. The p -values were 0.0001, 0.0001 and 0.5463 for ROE, ROA, and Tobin's Q, respectively. This meant that the H_0 Hypothesis was rejected for ROA and ROE as the p -values were less than 5% ($p < 0.05$). However, for Tobin's Q, the hypothesis was accepted ($p > 0.05$). Hence, for ROE and ROA dependent variables, the fixed effect model was better suited to run the analysis, while the random effect model was better suited for Tobin's Q analysis.

3.8.1 ROA Estimation Procedure

Numerous statistical assumptions are applied in regression analysis. Numerous diagnostic tests were done to ensure the validity of these statistical assumptions. These tests include cross-section dependence, autocorrelation and heteroskedasticity tests. Table 3 below presents the outcomes of ROA testing assumptions.

The heteroscedasticity test was used to confirm the existence of heteroscedasticity in the dataset. The result of the heteroscedasticity test in the table below is determined as $p = 0.0000$ and $p = 0.9972$ for cross-section and period heteroscedasticity, respectively. Hence, it was found that there is a heteroscedasticity problem in the ROA model as the $p < 0.05$ on the cross-section heteroscedasticity test. This suggests the rejection of the null hypothesis, which posits that there is no heteroscedasticity, implying that the residuals are homoscedastic. A 5% significance level was applied to reject the null hypothesis.

The Durbin–Watson statistic was employed to test the presence of autocorrelation among residuals. The test assumed that there is autocorrelation if the result is less than 2. The table below suggests autocorrelation as the DW test was 1.105466 (less than 2). The Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD were used to test the correlation (cross-section dependence) between units. The result indicates cross-section dependence, as Pesaran CD, Pesaran scaled LM, and Breusch-Pagan LM p -values were 0.0033, 0.0022 and 0.0027, respectively, which shows $p < 0.05$. This meant that the null hypothesis, which states no correlation between units, was rejected. A 5% significance level was applied to reject the null hypothesis.

TABLE 3: ASSESSING DEVIATIONS FROM THE ROA MODEL ASSUMPTION

	Value	Probability	Result
Heteroscedasticity test			
Panel Period Heteroskedasticity LR Test	5.180151	0.9972	Residuals are homoscedastic.
Panel Cross-section Heteroskedasticity LR Test	73.14901	0.0000	Residuals are heteroscedastic.
Autocorrelation			
Durbin–Watson test	1.105466		Autocorrelation exist
Cross-Section Dependence			
Breusch-Pagan LM test	186.4663	0.0027	There is evidence of cross-sectional dependence among residuals.
Pesaran scaled LM test	3.059970	0.0022	There is evidence of cross-sectional dependence among residuals.
Pesaran CD test	2.939703	0.0033	There is evidence of cross-sectional dependence among residuals.

3.8.2 ROE Estimation Procedure

To ensure the validity of the ROE model cross-section dependence, autocorrelation and heteroskedasticity tests were conducted. Table 4 below presents the outcomes of ROE testing assumptions. The heteroscedasticity test was used to confirm the existence of heteroscedasticity in the dataset. The result of the heteroscedasticity test in the table below is determined as $p=0.0000$ and $p=0.9988$ for cross-section and period heteroscedasticity, respectively. Hence, the test found a heteroscedasticity problem in the ROE model as the $p<0.05$ on the cross-section heteroscedasticity test. This suggests the rejection of the null

hypothesis, which posits that there is no heteroscedasticity, implying that the residuals are homoscedastic. A 5% significance level was applied to reject the null hypothesis.

The Durbin–Watson statistic was employed to test the presence of autocorrelation among residuals. The test assumes that there is autocorrelation if the result is less than 2. The table below suggests autocorrelation as the DW test was 0.969463 (less than 2). The Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD were used to test the correlation (cross-section dependence) between units. The result indicated cross-section dependence, as Pesaran CD, Pesaran scaled LM, and Breusch-Pagan LM p -values were 0.0001, 0.0082 and 0.0072, respectively, which shows $p < 0.05$. This suggests the rejection of the null hypothesis, which posits that there is no correlation between units. A 5% significance level was applied to reject the null hypothesis.

TABLE 4: ASSESSING DEVIATIONS FROM THE ROE MODEL ASSUMPTION.

	Value	Probability	Result
Heteroscedasticity test			
Panel Period Heteroskedasticity LR Test	4.525350	0.9988	Residuals are homoscedastic.
Panel Cross-section Heteroskedasticity LR Test	61.78814	0.0000	Residuals are heteroscedastic.
Autocorrelation			
Durbin–Watson test	0.969463		Autocorrelation exist
Cross-Section Dependence			
Breusch-Pagan LM test	179.6330	0.0072	There is evidence of cross-sectional dependence among residuals
Pesaran scaled LM test	2.645642	0.0082	There is evidence of cross-sectional dependence among residuals.
Pesaran CD test	3.944442	0.0001	There is evidence of cross-sectional dependence among residuals.

3.8.3 Tobin's Q Estimation Procedure

Cross-section dependence, autocorrelation and heteroskedasticity tests were conducted to ensure the validity of Tobin's Q model. Table 5 below presents the outcomes of Tobin's Q testing assumptions. The heteroscedasticity test was used to confirm the existence of heteroscedasticity in the dataset. The result of the heteroscedasticity test in the table below was determined as $p=0.0000$ and $p=0.8175$ for cross-section and period heteroscedasticity, respectively. Hence, there is a heteroscedasticity problem in the Tobin's Q model as the $p<0.05$ on the cross-section heteroscedasticity test. This suggests the rejection of the null hypothesis, which posits that there is no heteroscedasticity, implying that the residuals are homoscedastic. A 5% significance level was applied to reject the null hypothesis.

The Durbin–Watson statistic was employed to test the presence of autocorrelation among residuals. The test assumes that there is autocorrelation if the result is less than 2. The table below suggests autocorrelation as the DW test was 0.831606 (less than 2). The Pesaran CD, Pesaran scaled LM and Breusch-Pagan LM were used to test the correlation (cross-section dependence) between units. The result indicates that there is cross-section dependence, as Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD p -values were 0.0488, 0.0847 and 0.0008, respectively, which shows $p<0.05$ for two of the three tests employed. This suggests the rejection of the null hypothesis, which posits that there is no correlation between units. A 5% significance level was applied to reject the null hypothesis.

TABLE 5: ASSESSING DEVIATIONS FROM THE TOBIN’S Q MODEL ASSUMPTION

	Value	Probability	Result
Heteroscedasticity Test			
Panel Period Heteroskedasticity LR Test	11.70822	0.8175	Residuals are homoscedastic.
Panel Cross-section Heteroskedasticity LR Test	119.7581	0.0000	Residuals are heteroscedastic.
Autocorrelation Test			
Durbin–Watson test	0.831606		Autocorrelation exist
Cross-Section Dependence Test			
Breusch-Pagan LM test	164.4307	0.0488	There is evidence of cross-sectional dependence among residuals
Pesaran scaled LM test	1.723864	0.0847	There is no evidence of cross-sectional dependence among residuals.
Pesaran CD test	3.370216	0.0008	There is evidence of cross-sectional dependence among residuals.

3.9 Validity and Reliability

Using valid and reliable data results in reliable results. To enhance validity and reliability, data were cross-checked between different sources, such as audited integrated reports and Bloomberg. To ensure consistency, financial measures used, ROA, ROE and Tobin’s Q were computed using standardised formulas. Although Bloomberg provides pre-calculated ratios, they were verified using the standard ratios as indicated above. Further, the heteroscedasticity-robust standard error estimates model was used as a robustness check to address the autocorrelation, cross-section dependence, and heteroscedasticity.

3.10 Summary

Tobin’s Q-regression model was based on the random effect, while the ROA and ROE regression models were based on the fixed effect as recommended by the Hausman Test. The fixed effect is more appropriate for ROE and ROA analysis, as its better accounts for the companies’ heterogeneity, because the individual companies' intercept terms vary (Busch and

Hoffmann, 2011). Further, the time-invariant entity's characteristics, like brand image and management capabilities that may impact carbon emissions, are controlled. The model was adopted from Ganda and Milondzo (2018) and tailored to meet this study's specifications. After considering data availability and sampling criteria, the final sample comprises 17 JSE-listed Industrial metal and mining companies. The following chapter presents, interprets and discusses the findings of the study.

CHAPTER 4: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This section outlines, interprets and discusses the findings of the study. It includes both the main regression result and robustness check estimates. To address the autocorrelation, cross-section dependence, and heteroscedasticity noted in the previous chapter, the heteroscedasticity-robust standard error estimates model was used as a robustness check. The dataset includes 85 observations derived from 17 JSE-listed industrial metal and mining companies assessed in the five years from 2018 to 2022.

4.2 Diagnostics Test Results

Robustness checks were conducted to analyse the models before presenting and discussing the study's main findings. Due to the autocorrelation, cross-section dependence, and the existence of heteroscedasticity noted in Tables 3, 4 and 5 above, the heteroscedasticity-robust standard error estimates model was utilised for the ROA, Tobin's Q and ROE as the dependent variables model. Numerous scholars have used this model previously (Busch and Hoffmann, 2011; Ganda and Milondzo, 2018). The robust model assists in obtaining more consistent estimates and increases the reliability of the results.

4.2.1 ROA Analysis

Table 6 below presents the robust estimation for ROA as the dependent variable. The robust estimation result indicates that ROA is significantly and negatively related to leverage and carbon intensity. Specifically, as $p < 0.01$, a one-unit increase in leverage and carbon intensity results in a 0.574812 and 0.152336 decrease in ROA, respectively. This suggests that the high carbon emissions and debt levels negatively impact financial performance.

Conversely, ROA is positively related to size and growth, with growth significantly related to ROA at 5% significance level. This suggests that a company's size alone may not significantly impact ROA. A one-unit increase in size and growth results in a ROA increase of 0.254790 and 0.189646, respectively.

TABLE 6: SUPPLEMENTARY ROBUST ROA ANALYSIS

Variable	Coefficient	Prob.	z-Statistic	Std. Error
C	16.65390	0.2045	1.268864	13.12505
SIZE	0.254790	0.6296	0.482344	0.528234
LEVERAGE	-0.574812	0.0000	-6.834668	0.084102
GROWTH	0.189646	0.0000	6.041994	0.031388
CARBON_INTENSITY	-0.152336	0.0000	-6.810825	0.022367

Note: Figures in parentheses are the heteroscedasticity-robust standard errors. All coefficients below 5% are significant ($p < 0.05$). Hence, regressions are all tested at a significant level of 5%. C is the constant variable in the model.

4.2.2 ROE Analysis

Table 7 below presents the ROE robust estimate result. At a 5% significance level, the robust estimation result indicates that leverage, growth and carbon intensity are statistically significant variables when explaining ROE.

Based on the findings below, size and growth are positively related to ROE. This suggests that a 1 unit increase in size and growth leads to a 1.283481 and 0.380832 increase in ROE, respectively. However, the relationship between size and ROE is insignificant, suggesting that size alone may not significantly affect ROE.

Conversely, the ROE is negatively and significantly related to leverage and carbon intensity. Specifically, as $p < 0.01$, a one-unit increase in leverage and carbon intensity results in a 0.772075 and 0.264246 decrease in ROE, respectively. This suggests that the increased debt levels and carbon emissions lead to lower shareholders' returns.

TABLE 7: SUPPLEMENTARY ROBUST ROE ANALYSIS

Variable	Coefficient	Prob.	z-Statistic	Std. Error
C	4.528969	0.8530	0.185274	24.44470
SIZE	1.283481	0.1920	1.304606	0.983807
LEVERAGE	-0.772075	0.0000	-4.929097	0.156636
GROWTH	0.380832	0.0000	6.514581	0.058458
CARBON_INTENSITY	-0.264246	0.0000	-6.343402	0.041657

Note: Figures in parentheses are the heteroscedasticity-robust standard errors. All coefficients below 5% are significant ($p < 0.05$). Hence, regressions are all tested at a significant level of 5%. C is the constant variable in the model.

4.2.3 Tobin's Q Analysis

Table 8 below presents the Tobin's Q robust estimate result. The robust estimation result indicates that size and growth are statistically significant variables when explaining Tobin's Q, at a 5% significance level.

Results below show that size, leverage, and growth positively relate to Tobin's Q. A 1 unit increase in these control variables (size, leverage and growth) results in a 0.086626, 0.001182 and 0.005300 increase in Tobin's Q, respectively. Both size and growth significantly explain the variations in the dependent variable. This suggests that investors value big companies that experience higher growth.

Conversely, a negative relationship exists between Tobin's Q and carbon intensity. A 1 unit decrease in carbon intensity results in a corresponding increase of 0.000717 in Tobin's Q. At $p=0.8185$ and $p=0.6008$ for leverage and carbon intensity, respectively, the relationship with Tobin's Q is insignificant. This suggests that both leverage and carbon intensity do not significantly detail the variation in the dependent variable.

TABLE 8: SUPPLEMENTARY ROBUST TOBIN'S Q ANALYSIS

Variable	Coefficient	Prob.	z-Statistic	Std. Error
C	-0.898715	0.2636	-1.117863	0.803958
SIZE	0.086626	0.0074	2.677262	0.032356
LEVERAGE	0.001182	0.8185	0.229439	0.005152
GROWTH	0.005300	0.0058	2.756614	0.001923
CARBON_INTENSITY	-0.000717	0.6008	-0.523315	0.001370

Note: Figures in parentheses are the heteroscedasticity-robust standard errors. All coefficients below 5% are significant ($p < 0.05$). Hence, regressions are all tested at a significant level of 5%. C is the constant variable in the model.

4.3 Results Presentation and Analysis

Table 9 presents a summary of descriptive analysis (standard deviation, median, mean, maximum, and minimum) for the 85 observations from the 17 JSE-listed industrial metal and mining companies between 2018 and 2022. Tobin's Q average (1.414235) and median (1.208100) suggest a healthy market valuation. However, the wide difference between maximum and minimum values hints at volatility in the companies' share performance. This reflects varying investor perceptions and market risk within the industrial metal and mining sector.

The average ROE (16.79012) and median (17.15700) indicate that shareholders receive a reasonable average return on the equity investment. However, the large standard deviation of 24.75707 and the wide variation (maximum of 87.47970 and minimum of -56.14010) suggest that there is a significant variability among companies' performance. This variability is likely driven by the differences in production efficiency.

The mean of 9.106188 (median of 9.878900) suggests that the sampled companies generate a 9% average return from utilising their assets. The maximum of 48.67280 indicates healthy returns from certain companies, while the minimum of -32.36210 reflects poor asset efficiency.

For carbon intensity, the average (49.34731) and median (36.47590) reflect moderate emissions overall. Furthermore, the average of control variables, size (24.32876), leverage

(13.88796) and growth (16.97845) vary, indicating structural differences among companies in the respective industry. The overall descriptive stats indicate a significant heterogeneity in variables, which may be due to different factors, including differences in production efficiencies and environmental management practices.

TABLE 9: SUMMARY OF DESCRIPTIVE STATISTICS

Variable	Observations	Mean	Median	Maximum	Minimum	Std. Dev.
TOBIN_S_Q	85	1.414235	1.208100	4.393800	0.569200	0.707493
ROE	85	16.79012	17.15700	87.47970	-56.14010	24.75707
ROA	85	9.106188	9.878900	48.67280	-32.36210	14.44581
SIZE	85	24.32876	24.91546	27.76952	21.27211	1.685188
LEVERAGE	85	13.88796	13.93860	35.07330	0.000100	10.52573
GROWTH	85	16.97845	10.90990	99.09620	-33.83040	28.07433
CARBON_INTENSITY	85	49.34731	36.47590	217.8114	6.449900	39.97925

Table 10 presents the variables' correlation coefficient. Tobin's Q is positively correlated with ROE (0,544668489), ROA (0,513316399), firm size (0,244715014), and growth (0,304445302). This suggests that big companies with good growth and profitability have high market valuations. In contrast, leverage (-0,244280857) and carbon intensity (-0,082564145) indicate a negative and weak correlation with Tobin's Q, suggesting that high debt and carbon emissions levels may reduce company value.

ROE is positively associated with ROA (0,976980633), size (0,278648331) and growth (0,543693516). However, it is negatively associated with leverage (-0,323711225) and carbon intensity (-0,416679789). Similarly, ROA demonstrates a negative correlation with leverage (-0,382792609) and carbon intensity (-0,389728494) and a positive relationship with size (0,249299416) and growth (0,507759433). The consistent negative association between carbon intensity and financial performance measures (ROA and ROE) suggests that companies emitting more carbon tend to have poor financial performance. This aligns with study findings of Ganda and Milondzo (2018), which provide that companies that effectively reduce carbon emissions can increase their financial performance through efficiency gains.

The strong correlation of 0,976980633 between ROE and ROA indicates a potential multicollinearity risk. This could affect the regression estimates if they are both used simultaneously in the model. This risk is, however, eliminated as these variables are dependent and analysed together. There is a low risk of multicollinearity with other variables, as the correlation is low.

TABLE 10: VARIABLES CORRELATION COEFFICIENT

Correlation	TOBIN'S Q	ROE	ROA	SIZE	LEVERAGE	GROWTH	CARBON INTENSITY
TOBIN'S Q	1						
ROE	0,544668489	1					
ROA	0,513316399	0,976980633	1				
SIZE	0,244715014	0,278648331	0,249299416	1			
LEVERAGE	-0,244280857	-0,323711225	-0,382792609	-0,001895396	1		
GROWTH	0,304445302	0,543693516	0,507759433	0,043576626	-0,099009451	1	
CARBON_INTENSITY	-0,082564145	-0,416679789	-0,389728494	-0,171792427	0,103846632	-0,00041552	1

4.3.1 ROA Analysis

Table 11 presents the ROA analysis result. The fixed effect model was used to run the analysis as recommended by the Hausman test in Table 3. The results indicate a statistically significant negative relationship between ROA and carbon intensity (carbon emissions), at a 5% significance level. A one-unit increase in carbon intensity results 0.161987 decrease in ROA. This suggests that as carbon emissions increase, companies tend to generate less profit from their assets. This could possibly be due to increased production costs and increased CBT liability. This finding is consistent with institutional theory, which suggests that companies that respond to external environmental pressures can reduce costs and improve efficiency.

These findings are consistent with the findings of Yu, Hao, Cai, Sun, and Zhang (2022), which concluded that ROA is increased by the implementation of ETS. However, they contravene the

findings of Busch et al. (2022), which concluded that higher carbon emissions are associated with higher ROA. The variation in findings may indicate a difference in the regional regulatory framework.

The ROA relationship with leverage is negative but statistically insignificant, indicating that the debt level does not significantly affect the assets' efficiency and productivity. Conversely, firm growth and size indicate a significant positive effect on ROA. This suggests that fast-growing and big companies use their assets more effectively and efficiently, thus achieving increased profitability. Overall, the analysis reveals that size, growth, and carbon intensity are key ROA predictors in the JSE-listed industrial metal and mining industry.

TABLE 11: ROA FIXED EFFECT MODEL

Variable	Coefficient	Prob.	t-Statistic	Std. Error
C	-453.8630	0.0006	-3.595718	126.2232
SIZE	19.30542	0.0003	3.790006	5.093771
LEVERAGE	-0.140080	0.5485	-0.603144	0.232249
GROWTH	0.190313	0.0000	5.607158	0.033941
CARBON_INTENSITY	-0.161987	0.0067	-2.804810	0.057753

Notes: All coefficients below 5% are significant ($p < 0.05$). Hence, regressions are all tested at a significant level of 5%. C is the constant variable in the model.

4.3.2 ROE Analysis

Table 12 presents the ROE analysis result. The fixed effect model was used to run the analysis as recommended by the Hausman Test in Table 4. The results indicate a statistically significant negative relationship between ROE and carbon intensity (carbon emissions). Specifically, a one-unit increase in carbon intensity results in a 0.326972 decrease in ROE. This suggests that in the industrial metal and mining industry, high carbon emissions are related to reduced shareholders' returns.

This relationship suggests that companies investing in carbon reduction initiatives can increase the shareholders' returns by improving their reputation and legitimacy, consistent with legitimacy theory. Although ROE is negatively related to leverage, the relationship is not

significant. Conversely, firm size and firm growth have a significant positive effect on ROE. These findings suggest that fast-growing and large companies deliver stronger shareholders' returns.

These findings are consistent with existing South African study findings by Ganda and Milondzo (2018), which also found the negative relationship between carbon emissions and ROE. In the global context, they are aligned with the findings of Gallego-Álvarez et al. (2015). However, they contradict Adu et al. (2023), who found that better carbon performance results in poor financial performance (ROE). The variations in these findings may be due to different regions and time periods used.

Overall, high carbon emissions diminish shareholders' returns and value, emphasising the importance of adopting carbon reduction practices in the industrial metal and mining industry.

TABLE 12: ROE FIXED EFFECT MODEL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-678.5299	191.2406	-3.548044	0.0007
SIZE	29.12482	7.717566	3.773836	0.0004
LEVERAGE	-0.221303	0.351880	-0.628915	0.5316
GROWTH	0.350898	0.051424	6.823603	0.0000
CARBON_INTENSITY	-0.326972	0.087502	-3.736742	0.0004

Notes: All coefficients below 5% are significant ($p < 0.05$). Hence, regressions are all tested at a significant level of 5%. C is the constant variable in the model.

4.3.3 Tobin's Q Analysis

Table 13 presents the result of Tobin's Q analysis. The random effect model was used to run the analysis as recommended by the Hausman test in Table 5. The results indicate a statistically insignificant negative relationship between Tobin's Q and carbon intensity (carbon emissions). This weak association suggest that the market does not fully consider companies' carbon emissions. Investors appear to be more focused on the share price and dividends rather than environmental performance. This reflects that South Africa's carbon emissions disclosure is still largely voluntary and thus often ignored by investors.

Conversely, firm growth has a significant positive relationship with Tobin's Q, indicating that investors still prefer a company's growth prospect more than its environmental performance. However, the impact of firm size on Tobin's Q is insignificant. Overall, carbon emissions do not influence the market-based performance in the industrial metal and mining sector. These findings align with the earlier reviewed study of Miah et al. (2021), who reported that carbon emissions reduce the Tobin's Q of companies in emerging economies, but contradict the findings of Busch et al. (2022). The differences in findings may be due to differences in investor awareness.

TABLE 13: TOBIN'S Q RANDOM EFFECT MODEL RESULT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.761933	2.122478	-0.358983	0.7206
SIZE	0.095749	0.085449	1.120543	0.2658
LEVERAGE	-0.004123	0.009050	-0.455578	0.6499
GROWTH	0.005369	0.001658	3.237199	0.0018
CARBON_INTENSITY	-0.003793	0.002094	-1.811640	0.0738

Notes: All coefficients below 5% are significant ($p < 0.05$). Hence, regressions are all tested at a significant level of 5%. C is the constant variable in the model.

4.4 Discussion

This study contributes to the existing literature on sustainability and corporate governance. The focus is on the relationship between financial performance and carbon emissions of the JSE-listed industrial metal and mining companies in South Africa. The study used panel data analysis to examine the relationship. Using panel data and applying the fixed effects model, the study finds that carbon emissions (measured by carbon intensity) are negatively related to accounting-based, short-term financial performance (measured by ROA and ROE). Further, using the random effect model, the results indicate that carbon emissions are weakly negatively related to long-term, market-based financial performance. The robust estimations also correspond to these results, indicating the negative carbon emission relationship with financial performance.

These results directly achieve both objectives: (1) to investigate the nature of the relationship between carbon emission and financial performance, and (2) to assess the impact of carbon emission on each financial performance indicator. The consistent negative relationship with ROA and ROE is consistent with the interpretation that companies with increased carbon emissions face reputational damage, regulatory pressures and cost inefficiencies that decrease profitability.

The fixed effect model applied to ROA and ROE indicated a significant negative relationship with carbon emissions for both dependent variables. This suggests that companies with high carbon emissions have low returns on equity and assets. These results mean that high carbon emissions in the short term can result in high costs, like penalties, reputational costs and CBT, which result in decreased ROA and ROE.

When ROE is used to measure financial performance, the results are consistent with existing findings of Gallego-Álvarez et al. (2015), Ganda and Milondzo (2018), and Sakin and Kefe (2024), which also found the negative relationship between ROE and carbon emission. However, these findings contravene the findings of Adu et al. (2023).

Similarly, the ROA findings align with the findings of Delmas et al. (2015), and Yu et al. (2022), which also noted the negative relationship between ROA and carbon emission. However, they contravene the findings of Busch et al. (2022), which noted the positive relationship between ROA and carbon emissions. These differences in findings may be due to the industries, region, and methodology used.

Tobin's Q random effect model result indicated a negative relationship with carbon emissions. At a 5% significance level, the relationship was insignificant. This suggests that in the industrial metal and mining sector in South Africa, the market is not yet sensitive to carbon emitted by companies. Further, investors' decisions are not influenced by the emissions, indicating that investors still only consider financial metrics. Results are consistent with the existing literature of Miah et al. (2021), and Sakalsız and Özçelik (2024). However, these findings contravene the findings of Busch et al. (2022), and Wang et al. (2014), which noted that the positive relationship between Tobin's Q and carbon emissions. The main difference in findings may be due to Tobin's Q computation and investor perceptions of different regions.

Overall, the results reveal that accounting-based financial performance, specifically ROA and ROE, significantly decrease as carbon emissions increase. However, market-based financial performance, Tobin's Q, have an insignificant statistical relationship with carbon emissions,

suggesting a neutral response from investors. This indicates that carbon reduction activities result in operational, shareholders and possibly reputational gains. However, they are not valued by shareholders, indicating a gap between the market response and sustainability activities.

The result supports the view of going green, which means that companies can be environmentally friendly without compromising their financial performance. Companies that are proactive in implementing environmentally friendly initiatives can gain a competitive advantage. Further, policymakers and the government can take this as an opportunity to implement carbon reduction policies, as there is a financial gain for companies that reduce their emissions. Hence, companies must keep their carbon emissions minimal.

These results support the institutional, stakeholder and legitimacy theory. For institutional theory, a negative association suggests that institutional pressures, such as CBT, possibly encourage sustainable behaviour from companies. However, these pressures are not yet fully internalised by investors in the investment decisions due to limited market response indicated by Tobin's Q. Results also support the legitimacy theory as companies manage and disclose carbon emissions to obtain and maintain the public trust. Further, Stakeholder theory is reinforced by the result, as companies that manage their carbon emissions experience reputational and operational benefits that improve financial performance.

4.5 Summary

This chapter outlined, interpreted and discussed the findings of the study, focusing on the relationship between financial performance and carbon emissions among JSE-listed industrial metal and mining companies from 2018 to 2022. The descriptive statistics presented wide variations across companies in terms of profitability and carbon emissions levels, suggesting heterogeneity in environmental management and operational efficiency.

The correlation analysis indicated a negative association between carbon emissions and both ROE and ROA, suggesting that companies with higher carbon emissions perform poorly financially. The regression analysis, specifically the panel data analysis, confirmed these findings, with ROA and ROE showing a statistically significant negative relationship with carbon emissions. However, Tobin's Q indicated a negative but statistically insignificant relationship, suggesting that market-based performance is not strongly influenced by carbon emissions.

Overall, these results support the institutional, stakeholder and legitimacy theories, indicating that regulation and stakeholder pressures only influence the internal financial performance. Finally, the next chapter provides a summary of the study, conclusion, recommendations and suggestions for future research.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter synthesises the study's key findings, draws conclusions and provides recommendations to different stakeholders and companies. It further offers suggestions for future research in response to the study's limitations.

5.2 Summary of the Study

In developing countries like South Africa, companies' performance plays a vital role in the economic development (Sakin and Kefe, 2024). To ensure that companies survive the competitive market, they should focus on the triple bottom line and not only aim to meet financial profitability targets. Investing in environmental initiatives such as environmental rehabilitation and emissions reductions can improve profitability and market value by improving the company's reputation (Gallego-Álvarez et al., 2015).

Despite the increasing emphasis on sustainability, the financial implications of carbon emissions remain unknown, especially for the carbon-intensive industries, triggering this study's focus on JSE-listed industrial metal and mining companies. Addressing this gap, this study examined the relationship between carbon emission and financial performance and assessed the impact of carbon emission on financial performance indicators. This study was guided by the legitimacy, stakeholder and institutional theories, which provided the framework for understanding why companies might adopt and implement carbon reduction practices.

Secondary data was sourced from the Bloomberg ESG database for both carbon emissions and financial performance. This data was supplemented by the audited and integrated financial statements from the company website. The study applied a panel data multiple regression approach to analyse three financial performance measures, ROA, ROE and Tobin's Q, controlling for size, leverage, and growth.

5.3 Conclusions

This study attempted to answer the following.

1. What is the nature of the relationship between financial performance and carbon emissions of JSE-listed industrial metal and mining companies?

2. How do carbon emissions impact ROA, ROE and Tobin's Q for the industrial metal and mining companies?

A panel data analysis was conducted to answer the above questions. Financial performance measures such as ROE, Tobin's Q and ROA were used as the dependent variables. The following answers the study's questions:

- ROA model: The study found that carbon emissions are significantly negatively related to ROA. This suggests that a decrease in carbon emissions are associated with increased ROA, implying that high-emitting companies are less efficient in utilising their assets to generate profit. This might be due to increased CBT cost, reputational damage, or operational inefficiencies. Control variables indicated mixed results, with firm size and growth having a positive relationship with ROA and leverage having a negative relationship. Numerous control variables, namely size and growth, were significant at a 5% significance level. Hence, these variables improve the model's explanatory power. This finding aligns with the South African findings of Ganda and Milondzo (2018), but contrasts global findings of Adu et al. (2023)
- ROE Model: The result indicates a similar significant negative relationship between the dependent variable and carbon emission as for ROA. This suggests that a decrease in carbon emissions is associated with increased shareholder returns. This consistent finding between ROA and ROE confirms that high carbon emissions are detrimental to operational profitability. Control variables indicated mixed results, with firm size and growth having a positive relationship with ROE and leverage having a negative relationship. Numerous control variables, namely size and growth, were significant at a 5% significance level. Hence, these variables improve the model's explanatory power. This is consistent with the global findings of Yu et al. (2022).
- Lastly, when Tobin's Q was utilised, the result indicated that the variable is negatively associated with carbon emissions. The relationship is statistically insignificant, suggesting that investors do not penalise or favour environmentally friendly companies. This indicates a critical point that, as much as carbon emissions harm internal financial performance (ROA and ROE), the market is neutral to it. However, Tobin's Q is positively related to size and growth but negatively associated with leverage. Out of all the control variables, growth is the main variable that enhances the models' explanatory

power (significant at 5%). This weak relationship is consistent with findings of the study done on the developing economy by Sakalsız and Özçelik (2024).

Therefore, based on the above and in relation to objective one, a relationship exists between carbon emissions and financial performance. The relationship noted is negative for accounting-based financial performance, ROA and ROE. In relation to objective two, results indicated that Tobin's Q have an insignificant relationship with carbon emission, while ROA and ROE increase when carbon emissions decrease. This suggests that investors have not yet considered carbon emissions in their decisions and that carbon emission disclosure practices are still developing in South Africa (legitimacy theory). The significant negative relationship with accounting-based measures supports the institutional and stakeholder theory, indicating that regulatory and operational pressures are effective. Further, it suggests that carbon-intensive companies are less efficient in their asset utilisation, and they also provide fewer returns.

Institutional pressures like CBT and responding to stakeholders' expectations regarding managing carbon emissions appear to create an incentive for companies to implement sustainable practices, resulting in potential financial and reputational gains. These insights inform the targeted recommendations below.

5.4 Recommendations

This study's result indicates that an increase in carbon emissions is associated with a negative impact on companies' financial performance. This suggests that environmentally friendly entities can effectively manage and increase their financial performance. These findings indicate an urgent need for governments and policymakers to strengthen the existing carbon emission reduction measures (Sakin and Kefe, 2024). Policymakers and the government should also introduce compliance incentives to encourage companies to be environmentally friendly. Further, strict enforcement of CBT is essential to minimise carbon emissions and improve companies' financial performance, which will ultimately result in an improved economy.

Companies should take the findings as an incentive to engage in carbon emission reduction initiatives. This is because reducing carbon emissions effectively can result in better financial performance and a competitive advantage. Adopting and implementing the carbon emissions reduction initiatives should be seen as a strategic lever and not an additional cost.

Given the neutral market response to carbon emissions, environmentally friendly investors should incorporate carbon emissions into their decision-making. The study findings confirmed that less emitting companies are more profitable, suggesting they may be better investment options for investors. This will promote the low-carbon emitting companies and sustainable behaviour. These recommendations foster the “win-win” outcomes.

5.5 Suggestions for Further Study

This study’s limitation created an interesting avenue for future research. Suggestions for further study include:

- Future researchers can use more years to analyse the relationship, and not only limit the research to 5 years of panel data.
- Other scholars can use other financial performance measures to verify this study's robustness. For example, one can use ROS, net income over net sales, or ROI, net income over net assets.
- Researchers may use a different sector from the industrial metal and mining industry.

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APPENDICES

Appendix A: Raw Dataset

Firm	Year	ROA	ROE	Tobin's Q	growth	leverage	Total assets	Size (Log of TA)	Carbon intensity
Kumba Iron Ore	2018	15,32	27,46	1,89	- 1,41	0,00	63 051 000 000	24,87	21,00
Kumba Iron Ore	2019	25,02	45,49	2,47	40,59	0,81	66 941 000 000	24,93	15,56
Kumba Iron Ore	2020	30,48	54,45	2,86	24,61	0,62	82 517 000 000	25,14	11,36
Kumba Iron Ore	2021	40,47	72,27	2,26	27,45	0,51	81 883 000 000	25,13	9,70
Kumba Iron Ore	2022	18,19	34,95	2,42	- 27,49	0,37	82 659 000 000	25,14	13,43
Merafe Resources Limited	2018	10,57	14,34	0,80	- 4,80	0,19	6 579 785 000	22,61	18,85
Merafe Resources Limited	2019	- 24,45	- 32,92	0,73	- 4,05	0,54	4 559 293 000	22,24	18,26
Merafe Resources Limited	2020	- 26,15	- 35,46	0,61	- 11,13	0,61	3 113 094 000	21,86	14,36
Merafe Resources Limited	2021	41,54	55,35	0,84	68,59	0,30	4 945 183 000	22,32	12,08
Merafe Resources Limited	2022	26,54	34,81	0,82	- 1,49	0,23	5 680 632 000	22,46	12,61
Hulamin Limited	2018	- 11,26	- 18,30	0,63	11,94	12,59	6 511 459 000	22,60	33,73
Hulamin Limited	2019	- 22,37	- 37,80	0,57	- 7,15	9,36	4 260 028 000	22,17	36,48
Hulamin Limited	2020	- 5,47	- 9,78	0,64	- 20,17	19,03	4 503 053 000	22,23	38,12
Hulamin Limited	2021	11,39	22,53	0,76	52,24	14,50	5 881 515 000	22,50	28,52
Hulamin Limited	2022	4,91	9,74	0,65	22,40	15,49	6 321 574 000	22,57	22,68
Glencore plc	2018	2,58	7,14	1,04	7,32	27,20	1 850 457 800	21,34	10,37
Glencore plc	2019	- 0,32	- 0,94	1,01	- 2,45	29,86	1 734 123 400	21,27	9,84

Glencore plc	2020	- 1,57	- 4,89	1,04	- 33,83	31,76	1 731 248 800	21,27	10,25
Glencore plc	2021	4,05	12,82	1,21	43,15	27,17	2 031 629 600	21,43	8,73
Glencore plc	2022	13,32	38,77	1,27	25,64	21,70	2 259 081 700	21,54	6,45
Anglo American plc	2018	6,65	15,24	1,09	5,21	17,19	750 641 100 000	27,34	44,29
Anglo American plc	2019	6,55	14,66	1,20	8,19	19,12	784 797 200 000	27,39	38,93
Anglo American plc	2020	3,52	8,25	1,24	- 14,81	21,61	917 473 800 000	27,54	36,77
Anglo American plc	2021	13,32	31,92	1,33	63,30	19,48	1 051 345 600 000	27,68	23,59
Anglo American plc	2022	6,77	16,37	1,30	- 15,49	21,31	1 148 547 900 000	27,77	23,13
Gold Fields Limited	2018	- 5,56	- 11,88	1,04	- 6,66	33,76	84 988 600 000	25,17	40,06
Gold Fields Limited	2019	2,59	6,03	1,44	15,10	33,21	91 702 700 000	25,24	33,99
Gold Fields Limited	2020	10,30	22,45	1,55	31,18	26,17	109 637 900 000	25,42	22,67
Gold Fields Limited	2021	10,65	20,66	1,78	7,79	20,32	117 089 200 000	25,49	27,64
Gold Fields Limited	2022	9,68	17,37	1,69	2,18	20,08	125 033 900 000	25,55	24,45
South32 Limited	2018	8,92	12,72	1,19	8,62	6,14	208 172 600 000	26,06	31,02
South32 Limited	2019	2,61	3,73	1,06	- 3,64	6,14	207 596 300 000	26,06	29,16
South32 Limited	2020	- 0,46	- 0,66	0,80	- 31,12	7,40	238 735 300 000	26,20	40,13
South32 Limited	2021	- 1,45	- 2,11	1,10	9,30	9,11	189 584 400 000	25,97	24,53
South32 Limited	2022	18,05	27,05	1,11	69,27	11,18	265 737 700 000	26,31	21,12
Anglo American Platinum Ltd	2018	8,02	15,38	2,09	13,57	7,04	89 288 000 000	25,22	55,21
Anglo American Platinum Ltd	2019	19,14	34,33	3,81	33,48	0,86	104 020 000 000	25,37	44,56
Anglo American Platinum Ltd	2020	24,43	43,66	3,11	8,26	0,58	144 377 000 000	25,70	36,58
Anglo American Platinum Ltd	2021	48,67	87,48	3,11	99,10	0,34	180 149 000 000	25,92	21,08

Anglo American Platinum Ltd	2022	27,53	49,40	2,59	- 23,53	0,26	176 914 000 000	25,90	24,92
Anglogold Ashanti	2018	1,92	5,00	1,38	- 26,03	30,86	95 534 300 000	25,28	52,05
Anglogold Ashanti	2019	- 0,18	- 0,45	1,97	5,67	32,11	95 919 300 000	25,29	24,90
Anglogold Ashanti	2020	13,11	30,09	1,75	25,59	27,16	112 560 500 000	25,45	19,13
Anglogold Ashanti	2021	7,94	16,08	1,59	- 8,99	26,18	127 464 800 000	25,57	23,17
Anglogold Ashanti	2022	2,91	5,77	1,51	11,72	27,07	136 533 500 000	25,64	20,00
Harmony Gold Mining Company	2018	- 11,41	- 16,36	0,63	6,17	14,21	39 521 000 000	24,40	125,84
Harmony Gold Mining Company	2019	- 6,83	- 10,85	0,85	31,59	16,10	36 736 000 000	24,33	123,58
Harmony Gold Mining Company	2020	- 2,16	- 3,82	1,45	8,67	17,40	44 692 000 000	24,52	117,70
Harmony Gold Mining Company	2021	10,88	18,66	1,03	42,70	7,11	48 803 000 000	24,61	105,13
Harmony Gold Mining Company	2022	- 2,20	- 3,44	1,04	2,19	7,27	46 808 000 000	24,57	111,34
Impala Platinum Holdings Limited	2018	- 15,29	- 25,42	0,66	- 2,68	15,65	66 168 000 000	24,92	96,04
Impala Platinum Holdings Limited	2019	2,21	3,85	1,16	35,63	12,79	66 954 000 000	24,93	78,74
Impala Platinum Holdings Limited	2020	19,72	31,79	1,30	43,64	9,24	95 855 000 000	25,29	52,18
Impala Platinum Holdings Limited	2021	42,31	62,83	1,82	85,50	1,05	126 475 000 000	25,56	31,95
Impala Platinum Holdings Limited	2022	22,68	31,65	1,25	- 8,68	0,77	156 087 000 000	25,77	34,41
Sibanye Stillwater Limited	2018	- 3,11	- 10,47	0,99	10,33	28,86	84 923 000 000	25,17	111,85
Sibanye Stillwater Limited	2019	0,07	0,23	1,65	43,96	23,86	101 071 800 000	25,34	101,57

Sibanye Stillwater Limited	2020	24,93	59,73	1,80	74,69	13,95	134 103 100 000	25,62	52,55
Sibanye Stillwater Limited	2021	23,03	44,54	1,38	35,17	13,45	152 994 000 000	25,75	42,40
Sibanye Stillwater Limited	2022	11,51	21,90	1,23	- 19,69	13,83	166 631 000 000	25,84	48,11
DRDGOLD Limited	2018	0,28	0,51	1,13	6,43	0,62	2 360 400 000	21,58	149,60
DRDGOLD Limited	2019	2,45	3,97	1,07	10,91	0,27	4 060 000 000	22,12	150,67
DRDGOLD Limited	2020	13,05	18,87	4,39	51,52	0,83	5 675 200 000	22,46	88,86
DRDGOLD Limited	2021	23,95	32,50	2,27	25,90	0,86	6 348 000 000	22,57	78,20
DRDGOLD Limited	2022	16,74	21,91	1,44	- 2,86	0,74	7 078 200 000	22,68	81,03
Pan African Resources plc	2018	- 32,36	- 56,14	1,08	- 13,27	34,55	4 815 900 000	22,30	217,81
Pan African Resources plc	2019	10,24	22,63	1,16	48,75	35,07	5 546 200 000	22,44	120,29
Pan African Resources plc	2020	11,63	24,12	1,64	26,10	30,44	6 406 200 000	22,58	81,43
Pan African Resources plc	2021	17,54	31,97	1,36	34,59	19,77	6 916 400 000	22,66	66,80
Pan African Resources plc	2022	15,98	25,98	1,41	2,02	10,62	7 435 500 000	22,73	60,23
Exxaro Resources Limited	2018	11,03	17,16	1,12	11,74	9,14	65 050 000 000	24,90	34,05
Exxaro Resources Limited	2019	14,65	25,60	1,18	0,92	12,35	68 840 000 000	24,96	42,06
Exxaro Resources Limited	2020	9,88	19,80	0,95	12,43	18,00	78 606 000 000	25,09	35,78
Exxaro Resources Limited	2021	16,42	32,34	0,97	13,30	14,21	75 717 000 000	25,05	30,36
Exxaro Resources Limited	2022	17,19	32,02	1,07	41,49	11,24	85 145 000 000	25,17	20,93
Northam Platinum Holdings Limited	2018	- 3,24	- 9,11	1,23	10,01	13,46	23 824 034 000	23,89	122,32

Northam Platinum Holdings Limited	2019	0,24	0,81	1,49	41,01	15,31	26 944 663 000	24,02	94,43
Northam Platinum Holdings Limited	2020	7,53	25,36	2,01	67,26	18,74	30 667 505 000	24,15	60,49
Northam Platinum Holdings Limited	2021	27,35	65,46	2,50	83,17	20,61	37 950 860 000	24,36	41,01
Northam Platinum Holdings Limited	2022	20,66	40,39	1,65	4,41	22,10	57 351 141 000	24,77	42,00
Tharisa plc	2018	11,52	15,58	0,98	16,26	16,98	6 459 896 000	22,59	45,22
Tharisa plc	2019	2,34	3,28	1,11	- 15,60	15,71	6 877 606 700	22,65	53,91
Tharisa plc	2020	9,02	12,84	0,78	18,41	13,94	8 453 194 900	22,86	40,24
Tharisa plc	2021	16,61	25,25	0,90	46,88	5,24	10 630 368 500	23,09	35,17
Tharisa plc	2022	18,58	30,67	0,77	15,03	6,60	17 230 037 800	23,57	32,81

Appendix B: ROA Heteroscedasticity Test Result

ROA Heteroscedasticity Test Result

Panel Cross-section Heteroskedasticity LR Test

Equation: ROA_FORMULA

Specification: ROA C SIZE LEVERAGE GROWTH CARBON_INTENSITY

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	73.14901	17	0.0000

LR test summary:

	Value	df
Restricted LogL	-315.4331	80
Unrestricted LogL	-278.8586	80

Unrestricted Test Equation:

Dependent Variable: ROA

Method: Panel EGLS (Cross-section weights)

Date: 07/19/24 Time: 17:14

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Iterate weights to convergence

Convergence achieved after 23 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.417683	7.280719	1.018812	0.3114
SIZE	0.722169	0.289953	2.490646	0.0148
LEVERAGE	-0.640782	0.049522	-12.93931	0.0000
GROWTH	0.138500	0.022278	6.216909	0.0000
CARBON_INTENSITY	-0.160864	0.017399	-9.245829	0.0000
Weighted Statistics				
R-squared	0.791039	Mean dependent var		19.30436
Adjusted R-squared	0.780590	S.D. dependent var		25.35215
S.E. of regression	11.16134	Akaike info criterion		6.679027
Sum squared resid	9966.043	Schwarz criterion		6.822712
Log likelihood	-278.8586	Hannan-Quinn criter.		6.736821
F-statistic	75.71142	Durbin-Watson stat		1.380752
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	0.431461	Mean dependent var		9.106188
Sum squared resid	9966.052	Durbin-Watson stat		0.960375

Panel Period Heteroskedasticity LR Test

Equation: ROA_FORMULA

Specification: ROA C SIZE LEVERAGE GROWTH CARBON_INTENSITY

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	5.180151	17	0.9972

LR test summary:

	Value	df
Restricted LogL	-315.4331	80
Unrestricted LogL	-312.8431	80

Unrestricted Test Equation:

Dependent Variable: ROA

Method: Panel EGLS (Period weights)

Date: 07/19/24 Time: 17:14

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Iterate weights to convergence

Convergence achieved after 13 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.31090	15.73082	-0.846167	0.4000
SIZE	1.280154	0.632834	2.022893	0.0464
LEVERAGE	-0.450566	0.101012	-4.460530	0.0000
GROWTH	0.235057	0.038665	6.079254	0.0000
CARBON_INTENSITY	-0.128216	0.024945	-5.139940	0.0000

Weighted Statistics

R-squared	0.593994	Mean dependent var	9.383195
Adjusted R-squared	0.573693	S.D. dependent var	15.47278
S.E. of regression	10.22166	Akaike info criterion	7.478661
Sum squared resid	8358.589	Schwarz criterion	7.622346
Log likelihood	-312.8431	Hannan-Quinn criter.	7.536455
F-statistic	29.26030	Durbin-Watson stat	1.011248
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.523162	Mean dependent var	9.106188
Sum squared resid	8358.612	Durbin-Watson stat	1.094836

ROE Heteroscedasticity Test Result

Panel Cross-section Heteroskedasticity LR Test

Equation: ROE_FORMULA

Specification: ROE C SIZE LEVERAGE GROWTH CARBON_INTENSITY

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	61.78814	17	0.0000

LR test summary:

	Value	df
Restricted LogL	-358.1791	80
Unrestricted LogL	-327.2851	80

Unrestricted Test Equation:

Dependent Variable: ROE

Method: Panel EGLS (Cross-section weights)

Date: 07/19/24 Time: 17:36

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Iterate weights to convergence

Convergence achieved after 12 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	28.94458	10.62729	2.723610	0.0079
SIZE	0.697273	0.382076	1.824962	0.0717
LEVERAGE	-1.096034	0.108707	-10.08247	0.0000
GROWTH	0.210570	0.019952	10.55381	0.0000
CARBON_INTENSITY	-0.329708	0.027560	-11.96306	0.0000

Weighted Statistics

R-squared	0.832765	Mean dependent var	42.77377
Adjusted R-squared	0.824403	S.D. dependent var	71.68782
S.E. of regression	19.88123	Akaike info criterion	7.818472
Sum squared resid	31621.07	Schwarz criterion	7.962158
Log likelihood	-327.2851	Hannan-Quinn criter.	7.876267
F-statistic	99.59219	Durbin-Watson stat	1.269382
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.385793	Mean dependent var	16.79012
Sum squared resid	31622.25	Durbin-Watson stat	0.751004

Panel Period Heteroskedasticity LR Test

Equation: ROE_FORMULA

Specification: ROE C SIZE LEVERAGE GROWTH CARBON_INTENSITY

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	4.525350	17	0.9988

LR test summary:

	Value	df
Restricted LogL	-358.1791	80
Unrestricted LogL	-355.9165	80

Unrestricted Test Equation:

Dependent Variable: ROE

Method: Panel EGLS (Period weights)

Date: 07/19/24 Time: 17:36

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Iterate weights to convergence

Convergence achieved after 8 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-41.10192	26.08630	-1.575613	0.1191
SIZE	2.787602	1.050873	2.652653	0.0096
LEVERAGE	-0.532576	0.166954	-3.189952	0.0020
GROWTH	0.480483	0.064153	7.489673	0.0000
CARBON_INTENSITY	-0.229117	0.041287	-5.549430	0.0000

Weighted Statistics

R-squared	0.629478	Mean dependent var	16.58879
-----------	----------	--------------------	----------

Adjusted R-squared	0.610952	S.D. dependent var	26.46237
S.E. of regression	16.90023	Akaike info criterion	8.492152
Sum squared resid	22849.42	Schwarz criterion	8.635838
Log likelihood	-355.9165	Hannan-Quinn criter.	8.549946
F-statistic	33.97791	Durbin-Watson stat	0.963367
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.556187	Mean dependent var	16.79012
Sum squared resid	22849.54	Durbin-Watson stat	1.000719

Tobin's Q Heteroscedasticity Test Result

Panel Cross-section Heteroskedasticity LR Test

Equation: TOBIN

Specification: TOBIN_S_Q C SIZE LEVERAGE GROWTH CARBON_INTENSITY

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	119.7581	17	0.0000

LR test summary:

	Value	df
Restricted LogL	-81.56393	80
Unrestricted LogL	-21.68486	80

Unrestricted Test Equation:

Dependent Variable: TOBIN_S_Q

Method: Panel EGLS (Cross-section weights)

Date: 07/19/24 Time: 17:37

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Iterate weights to convergence

Convergence achieved after 17 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.226759	0.167193	-1.356272	0.1788
SIZE	0.043842	0.007274	6.027505	0.0000
LEVERAGE	0.013693	0.001758	7.790395	0.0000
GROWTH	0.001867	0.000562	3.320181	0.0014
CARBON_INTENSITY	-0.000455	0.000823	-0.552919	0.5819
Weighted Statistics				
R-squared	0.687552	Mean dependent var		4.673687
Adjusted R-squared	0.671929	S.D. dependent var		4.110842
S.E. of regression	0.838986	Akaike info criterion		0.627879
Sum squared resid	56.31176	Schwarz criterion		0.771564
Log likelihood	-21.68486	Hannan-Quinn criter.		0.685673
F-statistic	44.01056	Durbin-Watson stat		1.070245
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	-0.339307	Mean dependent var		1.414235
Sum squared resid	56.31235	Durbin-Watson stat		0.523308

Panel Period Heteroskedasticity LR Test

Equation: TOBIN

Specification: TOBIN_S_Q C SIZE LEVERAGE GROWTH CARBON_INTENSITY

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	11.70822	17	0.8175

LR test summary:

	Value	df
Restricted LogL	-81.56393	80
Unrestricted LogL	-75.70982	80

Unrestricted Test Equation:

Dependent Variable: TOBIN_S_Q

Method: Panel EGLS (Period weights)

Date: 07/19/24 Time: 17:37

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Iterate weights to convergence

Convergence achieved after 5 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.957874	0.934790	-1.024694	0.3086
SIZE	0.099096	0.037618	2.634280	0.0101
LEVERAGE	-0.011072	0.005912	-1.872791	0.0648
GROWTH	0.004900	0.002414	2.029360	0.0457
CARBON_INTENSITY	-0.000705	0.001420	-0.496702	0.6208

Weighted Statistics

R-squared	0.179891	Mean dependent var	1.541292
-----------	----------	--------------------	----------

Adjusted R-squared	0.138886	S.D. dependent var	0.720749
S.E. of regression	0.658597	Akaike info criterion	1.899055
Sum squared resid	34.70002	Schwarz criterion	2.042740
Log likelihood	-75.70982	Hannan-Quinn criter.	1.956849
F-statistic	4.387015	Durbin-Watson stat	0.538609
Prob(F-statistic)	0.002941		

Unweighted Statistics

R-squared	0.174675	Mean dependent var	1.414235
Sum squared resid	34.70154	Durbin-Watson stat	0.787049

Appendix C: Cross-Section Dependence Test

ROA

Residual Cross-Section Dependence Test

Null hypothesis: No cross-section dependence (correlation) in residuals

Equation: ROA_FORMULA

Periods included: 5

Cross-sections included: 17

Total panel observations: 85

Note: non-zero cross-section means detected in data

Cross-section means were removed during computation of correlations

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	186.4663	136	0.0027
Pesaran scaled LM	3.059970		0.0022
Pesaran CD	2.939703		0.0033

ROE

Residual Cross-Section Dependence Test

Null hypothesis: No cross-section dependence (correlation) in residuals

Equation: ROE_FORMULA

Periods included: 5

Cross-sections included: 17

Total panel observations: 85

Note: non-zero cross-section means detected in data

Cross-section means were removed during computation of correlations

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	179.6330	136	0.0072
Pesaran scaled LM	2.645642		0.0082
Pesaran CD	3.944442		0.0001

Tobin's Q

Residual Cross-Section Dependence Test

Null hypothesis: No cross-section dependence (correlation) in residuals

Equation: TOBIN

Periods included: 5

Cross-sections included: 17

Total panel observations: 85

Note: non-zero cross-section means detected in data

Cross-section means were removed during computation of correlations.

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	164.4307	136	0.0488
Pesaran scaled LM	1.723864		0.0847
Pesaran CD	3.370216		0.0008

Appendix D: Durbin–Watson Test (Autocorrelation)

ROA

Dependent Variable: ROA

Method: Panel Least Squares

Date: 07/19/24 Time: 17:30

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-19.21231	16.67609	-1.152087	0.2527
SIZE	1.472445	0.671150	2.193914	0.0311
LEVERAGE	-0.414163	0.106857	-3.875873	0.0002
GROWTH	0.241975	0.039880	6.067547	0.0000
CARBON_INTENSITY	-0.118765	0.028418	-4.179203	0.0001
R-squared	0.525216	Mean dependent var		9.106188
Adjusted R-squared	0.501477	S.D. dependent var		14.44581
S.E. of regression	10.19964	Akaike info criterion		7.539604
Sum squared resid	8322.605	Schwarz criterion		7.683289
Log-likelihood	-315.4331	Hannan-Quinn criteria.		7.597398
F-statistic	22.12440	Durbin-Watson stat		1.105466
Prob(F-statistic)	0.000000			

ROE

Dependent Variable: ROE

Method: Panel Least Squares

Date: 07/19/24 Time: 17:32

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-41.66397	27.57391	-1.510992	0.1347
SIZE	2.854298	1.109746	2.572028	0.0120
LEVERAGE	-0.553742	0.176688	-3.134020	0.0024
GROWTH	0.451298	0.065942	6.843881	0.0000
CARBON_INTENSITY	-0.222088	0.046989	-4.726345	0.0000
R-squared	0.558033	Mean dependent var		16.79012
Adjusted R-squared	0.535935	S.D. dependent var		24.75707
S.E. of regression	16.86509	Akaike info criterion		8.545392
Sum squared resid	22754.51	Schwarz criterion		8.689077
Log-likelihood	-358.1791	Hannan-Quinn criteria.		8.603186
F-statistic	25.25226	Durbin-Watson stat		0.969463
Prob(F-statistic)	0.000000			

Tobin's Q

Dependent Variable: TOBIN_S_Q

Method: Panel Least Squares

Date: 07/19/24 Time: 17:33

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.821257	1.064573	-0.771443	0.4427
SIZE	0.096066	0.042845	2.242165	0.0277
LEVERAGE	-0.014427	0.006822	-2.114848	0.0376
GROWTH	0.006885	0.002546	2.704454	0.0084
CARBON_INTENSITY	-0.000369	0.001814	-0.203407	0.8393
R-squared	0.193327	Mean dependent var		1.414235
Adjusted R-squared	0.152993	S.D. dependent var		0.707493
S.E. of regression	0.651127	Akaike info criterion		2.036798
Sum squared resid	33.91731	Schwarz criterion		2.180484
Log-likelihood	-81.56393	Hannan-Quinn criteria.		2.094593
F-statistic	4.793181	Durbin-Watson stat		0.831606
Prob(F-statistic)	0.001618			

Appendix E: Supplementary Robust ROA Results

Dependent Variable: ROA

Method: Robust Least Squares

Date: 07/19/24 Time: 16:59

Sample: 2018 2022

Included observations: 85

Method: M-estimation

M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)

Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	16.65390	13.12505	1.268864	0.2045
SIZE	0.254790	0.528234	0.482344	0.6296
LEVERAGE	-0.574812	0.084102	-6.834668	0.0000
GROWTH	0.189646	0.031388	6.041994	0.0000
CARBON_INTENSITY	-0.152336	0.022367	-6.810825	0.0000
Robust Statistics				
R-squared	0.463589	Adjusted R-squared		0.436768
Rw-squared	0.722660	Adjust Rw-squared		0.722660
Akaike info criterion	97.58809	Schwarz criterion		112.3132
Deviance	5229.189	Scale		7.618246
Rn-squared statistic	153.0198	Prob(Rn-squared stat.)		0.000000
Non-robust Statistics				
Mean dependent var	9.106188	S.D. dependent var		14.44581
S.E. of regression	10.82323	Sum squared resid		9371.378

Appendix F: Supplementary Robust ROE Result

Dependent Variable: ROE

Method: Robust Least Squares

Date: 07/19/24 Time: 16:57

Sample: 2018 2022

Included observations: 85

Method: M-estimation

M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)

Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	4.528969	24.44470	0.185274	0.8530
SIZE	1.283481	0.983807	1.304606	0.1920
LEVERAGE	-0.772075	0.156636	-4.929097	0.0000
GROWTH	0.380832	0.058458	6.514581	0.0000
CARBON_INTENSITY	-0.264246	0.041657	-6.343402	0.0000
Robust Statistics				
R-squared	0.460418	Adjusted R-squared		0.433439
Rw-squared	0.684626	Adjust Rw-squared		0.684626
Akaike info criterion	91.72078	Schwarz criterion		106.7168
Deviance	17472.43	Scale		14.37935
Rn-squared statistic	128.4025	Prob(Rn-squared stat.)		0.000000
Non-robust Statistics				
Mean dependent var	16.79012	S.D. dependent var		24.75707
S.E. of regression	17.49641	Sum squared resid		24489.94

Appendix G: Supplementary Robust Tobin's Q Result

Dependent Variable: TOBIN_S_Q

Method: Robust Least Squares

Date: 07/19/24 Time: 16:54

Sample: 2018 2022

Included observations: 85

Method: M-estimation

M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)

Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.898715	0.803958	-1.117863	0.2636
SIZE	0.086626	0.032356	2.677262	0.0074
LEVERAGE	0.001182	0.005152	0.229439	0.8185
GROWTH	0.005300	0.001923	2.756614	0.0058
CARBON_INTENSITY	-0.000717	0.001370	-0.523315	0.6008
Robust Statistics				
R-squared	0.114881	Adjusted R-squared		0.070625
Rw-squared	0.210227	Adjust Rw-squared		0.210227
Akaike info criterion	101.1919	Schwarz criterion		116.2559
Deviance	20.69378	Scale		0.469091
Rn-squared statistic	16.43660	Prob(Rn-squared stat.)		0.002486
Non-robust Statistics				
Mean dependent var	1.414235	S.D. dependent var		0.707493
S.E. of regression	0.689254	Sum squared resid		38.00568

Appendix H: Summary of Descriptive Statistics

	TOBIN_S_Q	ROE	ROA	SIZE	LEVERAGE	GROWTH	CARBON_INTENSITY
Mean	1.414235	16.79012	9.106188	24.32876	13.88796	16.97845	49.34731
Median	1.208100	17.15700	9.878900	24.91546	13.93860	10.90990	36.47590
Maximum	4.393800	87.47970	48.67280	27.76952	35.07330	99.09620	217.8114
Minimum	0.569200	-56.14010	-32.36210	21.27211	0.000100	-33.83040	6.449900
Std. Dev.	0.707493	24.75707	14.44581	1.685188	10.52573	28.07433	39.97925
Skewness	1.805686	-0.037213	-0.086981	-0.150247	0.267869	0.690640	1.652531
Kurtosis	6.928637	3.758554	3.991688	2.078249	2.024349	3.205047	5.900400
Jarque-Bera	100.8532	2.057506	3.590216	3.328888	4.387803	6.906182	68.48077
Probability	0.000000	0.357453	0.166110	0.189296	0.111481	0.031648	0.000000
Sum	120.2100	1427.160	774.0260	2067.945	1180.476	1443.168	4194.522
Sum Sq. Dev.	42.04590	51484.66	17529.24	238.5483	9306.443	66206.10	134260.6
Observations	85	85	85	85	85	85	85

Appendix I: Variables Correlation Coefficient Result

Covariance Analysis: Ordinary

Date: 07/19/24 Time: 17:02

Sample: 2018 2022

Included observations: 85

Correlation	TOBIN_S_Q	ROE	ROA	SIZE	LEVERAGE	GROWTH	CARBON_INTENSITY
TOBIN_S_Q	1.000000						
ROE	0.544668	1.000000					
ROA	0.513316	0.976981	1.000000				
SIZE	0.244715	0.278648	0.249299	1.000000			
LEVERAGE	-0.244281	-0.323711	-0.382793	-0.001895	1.000000		
GROWTH	0.304445	0.543694	0.507759	0.043577	-0.099009	1.000000	
CARBON_INTENSITY	-0.082564	-0.416680	-0.389728	-0.171792	0.103847	-0.000416	1.000000

Appendix J: ROA Fixed Effect Model Result

Dependent Variable: ROA

Method: Panel Least Squares

Date: 07/19/24 Time: 13:48

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-453.8630	126.2232	-3.595718	0.0006
SIZE	19.30542	5.093771	3.790006	0.0003
LEVERAGE	-0.140080	0.232249	-0.603144	0.5485
GROWTH	0.190313	0.033941	5.607158	0.0000
CARBON_INTENSITY	-0.161987	0.057753	-2.804810	0.0067

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.776712	Mean dependent var	9.106188
Adjusted R-squared	0.706935	S.D. dependent var	14.44581
S.E. of regression	7.820306	Akaike info criterion	7.161674
Sum squared resid	3914.060	Schwarz criterion	7.765153
Log-likelihood	-283.3711	Hannan-Quinn criteria.	7.404410
F-statistic	11.13130	Durbin-Watson stat	1.752736
Prob(F-statistic)	0.000000		

Appendix K: ROE Fixed Effect Model Result

Dependent Variable: ROE

Method: Panel Least Squares

Date: 07/19/24 Time: 14:01

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-678.5299	191.2406	-3.548044	0.0007
SIZE	29.12482	7.717566	3.773836	0.0004
LEVERAGE	-0.221303	0.351880	-0.628915	0.5316
GROWTH	0.350898	0.051424	6.823603	0.0000
CARBON_INTENSITY	-0.326972	0.087502	-3.736742	0.0004

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.825486	Mean dependent var	16.79012
Adjusted R-squared	0.770950	S.D. dependent var	24.75707
S.E. of regression	11.84853	Akaike info criterion	7.992635
Sum squared resid	8984.818	Schwarz criterion	8.596114
Log-likelihood	-318.6870	Hannan-Quinn criteria.	8.235371
F-statistic	15.13659	Durbin-Watson stat	1.815726
Prob(F-statistic)	0.000000		

Appendix L: Tobin's Q Random Effect Model Result

Dependent Variable: TOBIN_S_Q

Method: Panel EGLS (Cross-section random effects)

Date: 07/19/24 Time: 14:09

Sample: 2018 2022

Periods included: 5

Cross-sections included: 17

Total panel (balanced) observations: 85

Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.761933	2.122478	-0.358983	0.7206
SIZE	0.095749	0.085449	1.120543	0.2658
LEVERAGE	-0.004123	0.009050	-0.455578	0.6499
GROWTH	0.005369	0.001658	3.237199	0.0018
CARBON_INTENSITY	-0.003793	0.002094	-1.811640	0.0738
Effects Specification				
			S.D.	Rho
Cross-section random			0.589789	0.6953
Idiosyncratic random			0.390431	0.3047
Weighted Statistics				
R-squared	0.232350	Mean dependent var		0.401459
Adjusted R-squared	0.193967	S.D. dependent var		0.432342
S.E. of regression	0.388154	Sum squared resid		12.05308
F-statistic	6.053528	Durbin-Watson stat		2.178131
Prob(F-statistic)	0.000262			
Unweighted Statistics				
R-squared	0.133157	Mean dependent var		1.414235
Sum squared resid	36.44719	Durbin-Watson stat		0.720308

Appendix M: SUPERVISOR'S PERMISSION TO SUBMIT FOR EXAMINATION

Date: 08/09/2025

Student name: Lungani Gcwensa

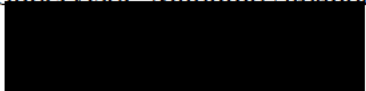
Student no: 215003332

Dissertation Title: The South African firms' relationship between carbon emissions and corporate financial performance

As the candidate's supervisors, I agree to the submission of this dissertation for examination. Based on the Turnitin report and to the best of our knowledge, the dissertation is primarily the student's work, and he has acknowledged all the sources he has used.

The student has also satisfied the requirements of English language competency.

Name of Supervisor: Mabutho Sibanda

Signature 

Appendix N: Turnitin Report



Turnitin report.pdf

Appendix O: Ethical Clearance



Ethical Clearance.pdf

Final