# Climate Mitigation Disclosure on Financial Performance and Market Stability: Evidence from South Africa


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# DECLARATION

I, Mokate George Ramafoko, declare that this research report is my own, except where otherwise indicated, referenced, and acknowledged. It is submitted in fulfilment of the requirements for the degree of Master of Management in Finance & Investment at the University of the Witwatersrand, Johannesburg. This research report has not, either in whole or in part, been submitted for any degree, diploma, or examination in this or any other university.

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Signed at Centurion

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## ABSTRACT

This paper investigates the impact of climate risk disclosure in South Africa on the market stability and performance. The main proxies of climate risk used in the study are greenhouse gas emission intensity and environmental performance rating. The study uses a difference-in-difference method to isolate the effect of climate risk disclosure on a portfolio of highly exposed firms. Firstly, the results show that high greenhouse gas emitting firms have lower returns and higher volatility before and after controlling for time effects. However, the difference-in-difference coefficient from the analysis shows evidence of a weak correlation at a 10% significance level between disclosure of climate risk on the market performance of high greenhouse gas emitting firms relative to low emitters. Secondly, the study could not establish evidence that stocks of high greenhouse gas emitting firms experience higher volatility after the disclosure of their emission inventory.

Results of the impact of environmental ratings on stock returns after adjusting for the time effect show that firms rated by the Climate Disclosure Project have lower returns than highly rated firms. However, the difference-in-difference coefficient is weak at a 10% significance level. The results are inconsistent with previous studies in developed countries where a strong correlation between climate risk and stock performance has been established. The findings from the study highlight that either climate risk is already factored into the stock prices, or the risk is viewed as immaterial to have an immediate impact on the equity market. The study addresses the existing literature gap on the effect of climate risk on developing countries' market stability and performance. Future work is required considering the evolving global focus on climate risk as a priority and the potential financial impact on firms’ sustainability.

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# CHAPTER 1: INTRODUCTION

## 1.1 Background

Climate change has become a new global business risk, which requires consideration in the pricing of stocks (Burke et al., 2015; Lesk et al., 2016). The World Economic Forum (WEF) global risk report (GRI, 2022) identifies climate action failure and extreme weather as the top two risks in the next ten years. South Africa is a signatory to the Paris Agreement, confirming its commitment towards limiting global warming to a science-based target of well below 2$^{o}$C and achieving net zero emissions in the second half of the century (COP 21, 2015). Scientific modelling of global temperatures highlights the importance of committing to the reduction of greenhouse gases (GHG) and avoiding the worst impacts associated with climate change (van Vuuren et al., 2011). Climate change impacts business in two folds: transition costs to greener technologies and mitigation costs against physical risks capable of disrupting firms' supply chain (Venturini, 2022). Hence, decarbonizing firms and economies requires an integrated approach.

Financial losses associated with extreme weather changes are severe to be ignored by managers (Huang et al., 2018). Temperature changes directly affect real Gross Domestic Product (GDP) growth (Dell et al., 2012). Such effects increase firms' environmental risks (Kim, 2022). Other scholars found climate risk to impact the devaluation of financial assets and an increase in the cost of capital (Matsumura et al., 2014; Chava, 2014). Investors in mutual funds consider transition risk undesirable and influence the preferential allocation of funds to low-carbon investments (Reboredo & Otero, 2020). Empirical evidence shows that climate change can increase earnings volatility (Huang et al., 2018). Therefore, managing climate change requires supportive policies (Adelle & Russel, 2013) to accelerate funding a just transition, providing incentives to decarbonize, and promoting climate-change performance disclosures.

Environmental disclosures are needed to inform investors of a firm's climate risk exposure (Chen & Gao, 2012). Scholars have explored using carbon emissions intensity (GHG) as a proxy to quantify climate risk (Abban & Hassan, 2021; Carney, 2015). At a policy level, experts recommend carbon tax as an effective tool (Stiglitz et al., 2017) to reduce GHG emissions. South Africa introduced the Carbon Tax Act of 2019 to encourage reducing carbon-intensive products and/or services. However, temporary sectorial discounts are provided to minimize economic shock. It is a cost borne by consumers and firms, likely to increase as discounts are withdrawn. Such an increase in costs will determine the future competitiveness of firms. Hence, climate change mitigation should be integral to an organization's strategy to sustain future returns. Investors are also pivoting towards funding firms with better Environmental, Social, and Governance (ESG) performance. Hence, future capital allocation to transition and expand will be subjected to environmental sustainability assessment.

In support of the global trends, South Africa joined the Carbon Disclosure Project (CDP) in 2001 to encourage voluntary climate risk disclosure to the capital market, debt financiers, governments, and other interested parties. A growing number of listed firms on the Johannesburg Stock Exchange (JSE) proactively increased their climate risk disclosure. In contrast, others were pressurized by their international stakeholders and exposed to stringent regulatory frameworks around capital allocation to carbon-intensive assets. The CDP is a non-profit organization supported by investors to provide benchmarked climate change mitigation and GHG intensity data. In 2017, the CDP was supported by 650 investors with US$87 trillion of assets (CDP, 2017). This growing support from investors signals the importance of climate mitigation in allocating funds, as evidenced by Reboredo and Otero, 2020. Such disclosure of environmental performance could be costly for firms, as it requires resources to verify, audit performance measures, and force management to commit resources towards climate risk mitigation and environmental stewardship. The benefit of such investments is reduced cost of debt, especially when the market is concerned about climate change (Thanh et al., 2021). Therefore, the investment in disclosure and associated performance must be valued appropriately by the financial markets. It is, however, unclear if the capital market in South Africa values climate risk mitigation investments. Furthermore, if so, how is this investment valued?

## 1.2 Research Gap

According to studies by Fama (1970,1991) on the efficient market hypothesis, efficient markets adjust prices as new information is availed. By implication, disclosure improves information pricing. Assuming this theory is valid for climate change, the financial market recognizes climate risk disclosure, environmental performance, and GHG emission intensity. Researchers have explored this argument's validity, suggesting investor bias takes precedence in an environment with high uncertainty (Della Croce et al., 2011). Other scholars investigated the causal relationship (Liesen et al., 2017; Lu & Taylor, 2018) between environmental performance disclosure in developed and emerging markets.

The gap this study intends to fill is understanding how the capital market values the climate risk disclosure of JSE-listed firms, considering South Africa's efforts to align with the Paris Agreement. With South Africa's progressive climate change policies, the effect of environmental stewardship and the modelling of carbon emission (GHG) intensity on the financial market and stock returns require further investigation. The study envisages establishing if a linkage exists between investment in climate risk mitigation and stock market performance and stability. This will enrich our understanding of how climate-related risks are factored into stock returns and volatility.

## 1.3 Research Objectives

The modelling of this information by the financial market is uncertain, including the associated effect on the volatility of stocks. If the risk is recognized by management in their investment decisions, is the same sentiment shared by investors? The research envisages understanding whether climate change disclosures enhance financial market stability and improve stock performance. The research further assesses whether GHG intensity and disclosure reduce financial risks by assessing the performance returns of these firms. This forms the basis for the research questions in the next section.

## 1.4 Research Questions

This research envisages answering the following questions:

- Does a portfolio of firms with high-carbon intensity show lower returns post-disclosure compared to firms with low-carbon intensity?
- Does a portfolio of firms with high-carbon intensity show higher stock volatility post-disclosure compared to firms with low-carbon intensity?
- Does a portfolio of firms with low environmental performance have higher stock volatility post-disclosure compared to firms with high environmental performance?
- Does a portfolio of firms with better environmental performance have better returns than other post-disclosure?

Hypothesis formulation:

- Ho: High GHG emitters have lower stock returns post-disclosure
- Ho: High GHG emitters have higher stock volatility post-disclosure,
- Ho: High environmental rating results in better stock returns post-disclosure and
- Ho: Low environmental rating increases stock volatility post-disclosure

The answers to the research questions and hypothesis formulated are envisaged to contribute to studies related to climate risks and associated impacts on stock performance.

## 1.5 Contribution of the study

This study empirically contributes to the literature by estimating the effect of climate risk disclosure (measured as GHG emission intensity and environmental rating) on financial market performance and stability using an event study that isolates its impact. With South Africa advancing the development of climate mitigation policies and legislative framework, this study will provide evidence of investor behaviour towards climate risks and the pricing of such risks in the valuation of stocks. This study further contributes by either reinforcing efficient hypothesis theory and/or contributing to behavioural finance theory by understanding the psychology of investors in dealing with information during periods of uncertainty.

## 1.6 Significance of the study

The findings of this study will have implications on policy making, funding decisions, insurance pricing, investment decisions, and capital allocation by firms. Firms need to understand the relationship between efforts and costs to mitigate climate change, increasing disclosure and inflow of capital into their business. The outcome of the study is also envisaged to guide policy decisions on capital allocation framework to mitigate climate change. For insurers, a significant correlation between climate change disclosure and performance helps risk profile firms determine appropriate climate-related risk factors for insurance pricing. The pressure on banks to divest from high-carbon footprint firms is increasing for the funders. Understanding this relationship helps guide capital allocation by the banks and determining pricing risks for funding. For the investors, the methodology currently used to factor climate change impact is unclear. The outcome of this research could assist with investment analysis and portfolio formation.

## 1.7 The structure of the report

The structure of this paper is arranged as follows. Section 2 of the research paper reviews the theoretical and empirical literature on portfolio theory, behavioural finance, modern finance, and market efficiency. Section 3 of the report describes the data collection and methodology used to examine the impact of climate change disclosure on asset or stock prices. Section 4 presents and discusses the results of the study. Section 5 concludes the key outcomes of the study.

# CHAPTER 2: LITERATURE REVIEW

## 2.1. Theoretical background

This study investigates if investors active in the JSE recognize or factor climate change performance by investigating the relationship between stock returns of firms and the level of absolute GHG emissions, information asymmetry related to climate change disclosure and the associated impact of climate change disclosure rating and valuation of the stock.

### 2.2.1. Effect of greenhouse gases and climate risk on financial market stability and performance

Scientific literature identifies climate change as a prominent risk with a potential impact on the economy (Burke et al., 2015), requiring global attention. According to Stern (2007), the impact of climate change is estimated to cost the global community 5% of gross domestic product yearly. The impact can be local and substantially affect a country's economic growth (Dell et al., 2012). Matsumura et al. (2014) found that carbon emissions reduce firms' value and the performance of green assets yielded lower returns than fossil fuel firms (Bak, 2017; Weber, 2016). The emission of carbon (GHG) is responsible for climate change risks classified into transitional and physical risks (Carney, 2015). Physical risks refer to negative weather-related events with the potential to disrupt economies and firms' activities (Tankov & Tantet, 2019), while transitional risks refer to costs associated with transitioning to low-carbon technologies.

Global extreme weather events between 1993 and 2012 are estimated to have caused fatalities and cost more than US$2.5 trillion in economic losses (Kreft & Eckstein, 2014). Hence, the relationship between temperature increases and economic growth is negative (Dell et al., 2012). These extreme weather patterns have devasting effects on financial assets and economic activity (Fuss, 2016). Effects are direct, causing damages to properties and assets, and indirect, causing supply chain disruptions, including customer assets (Kreft & Eckstein, 2014). If realized, both effects hurt the performance of firms and value creation. Such temperature shocks decreased the present value of assets by 7.9 percent (Balvers et al., 2017). In the case of carbon-intensive stocks, transition costs reduce the valuation of such stocks (Semieniuk et al., 2021). Such industries are termed "hard to abate" due to the unavailability of immediate cost-efficient technologies to decarbonize. They, therefore, require higher investments to reduce GHG emission intensity. Hence, transition risk is associated with a firm's technology (Semieniuk et al., 2021).

The dynamics of climate change present the world with climate risk, which is systematic. According to Asselt and Renn (2011), systematic risks capture the embedded nature of the risk in a larger context. Therefore, they are activated as direct risks or through a bundle of other risks (King et al., 2015). Hence, systematic risks with high uncertainty and ambiguity are complex and difficult to quantify (Renn et al., 2011, 2018). However, improved carbon intensity efficiency reduces systematic risk and improves financial performance (Tinks et al., 2020). Therefore, it is possible to mitigate systematic risk exposure by reducing carbon emissions. If the argument is valid, according to portfolio theory, investors exposed to high-carbon-intensive firms expect compensation or risk-adjusted returns for the exposure. Otherwise, they will divest from such risky assets or benefit from diversification of holding carbon-intensive assets (Griffin, 2018). Hence, under portfolio theory, the expectation is that assets with higher climate risk will offer lower returns and vice versa. In a study by Henriques and Sadorsky (2017), divestment from fossil fuel stocks was found to increase stock returns. However, the improved performance of low-carbon stocks relative to carbon-intensive stocks is only relevant in markets with higher social norms (Durand et al., 2013; Liston, 2016). It is investor sentiment that determines better-performing stocks (Liston, 2016).

However, Huang et al. (2018) found a significant negative correlation between climate risk and firm earnings and a positive correlation with earnings volatility. On the contrary, divestment in fossil fuel stocks and reinvestment in greener assets (lower climate risk) resulted in lower financial returns than investing in other assets (Hunt & Weber, 2019). Hence, as an evolving risk, climate change is researched more at a firm's level (Matsumura et al., 2014; Chava, 2014) to understand the impact on stock performance. It is, however, a concept dependent on supportive macro-policies, incentives, and other market-based instruments to attract investment into low-carbon firms (Polzin, 2017; Jones, 2015; Fabian, 2015). The contradictory views undoubtedly reaffirm the complexity and ambiguity of climate risk for investors to price stocks accordingly.

Hence, a reduction in this ambiguity provides investors with confidence about expected returns and in determining the profitability of investments (Polzin et al., 2019). Both information asymmetry, understanding, and knowledge of climate risk are attributed to low capital flow into carbon-intensive assets (Nelson & Pierpont, 2013; Kaminker & Stewart, 2012). Similarly, attracting insurers and pension funds to low-carbon assets requires supportive legislation addressing behavioural practices (Ameli et al., 2020). If supported by increased disclosure, investors and other key stakeholders will have the tools to quantify climate risks (Thomä et al., 2019) and build adequate financial models (Buhr, 2017).

### 2.2.2. Effect of environmental performance on financial performance and market stability

Like climate risks, environmental performance and disclosure provide a firm's legitimacy but can be costly (Peters & Romi, 2013). However, the concept of environmental management in an evolving operating environment that demands governance (Wagner, 2020), extensive knowledge and awareness of environmental issues (Ikram et al., 2019), and human competencies to manage could be complex for firms. Adopting environmental strategy is attributed to financial resources, internal organizational culture, and policies (Gandhi et al., 2018). Other studies have linked environmental performance to financial performance (Clarkson et al., 2011; Yang et al., 2011). The relationship is explained by resource-based theory, that firms with high environmental standards are expected to be conscious of removing waste, efficient usage of resources, value addition, and customer satisfaction (Farrukh et al., 2020; Gaikwad & Sunnapwar, 2020). Hence, an expectation that such firms will have better stock returns.

Developing a successful environmental strategy and the willingness to disclose publicly is a proactive, powerful voluntary governance tool for directors (Rodrigue et al., 2013) and management to strengthen stakeholder relations. Stakeholder theory suggests the importance of making business decisions that take into consideration sustainability performance and the disclosure thereof to create shared value for all stakeholders. The two aspects of consideration are maximizing shareholder value and the creation of societal value through improved earnings and stock returns and maximizing the sum gain of other stakeholders, respectively (Rezaee & Fogarty, 2019). To drive this mindset, effective boards have been found to openly disclose environmental performance to stakeholders and investors (Ben-Amar & Mcllkenny, 2015). With this disclosure, they can proactively manage potential reputational damages that may result in litigation, negative publicity, and brand damage. Hence, failure to manage other stakeholders at the expense of shareholders could be damaging. Therefore, management should focus on creating shareholder value, not wealth, when assessing stock pricing models (Hart & Zingales, 2017).

### 2.2.3. Effect of climate change disclosure on financial market stability and performance

Despite growing environmental disclosure by firms, investors remain biased toward their investment decisions, placing reliance on recent performance to determine the future performance of stocks, leading to suboptimal investment decisions (Della Croce et al., 2011). However, for insurers and pension funds, investment decisions often require environmental stewardship and an understanding of the local context (Halland et al., 2018). This demonstrates the importance of building investor knowledge and understanding low-carbon assets. Such knowledge could provide a mechanism that may enable investors to overcome barriers to switch to low-carbon assets.

Supporting this view, a study by Johnson et al. (2020) conducted in the Southern Asia power sector indicates the existence of a significant gap between the need to integrate climate-related risk within the investor decision-making process. The findings question the significance of climate-related risk in investment decisions, and this is contributed by investors' routines and mindsets and the pressure to invest large sums of money while having limited focus on governance. De Grauwe and Macchiarelli (2015) argue that investors’ behavioural characteristics are a barrier to transition to low-carbon investments. Hence, Lo (2012) questions the accuracy of the efficient market hypothesis (EMH) in classical portfolio theory in explaining investor behaviour, arguing that humans’ beliefs and mindsets determine their decisions. If the markets were efficient, newly available information would be quickly factored into the pricing of stocks to reach equilibrium, suggesting investor behaviour is inconsequential. If the market efficiency is entirely wrong, immediate profits will be made; however, it is the shock events that EMH fails to explain (Shiller, 2003). Hence, the positioning of the adaptive market hypothesis (AMH) is a complete explanation of investor behaviour of financial markets and investors (Lo, 2004, 2005).

The basis of AMH is that human behaviour is complex and comprised of multiple processing domains. This evolution derives from rapid changes in the macro-economic environment (Lo, 2012), where information asymmetry becomes crucial in bridging the knowledge gap and ambiguity (Domenech et al., 2017). As humans process these changes, investment decisions are driven by biases ranging from conservatism (Kariofyllas et al., 2017) to overconfidence and familiarity (Ady, 2018). Due to this complexity, mathematical classical asset pricing models have limitations in explaining investor behaviour. Although this study focuses less on the aspect of investor behaviour, the outcome of the analysis could assist in understanding the investment behaviour of JSE asset managers toward the evolving significance of climate risk in asset pricing.

Empirical evidence from a study by Grubb et al. (2014) probing the limits of EMH interviewing investors, finance experts, and academics revealed that investors favour investment stocks for which potential risk is perceived to be known over unknown policy risk related to climate change. Investors prefer to hold on to the portfolio allocation and investment until there is clarity on governing policy. This is an important consideration in this study, considering climate-change policies and disclosure standards are evolving in South Africa. Without concrete policies and mandatory reporting requirements, investors could struggle to optimize portfolios toward low-carbon risk exposure and develop appropriate valuation models for assets with different climate-risk profiles. Studies by Ahn et al. (2014) and Bossaerts et al. (2010), suggest investors are ambiguity-averse, however, this concept is not fully assessed for climate change-related risks. On the contrary, Bansal et al. (2019) argue that existing evidence proves climate risk is already reflected in stock prices, suggesting the market is efficient.

Griffin and Jaffe (2018) suggest that investors access climate risk information directly from the company’s voluntary or mandatory disclosures or external parties, including analysts and non-governmental agencies. They further assert that investors can extract such information through the responsiveness of asset prices to climate change disclosures. An investigation by Boral (2013) established that 90% of stocks with high-quality sustainability reports disclose fewer negative firm-related events. According to Hilderbrand and Winshet (2016), investors and asset managers indicate that they adjust their investment portfolios based on negative and positive climate-related information about a firm. However, other proponents in the literature argue that such changes are subject to investor’s knowledge and understanding of climate risk and bias (Kariofyllas et al., 2017; Johnson et al., 2020; Ady, 2018). Although disclosure is useful to inform investors, it does not make climate-related associated systematic risk disappear (Mercure, 2019). It therefore begs the question, how do investors on the JSE price climate-related risk?

In summary, theoretical literature provides an understanding of investor behaviour when faced with ambiguity. Climate risk is equally a complex and ambiguous concept. Global adjustment in terms of legislative framework, policies, reporting, and disclosure requirements to this risk is dissimilar across different jurisdictions. Hence, global comparison is difficult. In South Africa, there are developments to align with the developed world. Hence, this topic is increasingly becoming relevant, and the findings could be extended to other emerging markets undergoing similar adjustments.

## 2.2. Empirical evidence

The empirical evidence explored in this section covers previous research investigations on the effect of climate risk disclosure, i.e., GHG emissions and environmental performance, on financial performance, stock returns, and volatility in emerging and developed markets.

### 2.2.1. Effect of greenhouse gas emissions on financial performance

Matsumura et al. (2011) investigated the relationship between GHG emissions, firms' environmental performance, and asset prices of the 1443 S&P500 firms in the United States from 2006 to 2008. The financial data was collected from S&P500, while GHG emission data was hand-collected from public and annual questionnaire responses from the CDP, an independent non-profit organization. Environmental data was collected from KLD Stats, an American agency collecting ESG data. Panel data analysis established the existence of a negative correlation between high GHG emissions and a firm's value. A key limitation of the study is reliance on hand-collected information exposed to self-selection bias due to lower participation by firms with low environmental performance (Li et al., 2008).

Ziegler et al. (2011) conducted a further study of between 447 and 1,790 European and US firms over the years 2001–2006, to investigate corporate climate disclosure on the performance of a portfolio of firms. The data collected was analysed using the Carhart four-factor model (C4FM) (Carhart, 1997), and the investigation could not prove a significant correlation between corporate climate disclosure and the performance of any of the portfolios during that period. However, analysis of the energy sector from additional tests showed risk-adjusted abnormal returns in the US and for the period 2004-2006 in Europe. The latter results may suggest that firms do not equally value climate-related risks, or this could represent industry behavioural bias.

This was followed by Liesen et al.'s (2017) investigation of the effect of GHG disclosure and climate change on asset prices from 2005 to 2009, covering 443 European and US firms using the Carhart four-factor model. The study concluded that financial markets value climate change risk disclosure more than actual performance. The findings seem consistent with the literature that current risk is priced in the stock (Engle et al., 2021), and investors do not act on ambiguity (Hilderbrand & Winshet, 2016). On the contrary, the results did not recognize GHG emission intensity as a proxy for climate risk. The implication of these findings could suggest climate change risk is either already factored in the asset prices, the market is uncertain on how to evaluate the risk, or there is no obligatory incentive to comply. To understand the latter, Scholtens and van der Goot (2014) investigated the effect of carbon prices on the stock market value of 136 firms classified as high emitters (that included oil, gas, power, cement and lime, and iron and steel industries) after Phase I of the EU's Emission Trading Scheme (ETS).

The results show a positive and significant effect of carbon price changes on stock market returns in all four industries. In addition, the volatility of the market value of firms appears not to be influenced by the volatility of the EU ETS carbon prices. Another study of the high-carbon emission industries by Hapsoro and Ambarwati (2018) based on 62 oil, gas, and coal firms in Indonesia, China, Thailand, South Africa, and New Guinea Papua using the Partial Least Method concluded that leverage, profitability, and firm age have a positive effect on the disclosure of carbon emissions. In addition, the disclosure of GHG was found to reduce stock volatility and increase the trading volume. Complementary to these findings, an Indian study by Shrimali (2021) of the power supply market concluded that investments in renewable energy firms (low-carbon emitters) compared to fossil fuel firms (high-carbon emitters) have historically shown more attractive investment characteristics, including, on average, 12% higher annual returns, 20% lower annual volatility, and 61% higher risk-adjusted returns. Evidence from these studies suggests that the GHG intensity of firms influences stock volatility and returns.

To further understand this relationship, Krishnamurti and Velayuthamb (2018) studied 558 Australian listed firms between 2006 and 2009 and found firms with higher quality voluntary information disclosure on GHG emissions to have experienced reduced stock price volatility and improved market liquidity. On the contrary, investigating JSE 100 listed firms for 2008 and 2013, Bhima and Nhamo (2017) concluded that the consistency of carbon emissions through the CPD had no impact on the firm's stock prices. However, stock price volatility and the negative impact were noted during the 2013 reporting period for the high carbon-intensive firms due to the government signalling implementation of a carbon tax. The findings suggest that policy changes induce volatility. The findings are supported by evidence from a study by Ivan Diaz-Rainey et al. (2021) aimed at exploring the stock market, and option implied volatility response of the oil and gas industry to four policy events associated with the Paris Agreement and the election of Donald Trump. The study found the signing of the Paris Agreement to have significantly impacted the Oil and Gas sector stock returns and volatility. However, the announcement by Donald Trump to withdraw the US from the Paris Agreement negatively impacted some sub-sectors in the value chain and the overall sector. These findings suggest that investors price current policies when examining climate risk.

Australian study of the mining sector by Abban and Hassan (2021) using bi-directional causality and VAR model with the main variables being GHG emissions and FP measured by Torbin's Q and return on net asset found a correlation between scope one emissions (defined as direct emissions from owned or controlled resources) and FP measured using Torbin's Q. While Downar et al.'s (2021) study of the United Kingdom (UK) listed firms using difference-in-difference method concluded firms exposed to mandatory carbon emission reporting to have reduced emissions by 8% relative to a control group of other European firms. Furthermore, the costs of operating firms with reduced emissions were compared to other firms. This is an important observation, which contradicts the view that compliance with emission standards is costly.

Expanding on the relationship between GHG and FP, Gerged et al. (2021) confirmed a positive correlation between environmental disclosure and FP measured as Torbin's Q of 405 firms listed on the stock exchange of five Gulf Corporation Council (GCC) for the period 2010 to 2014.

Ganda's (2022) study of 107 JSE-listed firms in South Africa examined the influence of carbon performance on corporate financial performance (FP) for the period 2014-2018 using a two-step generalized method of moments (GMM) panel process. Results of the study established carbon performance to be a transmission channel able to unlock the FP of a firm in the long run and have a strong correlation with the FP measured as Torbin's Q in the short run. This supports findings by Trinks et al.'s (2020) study of 1572 international firms for the period 2009 to 2017 that confirmed improvements in carbon performance to have a positive effect on Torbin's Q. Supportive of this evidence, Dzomonda and Fatoki's (2020) study of 32 JSE mining firms between 2011 and 2018 using panel regression analysis concluded that reduction in carbon emissions have a positive effect on earnings per share (EPS) and stock prices. Similarly, environmental performance had the same correlation. Although this study was limited to small sample size and concentration on the mining sector, the findings are consistent with other evidence conducted in other sectors.

In summary, empirical evidence linking GHG disclosure and stock prices in both developed and emerging markets is inconclusive; however, the effect on stock volatility was noted (Krishnamurti & Velayuthamb, 2018; Hapsoro & Ambarwati, 2018; Bhima & Nhamo, 2017), often triggered by policy changes. Firstly, the findings suggest climate risk is already factored in stock prices. Secondly, empirical evidence suggests the effect on stock prices sector-specific, impacting carbon-intensive firms. The scientific complexity of climate risk and its implication on the future of carbon-intensive assets could be a determining factor. However, consistent evidence across markets indicates a positive relationship between disclosure of good environmental performance and financial performance measured as Torbin's Q. Tobin's Q is the ratio of the market value of firms to their replacement. Evidence from the literature suggests Torbin's Q is proven to be the most reliable indicator of future stock price trends dominating other valuation ratios for its predictive power (Fell, 2001). Based on this evidence, the relationship between GHG emissions is explained in the short run by Torbin's Q and stock prices in the long run, hence contradictory linkages between GHG emissions and stock prices in the short run.

### 2.2.2. Factors affecting environmental, GHG emissions disclosure and financial performance

In the US Giannarakis et al. (2021) investigated the effect of voluntary disclosure on EP using a sample from 102 companies listed on the S&P 500 from 2009-2013. In their study, GHG emissions were used as a proxy for EP, and the Carbon Leadership Index (CLI) functioned as a proxy for carbon disclosure. The study's outcome indicated that higher GHG emissions levels affect openness to disclosure. The consequential implication of the finding is that a positive relationship exists between EP and environmental disclosure level. Another key finding is that firms with good EP ratings willingly disseminate more carbon performance data in their disclosures. Other authors have concurred with this behaviour detailed in the theoretical literature review. A study by Lee (2021) in the Korean context for 2011-2019 on a sample of 13,334 firm observations per annum found that overconfidence by the Chief Executive Officer (or equivalent) correlates positively with GHG emission disclosures and willingness to disseminate information.

However, Krishnamurti and Velayuthamb's (2018) study of 558 Australian listed firms between 2006 and 2009 concluded that firms with combined risk and audit committees have decreased levels of disclosure compared to firms with standalone risk committees. The authors argue that disclosure is a risk that should be managed contradictory to other scholars' view that disclosure reduces risk. Akbas and Canikli (2021) studied determinants of voluntary GHG emissions disclosure, using linear regression on 84 listed Turkish firms between 2014 and 2016, and found a correlation between firm size, institutional ownership, and market value and sensitivity of sampled firms, while board size is negatively related. Another key determinant observed was that transparency of the listed firms correlated with firm size, profitability, and institutional ownership. With increasing globalization, many firms expanded into foreign territories, exporting best practices to emerging economies. It can be argued that such firms will inherently be sized and more profitable.

In Europe, Allesi et al. (2021) found the negative existence of risk-adjusted premiums related to greenness defined based on GHG emissions and quality of environmental disclosures to individual asset returns using the Carhart four-factor model. The study indicated that disclosed performance is already factored in the asset price. The implication of this study is profound, as it highlights slow responsiveness towards diversification against climate risk even with increased disclosure. Another study by Ahmadi and Bouri (2016), analysing the top 40 listed French firms, found environmental disclosure to correlate with EP consistent with other studies. Aligned with Turkish empirical evidence from Akbas and Canikli (2021), firm size and profitability positively correlated with environmental disclosure. However, in their findings, capital need and spending also showed a positive association. The study also concluded that high-quality EP signals effective governance within a firm, thus improving relationships with stakeholders.

In summary, evidence from empirical studies in emerging and developing markets has found that the board, governance structure, and management have a pivotal role in determining firms' EP and willingness to disclose such information. Furthermore, increasing disclosure of environmental performance seems to improve relationships with external stakeholders. Such firms are positioned to achieve above-average performance in the long run. Hence, understanding the relationship between environmental and financial performance is important.

### 2.2.3. Effect of environmental performance on financial performance

Studies on environmental performance (EP) and financial (FP) performance have been explored globally using various methods, and the results varied. Empirical evidence from a Malaysian study by Ong et al. (2019) could not establish a correlation between environmental performance (EP) and financial performance (FP) using the Partial Least Square Model (PLS-CEM) for the analysis. The results further suggest that firms are likely to gain financial performance from reducing air emissions, wastewater, solid waste, hazardous materials, and environmental incidents. The findings support the resource-based theory, which suggests that the preservation of resources should create a competitive edge against peers. Furthermore, a study by Ganda and Wasara (2019) involving ten (10) South African mining companies indicated a negative relationship between environmental disclosure and return on investment using a quantitative method. Unfortunately, extrapolation of the findings has limitations due to the validity of the sample size and the endogeneity problem associated with the chosen analytical technique of PLS-CEM.

In the US, Zhou (2021) assessed the bi-directional causality relationship between ESG and FP measured as Torbin's Q for the top 500 US traded stocks by market capitalization. The study's findings established a positive relationship between EP and FP that varied across companies and industries due to heterogeneity across these sectors and industries. However, firms in other industry sectors showed a negative relationship. Furthermore, the study established a bi-directional relationship between EP and FP, supporting other evidence linking financial resources to the implementation of proactive environmental strategies. In the US, Lu and Taylor (2016) found a good correlation between environmental disclosure and FP but no correlation between EP and FP using the three-stage least square model (3SLS) method. On the contrary, studying Brazilian firms, Voinea et al. (2021) attributed implementations of effective environmental management systems (EMS) as a contributing factor to EP. established a positive correlation between EP and FP.

A study by Liu et al. (2021) of the Chinese listed firms between 2007 and 2018 using panel data identified environmental stewardship as a proxy to have strong relationships and brand equity with key stakeholders. However, the market does not compensate for environmental stewardship, showing a weak correlation between EP and FP. At a regional level, contrasting results were noted with the eastern province indicating a much higher correlation between EP and FP. In this context, the East is the economic hub of the country, industrialized with strong local compliance and tax policies that promote EP. This finding supports the argument that policy clarity and consistency are key to aligning government and industry towards a cleaner environment.

In India Kumar and Firoz (2022) used the multiple regression OLS method to establish a positive correlation between environmental disclosure and FP (using return on capital employed (ROCE) and return on assets (ROA) as proxies). In addition, the study found a high correlation between leveraged firms and FP, delineating that growing firms are likely to have better FP. Croatian evidence by Galant and Cvek (2021) shows that investment in greener long-term assets can be used to predict future profits or losses of firms and found that greener long-term investments lead to improved FP.

In addition to the relationship between greener assets and FP, Ramón et al. (2021) illustrated the impact of Environmental Social and Governance (ESG) disclosure on European corporate equity performance. The investigation suggests that ESG disclosure is associated with improved return growth, with the Governance pillar exhibiting the strongest effect on corporate performance. Secondly, the impact of ESG disclosure on volatility was found to be changing over time, suggesting opaque ratings limit the transmission of information disclosure into corporate performance.

In the US, Hoang et al. (2020) investigated the relationship between EP and FP of 361 US firms from 2007-2016. Environmental performance used disclosure rating, GHG emissions, waste management, and water usage. The panel regression method was used for data analysis. Empirical evidence showed that environmental disclosure positively influences asset prices, and reduced pollution emissions positively affect the current return on assets while damaging the long-term efficiency of capital deployed. The latter could be explained by expected climate change disruptions and changes in consumer behaviour towards “greener” products. Evidence from the study distinguishes environmental transparency and GHG emissions as prominent factors influencing EP, recognized by the market and in response to actual climate-related extremes the global world is experiencing today. Manifestation of these extreme weather-related events is expected to strengthen this correlation over time.

On the contrary, an Egyptian investigation by El-Mohr et al. (2021) of the relationship between EP and FP based on a sample of listed firms on the Egyptian Stock Market from 2007 to 2013 found an insignificant relationship between EP and FP. Contradictory results from other studies highlight the criticality of in-country policies toward driving intended behaviour. In the African context and for other emerging markets, the linkage between EP and FP could be weakened by a lack of supportive policies and incentives. In the context of this study, South Africa’s adoption of best practices is moving faster, necessitating an in-depth understanding of the linkage between EP and FP including events or policy decisions that may aggravate the impact of EP on FP.

Expanding on this insight, Jacob and Nerlinger (2021) effect of climate risk measured by carbon exposure on the valuation of stocks using the COVID-19 pandemic as a shock event. A global sample of stocks on the MSCI All Countries World Investable Market Index (ACWI IMI) and the data were subjected to difference-in-difference analysis comparing pre-shock, shock, and post-shock periods. Results found that carbon intensity affected returns significantly and negatively during a time of high uncertainty. Hence, high-emitting stocks suffered significantly more than in the pre-crisis period but recovered additional losses post-shock period. Conclusions drawn from the study suggest carbon-intensive stocks are exposed to higher risk levels in more stable economic times, thus justifying carbon premium.

Building on this evidence, Shahbaz et al. (2021) investigated how energy and stock markets affect the dynamics of green stock price returns, considering recent crises and increased uncertainty. The study focused on two periods of uncertainty, the 21st Conference of Parties (COP21) and the global financial crisis, to assess the causal relationship between the energy market, stock market, and green stock returns. Using parametric Granger-causality, the study found that clean energy markets react to crude oil and stock markets depending on the market regime and established a negative and significant cross relation when the stock market is in bullish condition and clean energy indices are in bearish conditions. These findings have important implications for portfolio diversification and hedging decisions of environmentally concerned investors (Shahbaz et al., 2021). This also supports policymakers in articulating policies that seek to avoid the contagion risk to ensure financial stability.

The findings from empirical studies linking EP and FP are generally inconclusive. This departure from most of the evidence from the literature is attributed to the chosen analytical technique and sampling. Supportive of other studies, the bi-directional relationship between FP and EP suggests a high propensity of financially stable firms to invest in EP and improve climate risk mitigation. In addition, evidence found greener firms to have improved FP compared to other firms. However, this is more recognized in an environment with clear climate risk policies. Finally, empirical evidence further highlights the vulnerability of carbon-intensive stocks not only to climate-related policy changes but also to other events that impact stock prices.

In conclusion, the literature review and empirical evidence provide insight into the relationship between climate risk disclosure and financial performance in developed and emerging markets. This evidence is relevant in this study to understand the effect of an event change on stock returns and volatility as South Africa is taking a progressive approach to encourage climate risk mitigation. The next section of this study covers details on the proposed methodology and selection of data envisaged to answer research questions.

# CHAPTER 3: RESEARCH METHODOLOGY AND DATA

## 3.1. Methodology

Previous research methodologies examined the effect of climate change and risk on stock returns using various adjusted Capital Asset Pricing models (Ziegler et al., 2007; Liesen et al., 2017). This study envisages determining the effect of climate risk on market performance and stability post-disclosure period using the difference-in-difference (DiD) method. According to Takahashi and Montgomery (2014), critical information is required before using the DiD method to isolate features of the control and treatment groups before and after the intervention to isolate changes associated with the intervention. Basis, our model is based on empirical evidence from Ball and Sheridan (2008) using pooled crossed-sectional panel data to show the effect of climate risk disclosure on the stock returns and volatility of "high-risk" firms relative to "low-risk" firms. The model uses the "low risk" firms as a control group. We observe changes in the stock returns and volatility of the treatment group ("high-risk" firms) before and after disclosure relative to the control group.

First, we use a panel adjustment model in equations (1) and (2). This method allows for treating unobserved firm-specific variables as indicated in the equation, thus solving potential endogeneity problems. However, as Murozumi et al. (2020) indicated, the estimation bias is possible if changes in these unobserved variables coincide with the disclosure period. To mitigate this potential bias to disclosure estimates, we introduce the model's macroeconomic control variables, real interest rates, and real gross domestic product growth rate.

$$\boldsymbol{R_{i,t} = \alpha . R_{i,t-1} + \beta_1 D_{i,t} + \beta_k Y'_{i,t} + \alpha_k X'_{i,t} + \mu_i} \tag{1}$$

$$\boldsymbol{\sigma_{i,t} = \alpha . \sigma_{i,t-1} + \beta_1 D_{i,t} + \beta_k Y'_{i,t} + \alpha_k X'_{i,t} + \mu_i} \tag{2}$$

where $R_{i,t}$ and $\boldsymbol{\sigma_{i,t}}$ represent the stock returns and volatility respectively; and the subscript i=1, 2,..,I represent a JSE listed stock; t=1,2…,T is the period. Aligned with the study by Brito and Bystedt (2010), lagged values of $\boldsymbol{\sigma_{i,t-1}}$ and $\boldsymbol{R_{i,t-1}}$ are utilized to reduce mean-reverting dynamics. This, however, also reduces the dependent variable size by (T-1). The dummy variable, $\boldsymbol{D_{i,t}}$ is used as a proxy for both GHG emission intensity and environmental rating, equal to 0 for the control group and 1 for the treatment group. An adjustment is made to the model by including the firm specific control variables, $\boldsymbol{Y'_{i,t}}$ to account for possible endogenous factors and $\boldsymbol{\beta_k}$ is the coefficient. The term $\boldsymbol{X'_{i,t}}$ captures cross-industry effects common to all the stocks with a coefficient, $\boldsymbol{\alpha_k}$ and $\boldsymbol{\mu_i}$ is an idiosyncratic disturbance term.

Finally, we deploy DiD model in equations (3) and (4) to establish the impact of disclosure on stock portfolio of high and low GHG emitters.

$$\boldsymbol{R_{i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 Post_{i,t} + \gamma Post_{i,t}.D_{i,t} + \alpha' R_{i,t-1} + \beta_3 r\_mgr_{i,t} + \beta_4 r\_RONA_{i,t} + \alpha_1 rgdpg_{i,t} + \alpha_2 r\_int_{i,t} + \alpha_3 \pi_{i,t} + \mu_i} \quad (3)$$

$$\boldsymbol{\sigma_{i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 Post_{i,t} + \gamma Post_{i,t}.D_{i,t} + \alpha' \sigma_{i,t-1} + \beta_3 r\_mgr_{i,t} + \beta_4 r\_RONA_{i,t} + \alpha_1 rgdpg_{i,t} + \alpha_2 r\_int_{i,t} + +\alpha_3 \pi_{i,t} + \mu_i} \quad (4)$$

where $\boldsymbol{R_{i,t}}$ and $\boldsymbol{\sigma_{i,t}}$ represent real returns and standard deviation and $\boldsymbol{\alpha'}$ is the coefficient of the lag dependent variables, $\boldsymbol{\sigma_{i,t-1}}$ and $\boldsymbol{R_{i,t-1}}$. The dummy variable $\boldsymbol{D_{i,t}}$ controls for unobserved differences between the treatment and control firms, with the dummy variable, $\boldsymbol{D_{i,t}}$ used as a proxy for both GHG emission intensity and environmental rating, equal to 0 or 1 for the control and treatment group, respectively. The model uses the real growth rate of market capitalization and real return on net asset, represented as $\boldsymbol{r\_mgr_{i,t}}$ and $\boldsymbol{r\_RONA_{i,t}}$ in equations (3) and (4) above. A selection of this proposed model acknowledges a risk of biased coefficient estimates because the lagged dependent variable in the regression model is endogenous concerning fixed effects. Like Murozumi et al. (2020), we argue that this coefficient bias reduces with a longer T (time) value. This study utilizes annual data over a period starting from 2000 to 2019, adequate to mitigate bias in our model estimates. The firms involved in the study are also large enough to mitigate this bias.

Further tests are computed to estimate the effect of exogenous factors on stock returns and volatility. The study's control variables selection is based on empirical evidence from Kwofie and Ansah's (2018) study that identified a long-run relationship between Ghana's stock market returns and inflation. Celik (2020), in Turkey, identified interest rates to have a negative and significant effect on stock returns and volatility of insurance companies. Similarly, Sanjaya et al.'s (2020) study in Indonesia identified inflation and interest rates to significantly affect their stock returns. However, on the contrary, a study of the Turkish beverage firms by Suharyanto and Achmad Zaki (2021) found interest rates to have had no effect on stock returns, identified inflation, Industrial Production Index (IPI), and exchange rate fluctuations to hurt stock returns. The findings support the theoretical basis, considering IPI is a proxy for economic activity.

After correcting for both the firm and country specific effects, the model isolates the net effects of disclosure on the treatment group as explained by Table 4.1 below.

***Table 3.1: Difference-in-Difference coefficients and interpretation***

| | After disclosure | Before disclosure | **after - before** |
|---|---|---|---|
| Treatment Group | $\beta_0 + \beta_1 + \beta_2 + \gamma$ | $\beta_0 + \beta_2$ | $\boldsymbol{\beta_1 + \gamma}$ |
| Control Group | $\beta_0 + \beta_1$ | $\beta_0$ | $\boldsymbol{\beta_1}$ |
| **Treatment - Control** | $\boldsymbol{\beta_2 + \gamma}$ | $\boldsymbol{\beta_2}$ | $\boldsymbol{\gamma}$ |

We note from equation (3) that the model corrects for the time effects, using $\boldsymbol{\beta_2\, Post_{i,t}}$ in the equation that controls for affected both the control and treatment groups, with $\boldsymbol{Post_{i,t}}$ assigned a dummy variable 1 for unobserved changes affecting both groups. To explain the coefficients in the table, first, we know the dummy variable, $\boldsymbol{Post_{i,t}}$ is assigned 0 before disclosure and 1 after the intervention and $\boldsymbol{D_{i,t}}$ is 1 for the treatment group and 0 for the control group. Assigning the values of the dummy variables in equation (3) results in the sum of the coefficients in column 1 of Table 4.1. The net difference between the two groups after the intervention is explained by a sum of coefficients **($\boldsymbol{\beta_2 + \gamma}$).** Before the intervention, $\boldsymbol{Post_{i,t}}$ is 0; hence the coefficients are represented in column 2 by $\beta_0 + \beta_2$ and $\beta_0$ for the treatment and control group, respectively. Hence, the difference between the two groups post-disclosure is represented by $\boldsymbol{\gamma}$**.** Therefore, a significantly positive or negative co-efficient $\boldsymbol{\gamma}$ indicates associated impact of the disclosure on stock returns and volatility.

Based on our understanding of the model, we explore data required for analysis. We note that environmental ratings of firms taking part in the CDP disclosure program are based on (1) effective company governance structure to manage climate risk, (2) management of climate risks and opportunities, (3) climate risk targets and initiatives, and GHG emissions accounting for scope 1, scope 2, and scope 3. An observation from published CDP reports since 2007 indicates consistent participation by firms, particularly the mining and financial services sectors. This could be explained by foreign ownership, regulatory environment, and financial position of these firms.

However, the number of participants disclosing environmental risk management plans is limited. Data for GHG emission inventory is augmented with company sustainability report of participating firms. First, we examine the effect of GHG emission intensity disclosure on financial stock returns and volatility. Then, we examine the effect of the environmental disclosure rating issued by the CDP on stock returns and volatility. The ratings issued are categorized as “high” for A and B-rated firms else a “low” rating is assigned. The high environmental performance group is used as a control group to understand the effects of implementing progressive climate change mitigation plans.

## 3.2. Data and Sample

Table 3.2 describes the variables used in the empirical models and the sources for the secondary data for this study.

***Table 3.2 below describes variables used in the empirical formula.***

| **Variables** | **Description** | **Source** |
|---|---|---|
| ***Independent variables*** | | |
| A dummy variable ($\boldsymbol{D}_{i,t}$) | Dummy variable that is equal to 0 for the treatment group, else 1 | CDP Reports Sustainability reports |
| Disclosure rating | Disclosure rating is based on a scoring a firm attains from the CDP the questionnaire. The rating is either High (A&B ratings) or Low | CDP Reports Sustainability reports. |
| Carbon intensity | Carbon emission intensity $CO_2$eq >0.5mt pa) and low ($CO_2$eq<0.5mt pa) | CDP Reports Sustainability reports |
| ***Dependent variables*** | | |
| Stock returns | Daily stock returns, annualized stock Returns and standard deviation calculated | Bloomberg |
| ***Firms' specific control variables*** | | |
| Size | Daily capitalization, annualized | Bloomberg |
| Return on net asset | Annual, computed as net income divided By total assets | EquityRT |
| ***Macro-economic control variables*** | | |
| Nominal interest rate | Annual 90-day T-bills | FRED database. |
| Inflation | Annual inflation | FRED database |
| Real GDP | Annual, nominal GDP adjusted for inflation | FRED database. |

The sample for this research is based on JSE-listed firms, categorized into consumer services, consumer goods, basic materials, technology, telecommunications, financials, industrials, and health care. Previous researchers argued the inclusion of the financial services sector due to (1) over-regulation of the industry, therefore expected to have disclosure requirements, (2) firms are highly leveraged (Foerster & Sapp, 2005), and (3) they have a low climate-related impact. Firstly, the argument is relevant for "pure" banking services if the regression model uses leverage as a control variable. Firm control variables in the study are limited to real market capitalization growth rate and real RONA denoted by r_mgr and r_RONA, respectively, in equation (3) and (4) above. Secondly, general categorization by the JSE of the financial services sector is extended to insurance, investment firms, and real estate firms. The exclusion of these firms would impact the population size of the control sample.

Using the data collected, the real interest rate is calculated by subtracting inflation from nominal inflation. Similarly, real RONA and growth rate of market capitalization are adjusted for inflation for the regression to calculate real returns. Data collected is from 2000 to 2019 to avoid bias caused by the Covid-19 pandemic. The timing also aligns with the first CDP disclosure for GHG and environmental ratings in 2007. However, the year of participation differed for firms sampled in the study; this effect is removed by assessing the disclosure impact starting in January 2010. This adjustment further helps reduce bias from the effects of the financial crisis of 2008 that caused volatility in global stock markets.

As indicated in Table 3.2, daily closing stock prices and market capitalizations were collected from Bloomberg, while RONA data was sourced from the EquityRT database. The daily stock returns are used to compute returns and standard deviation and similarly with market capitalization. Both returns are annualized and adjusted for inflation for analysis. Then, we run an OLS regression analysis with robust standard errors clustered around the firms. This is followed by OLS regression with time-effects and errors clustered around the firm. The third regression is a difference-in-difference OLS with robust standard errors around the firm. Finally, the same difference-in-difference OLS is computed without robust standard errors to assess the possibility of heteroskedasticity.

## CHAPTER 4: EMPIRICAL RESULTS

Research data was collected from 116 firms that have consistently published GHG emission data. The sample size was reduced to 104. Investigation into the effect of environmental rating disclosure was limited to published CDP reports. The final sample was reduced from 66 to 55 participating firms. Table 4.1 below summarizes a description of the sample collected for the study from participating JSE listed firms.

*Table 4.1a Sample A: Distribution of sample per industry – GHG emissions*

| Sample | GHG impact of stock returns and volatility | | | |
|---|---|---|---|---|
| **Industry** | **No. of firms** | **Distribution** | **No. of low GHG firms** | **No. of high GHG firms** |
| Consumer Goods | 11 | 11% | 7 | 4 |
| Consumer Services | 17 | 16% | 14 | 3 |
| Financial | 23 | 22% | 23 | |
| Health | 2 | 2% | 2 | |
| Technology | 2 | 2% | | 2 |
| Telecoms | 9 | 9% | 9 | |
| Industrials | 23 | 22% | 15 | 8 |
| Materials | 17 | 16% | 1 | 16 |
| **Total sample** | **104** | **100%** | **71** | **33** |
| Note: low GHG firms defined as firms with $CO_{2eq}$ emissions < 1mt pa; high firms $CO_{2eq}$>1mt pa | | | | |

From Table 4.1a above, the control sample, defined as firms with GHG emission intensity below 0.5 MT pa of $CO_2$ equivalent, contains 71 firms distributed more towards financials, industrials, and consumer services industries. Materials and industrial firms dominate high-carbon intensity firms, accounting to 72,72% of the sample size. This distribution is expected due to these sectors being energy intensive. The sample to assess the effect of environmental stewardship disclosure on Table 4.1b was categorized using 'A and B" CDP ratings for a high environmental rating and scores above "B" rating as performance.

*Table 4.1b Sample B: Distribution of sample per industry – Environmental rating*

| Sample | Environmental rating impact of stock returns and volatility | | | |
|---|---|---|---|---|
| **Industry** | **No. of firms** | **Distribution** | **No. of low GHG firms** | **No. of high GHG firms** |
| Consumer Goods | 4 | 4% | 2 | 2 |
| Consumer Services | 9 | 9% | 6 | 3 |
| Financial | 11 | 11% | 4 | 7 |
| Health | 2 | 2% | 1 | 1 |
| Technology | 1 | 1% | 1 | |
| Telecoms | 2 | 2% | 2 | |
| Industrials | 11 | 11% | 9 | 2 |
| Materials | 15 | 14% | 4 | 11 |
| **Total sample** | **55** | **100%** | **29** | **26** |
| Note: Low Environmental rating firms rated above "B"; high rated firms achieved "A&B" ratings | | | | |

Sample to test for the impact of environmental performance dominated by consumer services, financials, industrials, and materials. Common features of the participating firms are (1) the regulatory environment requires environmental stewardship, (2) foreign ownership influence to meet world standards, and (3) high GHG emission intensity increased awareness to implement climate risk management measures. The latter two are evident from the number of participating mining firms in the CDP disclosure program.

Before a detailed analysis of the results, we present correlation matrices of the control variable instruments in this study for the three distinct periods relevant to our analysis, namely (1) period 2000-2019, (2) period 2000-2009, and (3) period 2010-2019. Table 4.2 summarizes the correlation results. The first table shows a strong positive correlation between stock returns and market capitalization growth rate. Market capitalization is a product of stock price and number of shares outstanding; hence, there is a strong positive correlation between the two economic variables. Return on assets correlates second best with stock returns, followed by real GDP growth rate.

First, we note in Table 4.2a, Table 4.2b, and Table 4.2c below a positive correlation between real stock returns and real GDP growth rate throughout the three periods. However, an unexpectedly positive correlation exists between real interest rates and real stock returns for the periods 2000-2019 and 2000-2009, then turns negative after the financial crisis of 2008. This positive correlation contradicts the theoretical basis that a rise in interest rates reduces the money supply in the economy, reduces consumer spending, and finally eases inflation. However, the correlation between inflation and real stock returns is negative during the same period. Hence, we note a strong negative correlation between inflation and interest rates.

***Table 4.2a: Correlation matrices of research control variables: for periods 2000-2019***

| **2000-2019** | Real Stock Returns | Real GDP Growth Rate | Real interest Rates | Market Cap Growth Rate | Real return on Net Asset | Inflation |
|---|---|---|---|---|---|---|
| Real stock Returns | **1,000** | | | | | |
| Real GDP Growth Rate | 0,200 | **1,000** | | | | |
| Real interest Rates | 0,234 | 0,526 | **1,000** | | | |
| Market Cap Growth Rate | 0,736 | 0,188 | 0,233 | **1,000** | | |
| Real return on Net Asset | 0,261 | 0,236 | 0,220 | 0,197 | **1,000** | |
| Inflation | -0,347 | -0,310 | -0,629 | -0,315 | -0,281 | **1,000** |

The results show a strong positive correlation between stock returns and market capitalization growth rate. Market capitalization is a product of stock price and number of shares outstanding; hence, there is a strong positive correlation between the two economic variables.

*Table 4.2b: Correlation matrices of research control variables: for periods 2000-2009*

| **2000-2009** | Real Stock Returns | Real GDP Growth Rate | Real interest Rates | Market Cap Growth Rate | Real return on Net Asset | Inflation |
|---|---|---|---|---|---|---|
| Real stock Returns | **1,000** | | | | | |
| Real GDP Growth Rate | 0,152 | **1,000** | | | | |
| Real interest Rates | 0,371 | 0,520 | **1,000** | | | |
| Market Cap Growth Rate | 0,709 | 0,123 | 0,347 | **1,000** | | |
| Real return on Net Asset | 0,278 | 0,250 | 0,307 | 0,208 | **1,000** | |
| Inflation | -0,479 | -0,310 | -0,876 | -0,428 | -0,370 | **1,000** |

*Table 4.2c: Correlation matrices of research control variables: for periods 2000-2009*

| **2010-2019** | Real Stock Returns | Real GDP Growth Rate | Real interest Rates | Market Cap Growth Rate | Real return on Net Asset | Inflation |
|---|---|---|---|---|---|---|
| Real Stock Returns | **1,000** | | | | | |
| Real GDP Growth Rate | 0,198 | **1,000** | | | | |
| Real interest Rates | -0,169 | -0,384 | **1,000** | | | |
| Market Cap Growth Rate | 0,778 | 0,211 | -0,152 | **1,000** | | |
| Real return on Net Asset | 0,210 | 0,147 | -0,008 | 0,149 | **1,000** | |
| Inflation | 0,133 | -0,103 | -0,774 | 0,100 | -0,085 | **1,000** |

Based on an understanding of the interactions amongst the control variables in our model, we structure data analysis by formulated research hypothesis, i.e., (a) Ho: High GHG emitters have lower stock returns post-disclosure (b) Ho: High GHG emitters have higher stock volatility post-disclosure, (c) Ho: High environmental rating results in better stock returns post-disclosure and (d) Ho: High environmental rating reduces stock volatility relative firms' post-disclosure.

## 4.1.(a). Ho: High GHG emitters have lower returns than low GHG emitters post-disclosure.

The basic results of the study are based on equation (3) as indicated below. $\boldsymbol{R_{i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 Post_{i,t} + \gamma Post_{i,t}.D_{i,t} + \alpha' R_{i,t-1} + \beta_3\, r\_mgr_{i,t} + \beta_4\, r\_RONA_{i,t} + \alpha_1 rgdpg_{i,t} + \alpha_2 r\_int_{i,t} + \alpha_3 \pi_{i,t} + \mu_i}$

In examining the validity of the hypotheses, the focus will be on the significance of coefficient, $\boldsymbol{\gamma}$ that distinguishes the effect of disclosure between the control and treatment sample, as explained in Table 3.1 above. First, this period has the highest negative correlation between interest rates and stock returns. Then, we observe that the correlation between interest rates and real GDP growth rate is -0.121. However, as the interest rates start to ease post the financial crisis, economic growth rate continues to deteriorate as indicated by and increase in the negative correlation between the two variables for period 2010-2019. This explains the lag effect of interest rates on economic growth. Understanding this economic principle helps analyse regression coefficients in Table 4.3a and Table 4.3b below.

**<u>Table 4.3a: Effect of High GHG intensity on real stock returns for period 2000-2019</u>**

| RETURNS<br>VARIABLES | (1)<br>OLS | (2)<br>TE-OLS | (3)<br>DiD-OLS | (4)<br>DiD-OLS* |
|---|---|---|---|---|
| lqi1(α') | 0.105*** | 0.107*** | 0.105*** | 0.105*** |
| | (0.031) | (0.031) | (0.032) | (0.017) |
| r_RONA($\beta_4$) | -1.991*** | -1.700*** | -1.699*** | -1.699*** |
| | (0.298) | (0.288) | (0.288) | (0.253) |
| r_mgr($\beta_3$) | 0.626*** | 0.622*** | 0.621*** | 0.621*** |
| | (0.076) | (0.076) | (0.076) | (0.015) |
| r_int($\alpha_2$) | -0.610*** | -1.067*** | -1.070*** | -1.070*** |
| | (0.209) | (0.313) | (0.313) | (0.262) |
| INFL($\alpha_3$) | -1.607*** | -1.835*** | -1.840*** | -1.840*** |
| | (0.399) | (0.437) | (0.437) | (0.250) |
| rgdpgrowth($\beta_2$) | -0.100 | -0.253 | -0.244 | -0.244 |
| | (0.146) | (0.169) | (0.170) | (0.190) |
| GHG emiss($\beta_2$) | -0.008 | -0.008 | 0.002 | 0.002 |
| | (0.005) | (0.005) | (0.008) | (0.008) |
| Time dummy($\beta_1$) | | -0.027** | -0.021 | -0.021* |
| | | (0.012) | (0.013) | (0.011) |
| DiD coeff. (γ) | | | -0.020* | -0.020* |
| | | | (0.012) | (0.011) |
| Constant($\beta_0$) | 0.021 | 0.081** | 0.077** | 0.077*** |
| | (0.013) | (0.031) | (0.032) | (0.025) |
| Observations | 1,963 | 1,963 | 1,963 | 1,963 |
| R-squared | 0.534 | 0.536 | 0.537 | 0.537 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

The first column presents estimates of a simple pooled cross-section OLS that omits the common time effects from the estimation. The p-values in parentheses are for the robust standard errors clustered around the firms, except for the last column that presents standard errors. The OLS coefficients in the first column estimate an insignificant negative impact of real GDP growth rate on stock returns. The finding contradicts economic expectations and previous findings linked stock market performance and real GDP growth (Hsing & Hsieh, 2011; Suharyanto & Achmad Zaki, 2021). Theoretical literature and correlation matrices in Tables 4.2a, 4.2b, and 4.c above suggest the existence of a positive correlation between real GDP growth rate and stock returns. However, we note an unexpected negative coefficient in the regression outputs of real GDP growth rate is due to the lag effect of interest rates on economic growth, as indicated by the correlation matrix in Tables 4.2a and 4.2c.

On the contrary, results estimate that the impact of interest rates on stock returns for both high and low emitters is negative and significant. The negative coefficient indicates that an increase in real inflation rate reduces stock returns. Similarly, we note the negative impact of inflation on the real returns that is significant and high. These results are consistent with studies by Sanjaya et al. (2020) that isolated both inflation and interest rates as the key macroeconomic variables affecting financial performance of energy and mining firms, while Alzoubi (2022) found a 1% increase in interest rates to impact listed Amman Stocks by 5%. Similarly, Suhaibu et al. (2017) found a bidirectional relationship between interest rates to have a bidirectional relationship with stock market performance and a greater impact on inflation. This relationship is indicated in the Table above with the relative movement between real interest rates and inflation across all the regression models.

At a firm level, the r_RONA coefficient estimates are negative and significant. The latter finding supports the correlation between stock returns and RONA in Table 4.2 above. In contrast, the negative correlation in real terms is possibly dragged by including inflation in the regression model. On the contrary, we establish a positive and significant correlation between market capitalization growth rate and stock returns with and without the time effects.

The coefficient for GHG emissions for the treatment is negative with and without the time effects but insignificant, while on the contrary, the control sample is positive though insignificant. This coefficient estimates the mean difference between the control and treatment groups before disclosure. Therefore, the result, though not significant, indicates that the mean difference between the high GHG firms and control sample was negative. The coefficient for the dummy variable $\boldsymbol{Post_{i,t}}$ estimates the mean change in stock returns from before to after the control group. This estimate is between -0.041 at a 1% significance level for the high GHG firms in Table 4.3a. The intercept of the DiD-OLS regression in column 4 above is high and significant at a 1% significance level. However, the DiD coefficient estimate in Table 4.3a is weakly significant. Table 4.4 below summarizes the DiD regression coefficients in column 3.

**Table 4.3b: Effect of Low GHG intensity on real stock returns for period 2000-2019**

| VARIABLES | (1)<br>OLS | (2)<br>TE-OLS | (3)<br>DiD-OLS | (4)<br>DiD-OLS* |
|---|---|---|---|---|
| lRi1(α') | 0.105*** | 0.107*** | 0.105*** | 0.105*** |
| | (0.031) | (0.031) | (0.032) | (0.017) |
| r_RONA($\beta_4$) | -1.991*** | -1.700*** | -1.699*** | -1.699*** |
| | (0.298) | (0.288) | (0.288) | (0.253) |
| r_mgr($\beta_3$) | 0.626*** | 0.622*** | 0.621*** | 0.621*** |
| | (0.076) | (0.076) | (0.076) | (0.015) |
| r_int($\alpha_2$) | -0.610*** | -1.067*** | -1.070*** | -1.070*** |
| | (0.209) | (0.313) | (0.313) | (0.262) |
| INFL($\alpha_3$) | -1.607*** | -1.835*** | -1.840*** | -1.840*** |
| | (0.399) | (0.437) | (0.437) | (0.250) |
| rgdpgrowth($\beta_2$) | -0.100 | -0.253 | -0.244 | -0.244 |
| | (0.146) | (0.169) | (0.170) | (0.190) |
| GHG emiss($\beta_2$) | 0.008 | 0.008 | -0.002 | -0.002 |
| | (0.005) | (0.005) | (0.008) | (0.008) |
| Time dummy($\beta_1$) | | -0.027** | -0.041*** | -0.041*** |
| | | (0.012) | (0.012) | (0.013) |
| DiD coeff. (γ) | | | 0.020* | 0.020* |
| | | | (0.012) | (0.011) |
| Constant($\beta_0$) | 0.013 | 0.072** | 0.080*** | 0.080*** |
| | (0.016) | (0.031) | (0.030) | (0.025) |
| Observations | 1,963 | 1,963 | 1,963 | 1,963 |
| R-squared(adj.) | 0.534 | 0.536 | 0.537 | 0.537 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

The resulting estimate indicates that at time dummy period = 0 and GHG dummy = 0, the estimated mean returns of the firm in the control sample before the disclosure period is 0.080%. However, post-disclosure, when dummy period = 1, the estimated mean returns of the firms in the control sample is the "intercept + time dummy" coefficient calculated as 0.056%. Then, for the treatment group, before GHG disclosure, the estimated mean return is calculated from the regression analysis to be "intercept + GHG dummy," calculated as 0.097%. The model estimates the change in the mean returns of the treatment sample post-disclosure period to be "intercept+coefficient time dummy+GHG dummy+DiD dummy," calculated as 0.06%. is the results show that returns of both the control and treatment groups declined post-GHG emissions disclosure.

*Table 4.4 Summary of the DiD-OLS regression coefficients for a sample including banks.*

| **Period** | **Treatment Group (High GHG firms )** | **Control Group (Low GHG firms)** |
|---|---|---|
| Period 0 | 0.097 | 0.077 |
| Period 1 | 0.0056 | 0.056 |
| **Change in Stock Returns** | **-0.041** | **-0.021** |

From the table above, stock returns of high GHG emitting firms reduced by 0.041% after the disclosure period relative to 0.021% decline of the low GHG emitting firms. The difference in this decline explained by the **γ** coefficient estimate of the DiD-OLS analysis is -0.041%-(-0.021%) that equals to -0,02% for high emitters. Finally, we assessed heteroskedasticity by comparing the results of DiD-OLS with and without robust standard error clustered around the firms, and the coefficient estimates were found to be consistent.

In sum. y, the DiD-OLS coefficient estimate is weakly significant to confirm the hypothesis that high GHG firms have lower returns than low GHG firms' post-disclosure of climate risk. This finding is consistent with Bhima and Nhamo's (2017) study of the 100 JSE-listed firms from 2008 to 2013, which found the disclosure of GHG emissions to have had no impact on stock prices. On the contrary, Matsumura et al. (2011) in the United States established the existence of a negative correlation between high GHG emissions and firm's value. The results of the latter study are based on a sample from a developed market where policies around climate risk are advanced. Hence, investors factor this risk into asset pricing. In contrast to the developed countries, the maturity of climate risk policies in South Africa is at a developmental stage. Hence, Bhima and Nhamo (2017) observed increased stock volatility in 2013 following the government's carbon tax announcement. Any new information detrimental to market stability and pricing is expected to create uncertainty in the market, hence this observation.

On the contrary, the market could see climate disclosure without immediate impact on stock prices as less significant unless the associated impact is quantified. The new announcement induced uncertainty, on the associated impact to asset prices that was immediately priced into the stocks. Investors are risk averse (Ahn et al., 2014; Bossaerts et al., 2010), and climate risk was proven to be already priced in stock prices by Bansal et al. (2019), suggesting the market is efficient. Hence, the effect of climate risk disclosure in South Africa had muted effects on the stock markets. In the next section, we analyse the effect of GHG emission disclosure on stock volatility to assess the hypothesis that high GHG emitters have higher stock return volatility than low GHG emitters.

## 4.1.(b). Ho: High GHG emissions have higher stock volatility than low GHG emitters post-disclosure.

Results of the impact of GHG disclosure on stock volatility are displayed in Table 4.5a and Table 4.5b below.

**4.5a. Effect of High GHG intensity on stock volatility for the period 2000-2019**

| VARIABLES | (1)<br>OLS | (2)<br>TE-OLS | (3)<br>DiD-OLS | (4)<br>DiD-OLS* |
|---|---|---|---|---|
| lqi1(α') | 0.67*** | 0.67*** | 0.67*** | 0.67*** |
| | (0.067) | (0.067) | (0.067) | (0.017) |
| r_RONA($\beta_4$) | 11.48** | 12.39* | 12.38* | 12.38*** |
| | (5.742) | (6.633) | (6.630) | (3.777) |
| r_mgr($\beta_3$) | -0.63 | -0.64* | -0.64* | -0.64*** |
| | (0.392) | (0.382) | (0.381) | (0.230) |
| r_int($\alpha_2$) | 13.67*** | 12.25*** | 12.27*** | 12.27*** |
| | (4.562) | (3.834) | (3.851) | (3.926) |
| INFL($\alpha_3$) | 23.64*** | 22.93*** | 22.95*** | 22.95*** |
| | (6.487) | (6.067) | (6.082) | (3.715) |
| rgdpgrowth($\beta_2$) | 0.46 | 0.02 | 0.01 | 0.01 |
| | (2.213) | (2.528) | (2.531) | (2.617) |
| GHG emiss($\beta_2$) | -0.03 | -0.03 | -0.08 | -0.08 |
| | (0.087) | (0.087) | (0.127) | (0.116) |
| Time dummy($\beta_1$) | | -0.08 | -0.11 | -0.11 |
| | | (0.132) | (0.147) | (0.159) |
| DiD coeff. (γ) | | | 0.09 | 0.09 |
| | | | (0.135) | (0.160) |
| Constant($\beta_0$) | -0.01 | 0.18 | 0.19 | 0.19 |
| | (0.238) | (0.462) | (0.468) | (0.369) |
| Observations | 1,963 | 1,963 | 1,963 | 1,963 |
| R-squared(adj.) | 0.465 | 0.465 | 0.465 | 0.465 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

The coefficients of real interest rates and inflation are significant and high, indicating both macroeconomic variables' severe impact on the stock markets. The real GDP growth rate effect is muted with and without time effects. The regression coefficient for real market capitalization growth is negative at a 10% confidence level, suggesting that when market capitalization increases, volatility declines.

**4.5b. Effect of Low GHG intensity on stock volatility for the period 2000-2019**

| VARIABLES | (1) OLS | (2) TE-OLS | (3) DiD-OLS | (4) DiD-OLS* |
|---|---|---|---|---|
| lqi1(α') | 0.666*** | 0.666*** | 0.666*** | 0.666*** |
| | (0.067) | (0.067) | (0.067) | (0.017) |
| r_RONA($\beta_4$) | 11.484** | 12.387* | 12.383* | 12.383*** |
| | (5.742) | (6.633) | (6.630) | (3.777) |
| r_mgr($\beta_3$) | -0.632 | -0.645* | -0.640* | -0.640*** |
| | (0.392) | (0.382) | (0.381) | (0.230) |
| r_int($\alpha_2$) | 13.665*** | 12.252*** | 12.272*** | 12.272*** |
| | (4.562) | (3.834) | (3.851) | (3.926) |
| INFL($\alpha_3$) | 23.638*** | 22.931*** | 22.953*** | 22.953*** |
| | (6.487) | (6.067) | (6.082) | (3.715) |
| rgdpgrowth($\beta_2$) | 0.455 | 0.020 | 0.014 | 0.014 |
| | (2.213) | (2.528) | (2.531) | (2.617) |
| GHG emiss($\beta_2$) | 0.033 | 0.033 | 0.081 | 0.081 |
| | (0.087) | (0.087) | (0.127) | (0.116) |
| Time dummy($\beta_1$) | | -0.084 | -0.021 | -0.021 |
| | | (0.132) | (0.144) | (0.187) |
| DiD coeff. (γ) | | | -0.092 | -0.092 |
| | | | (0.135) | (0.160) |
| Constant($\beta_0$) | -0.038 | 0.144 | 0.110 | 0.110 |
| | (0.239) | (0.448) | (0.441) | (0.376) |
| Observations | 1,963 | 1,963 | 1,963 | 1,963 |
| R-squared | 0.465 | 0.465 | 0.465 | 0.465 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

The effect of real GDP growth is low and insignificant, like an observation for stock returns. The intercept coefficient in column three is 0.19 and insignificant for high GHG stocks. The results indicate that the estimated mean standard deviation of the control group before GHG disclosure is 0.19%. The coefficient of GHG dummy variable is -0.08 and insignificant, while the introduction of time effects reduces volatility. However, the DiD-coefficient estimates in columns three and four are small and insignificant. Table 4.6 below summarizes the interaction of the regression coefficient in Table 4.5a.

***Table 4.6 Summary of the DiD-OLS regression coefficients for a sample including banks.***

| **Period** | **Treatment Group (High GHG firms)** | **Control Group (Low GHG firms)** |
|---|---|---|
| Period 0 | 0.11 | 0.19 |
| Period 1 | 0.19 | 0.18 |
| **Change in Stock Volatility** | **0.08** | **-0.01** |

As indicated in Table 4.6 above, the standard deviation of high GHG stocks before the disclosure period was lower than that of low GHG stocks. The change in stock standard deviation for high GHG firms post disclosure increased by 0.08%, while low GHG stocks decreased by 0.01%. The net change or difference-in-difference outcome between the two periods for high GHG stocks is 0.08-(-0.01) = 0.09, indicated as **γ** in the results in Table 4.5a. However, this difference is not statistically significant to draw a meaningful conclusion based on regression in column 4.

In summary, the results confirm the significant impact of interest rates on stock market stability, while real GDP growth rate effect is statistically insignificant with and with time effects. The coefficients of the two firm specific variables are weakly significant. Although the volatility of the firms with high GHG emissions increased post-disclosure, the results are not statistically significant and conclusive. The results are contradictory to empirical evidence by (Krishnamurti & Velayuthamb, 2018; Hapsoro & Ambarwati, 2018; Bhima & Nhamo, 2017) that found stock volatility to often be triggered by policy changes compared to stock returns. However, voluntary disclosure could not necessarily be a policy change. Bhima and Nhamo (2017) noted increased stock volatility of high GHG firms based on a sample of 100 JSE firms in 2003, upon the South African government's announcement to introduce carbon tax.

Climate risk mitigation depends on supportive macro-policies, incentives, and other market-based instruments (Polzin, 2017; Jones, 2015; Fabian, 2015). Any ambiguity in policies impacts investor decisions that could result in market instability. Polzin et al. (2019) argue that reducing this ambiguity increases investor confidence about expected returns. As the information asymmetry, knowledge, and understanding of the impact of carbon tax improve investor confidence and forecasting (Buhr, 2017) is expected to mature as the tools to quantify the risk improve (Thomä et al., 2019). This theoretical argument explains the findings in this research that indicate that voluntary disclosures without potential short to medium term impact on future earnings and/or contingent liability should not affect market stability and performance.

In the next section, we analyse the results of the impact of environmental rating by firms on stock returns and volatility.

## 4.2.(a). Ho: High environmental rating results in better stock returns post-disclosure.

Table 4.7a and Table 4.7b below present the results of regression analysis for firms with low and high environmental ratings, respectively. The control group for this investigation is stocks with high environmental rating while the treatment group is represented by firms with low environmental ratings. The results in column 1 indicate that the interest rate coefficients are positive and insignificant until we control the time effects in column 2. After controlling for the time effects in column 2, both inflation and interest rates are negative and significant, as expected. The real GDP growth rate estimate also changes from positive to negative after controlling for time effects and is significant at the 5% level. The negative effect is contradictory to theoretical expectation that economic growth improves market performance. The highly negative inflation influences the behaviour in the regression model.

**4.7a. Effect of Low Environmental rating on stock returns for the period 2000-2019**

| VARIABLES | (1)<br>OLS | (2)<br>TE-OLS | (3)<br>DiD-OLS | (4)<br>DiD-OLS* |
|---|---|---|---|---|
| lRi1(α') | 0.046 | 0.068* | 0.066* | 0.066** |
| | (0.037) | (0.035) | (0.035) | (0.032) |
| r_RONA($\beta_4$) | 0.390*** | 0.323*** | 0.315*** | 0.315*** |
| | (0.105) | (0.100) | (0.098) | (0.067) |
| r_mgr($\beta_3$) | 0.097* | 0.093* | 0.092* | 0.092*** |
| | (0.052) | (0.047) | (0.047) | (0.011) |
| r_int($\alpha_2$) | 0.435 | -2.101*** | -2.098*** | -2.098*** |
| | (0.262) | (0.486) | (0.485) | (0.468) |
| INFL($\alpha_3$) | -0.406 | -2.371*** | -2.375*** | -2.375*** |
| | (0.316) | (0.464) | (0.463) | (0.384) |
| rgdpgrowth($\beta_2$) | 0.280 | -0.571** | -0.559** | -0.559* |
| | (0.229) | (0.261) | (0.265) | (0.339) |
| Env. dummy($\beta_2$) | -0.014* | -0.013* | 0.003 | 0.003 |
| | (0.008) | (0.007) | (0.009) | (0.013) |
| Time dummy($\beta_1$) | | -0.118*** | -0.103*** | -0.103*** |
| | | (0.016) | (0.017) | (0.019) |
| DiD coeff. (γ) | | | -0.029* | -0.029 |
| | | | (0.017) | (0.018) |
| Constant($\beta_0$) | 0.030 | 0.277*** | 0.270*** | 0.270*** |
| | (0.023) | (0.044) | (0.045) | (0.041) |
| Observations | 1,041 | 1,041 | 1,041 | 1,041 |
| R-squared(adj.) | 0.152 | 0.191 | 0.193 | 0.193 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

It is noted from the table above, in columns 1 and 2, that the real return on net asset coefficient is weakly significant while controlling for the time effects indicates a negative effect on stock returns. The intercept of the equation is significant post-disclosure period at 0.27. This indicates that the mean estimated returns of control sample returns before disclosure is estimated at 0.27%. The coefficient estimates for the time variable are negative and significant, suggesting an overall decline in returns post-disclosure period. Hence, the post-disclosure mean estimate of the control sample is 0.167% (i.e., intercept + time variable dummy), implying an overall reduction in the real stock returns of the firms in the control sample. Stocks with high environmental ratings also show a reduction in real returns after controlling for the time effects, as indicated below.

**4.7b. Effect of High Environmental rating on stock returns for the period 2000-2019**

| VARIABLES | (1) OLS | (2) TE-OLS | (3) DiD-OLS | (4) DiD-OLS* |
|---|---|---|---|---|
| lRi1(α’) | 0.046 | 0.068* | 0.066* | 0.066** |
| | (0.037) | (0.035) | (0.035) | (0.032) |
| r_RONA($\beta_4$) | 0.390*** | 0.323*** | 0.315*** | 0.315*** |
| | (0.105) | (0.100) | (0.098) | (0.067) |
| r_mgr($\beta_3$) | 0.097* | 0.093* | 0.092* | 0.092*** |
| | (0.052) | (0.047) | (0.047) | (0.011) |
| r_int($\alpha_2$) | 0.435 | -2.101*** | -2.098*** | -2.098*** |
| | (0.262) | (0.486) | (0.485) | (0.468) |
| INFL($\alpha_3$) | -0.406 | -2.371*** | -2.375*** | -2.375*** |
| | (0.316) | (0.464) | (0.463) | (0.384) |
| rgdpgrowth($\beta_2$) | 0.280 | -0.571** | -0.559** | -0.559* |
| | (0.229) | (0.261) | (0.265) | (0.339) |
| GHG emiss($\beta_2$) | 0.014* | 0.013* | -0.003 | -0.003 |
| | (0.008) | (0.007) | (0.009) | (0.013) |
| Time dummy($\beta_1$) | | -0.118*** | -0.132*** | -0.132*** |
| | | (0.016) | (0.019) | (0.019) |
| DiD coeff. (γ) | | | 0.029* | 0.029 |
| | | | (0.017) | (0.018) |
| Constant($\beta_0$) | 0.017 | 0.265*** | 0.272*** | 0.272*** |
| | (0.026) | (0.044) | (0.044) | (0.041) |
| Observations | 1,041 | 1,041 | 1,041 | 1,041 |
| R-squared(adj.) | 0.152 | 0.191 | 0.193 | 0.193 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

The environmental dummy variable for low environmental stocks (in Table 4.8a) in columns 1 and 2 above is negative and weakly significant. The negative sign implies these stocks generally have lower returns than highly rated firms, as indicated in Table 4.9b. However, the significance of the coefficient is not significant in the difference-in-difference regressions presented in columns 3 and 4 of both Table 4.9a and Table 4.9b. The DiD-coefficient with robust standard errors clustered around the firm is negative and at 10% significance level for firms with low environmental performance or higher climate risk exposure. To unpack these results, we compute the mean estimated returns of the firms in the treatment group to be 0.167% (calculated as “intercept+ env. dummy” in the table above). Post-disclosure, the mean difference in return for these firms is 0.141%, indicating deteriorating returns during this period. These results are summarized in Table 4.8. below.

***Table 4.8 Summary of the DiD-OLS regression coefficients for a sample including banks.***

| **Period** | **Treatment Group (Low Environmental rating firms)** | **Control Group (High Environmental rating firms)** |
|---|---|---|
| Period 0 | 0.273 | 0.27 |
| Period 1 | 0.141 | 0.167 |
| **Change in Stock Returns** | **-0.132** | **-0.103** |

Based on the table above, real returns of firms with lower environmental ratings were relatively on par with highly rated firms prior to disclosure period. The mean real returns of these firms declined to 0.141 post-disclosure, while the mean real returns of firms with high environmental ratings declined to 0.167, resulting in a lower net change relative to the treatment group. Therefore, the DiD mean results of the two groups are -0.132-(-0.103) = -0.029. Therefore, the effect of disclosure on firms with low environmental performance resulted in a mean decline in returns of 0.03%. The DiD coefficient is significant at the 10% level. Studies of the US firms by Huang et al. (2020) also found a positive relationship between environmental disclosure and stock prices. Similarly, Kumar and Firoz (2022) found this positive relationship in India, a developing country like South Africa.

Climate risk disclosure comprises GHG emission inventories and environmental stewardship performance based on various matrices. Therefore, it is not coincidental that high environmental stewardship and low GHG emitting firms display slightly better stock returns. Liu et al. (2021) found that this environmental stewardship helps build strong relationships and brand equity with key stakeholders. However, it is often not compensated by the market adequately, hence a weaker correlation between environmental performance and stock prices. In another study, although Lu and Taylor (2016) found a good correlation between environmental disclosure and stock performance, there was no correlation between a high rating and stock performance. These findings perhaps explain the weak correlation found in this study between environmental stewardship and stock prices of the sampled JSE firms.

In the next section, we investigate the effect of environmental rating on the stability of stock returns using the standard deviation of the stock returns as a proxy. The control sample for this investigation remains firms with high environmental ratings, and treatment sample comprises firms with low ratings.

## 4.2.(b). Ho: Low environmental rating results in higher stock volatility post-disclosure

The effects of macro-economic control variables on stock volatility are consistent with results established in the analysis of GHG emission impact. We establish that interest rates have a weakly significant negative impact on market stability (or stock returns) after controlling for the time effects. The impact on real GDP growth rate is high but insignificant. We find firm specific variables to be insignificant. Inflation coefficient estimates are significant for all regressions with robust standard errors clustered around the firms.

**4.9a. Effect of Low Environmental rating on stock volatility for the period 2000-2019**

| VARIABLES | (1)<br>OLS | (2)<br>TE-OLS | (3)<br>DiD-OLS | (4)<br>DiD-OLS* |
|---|---|---|---|---|
| lqi1(α') | 0.794*** | 0.796*** | 0.796*** | 0.796*** |
| | (0.155) | (0.156) | (0.156) | (0.028) |
| r_RONA($\beta_4$) | -0.964 | -0.904 | -0.890 | -0.890** |
| | (0.670) | (0.623) | (0.606) | (0.402) |
| r_mgr($\beta_3$) | -0.160 | -0.155 | -0.155 | -0.155** |
| | (0.141) | (0.136) | (0.136) | (0.068) |
| r_int($\alpha_2$) | 1.102 | 3.668* | 3.666* | 3.666 |
| | (2.634) | (1.944) | (1.942) | (2.922) |
| INFL($\alpha_3$) | 4.177 | 1.028 | 1.042 | 8.373*** |
| | (3.185) | (2.654) | (2.653) | (2.375) |
| rgdpgrowth($\beta_2$) | 3.023 | 3.848 | 3.837 | 3.837* |
| | (2.447) | (3.073) | (3.057) | (2.036) |
| Env. dummy($\beta_2$) | 0.069 | 0.068 | 0.041 | 0.041 |
| | (0.051) | (0.050) | (0.038) | (0.081) |
| Time dummy($\beta_1$) | | 0.121 | 0.095 | 0.095 |
| | | (0.117) | (0.092) | (0.118) |
| DiD coeff. (γ) | | | 0.049 | 0.049 |
| | | | (0.078) | (0.111) |
| Constant($\beta_0$) | -0.004 | -0.258 | -0.244 | -0.244 |
| | (0.221) | (0.449) | (0.435) | (0.254) |
| Observations | 1,041 | 1,041 | 1,041 | 1,041 |
| R-squared(adj.) | 0.492 | 0.493 | 0.493 | 0.493 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

The coefficient for environmental performance is positive for stocks with low environmental performance and negative for high performing firms but insignificant across all regression equations. This indicates that before disclosure, the stocks already had a higher volatility in their returns. The time dummy variable coefficient is positive but not statistically significant across all regression models. The results indicate that post disclosure, firms with low environmental performance had a higher mean return standard deviation than firms with higher environmental stewardship. The regression intercept in Table 4.9a is insignificant; thus, it is not possible for any inference to the stock return volatility of the control sample before disclosure. The coefficient estimates of the DiD estimator in column 4 above for both samples are positive but insignificant. However, to demonstrate the logic, we continue demonstrating the changes in stock volatility between the treatment and control groups before and after the disclosure period. The results of this demonstration are summarized in Table 4.9a below.

**4.9b. Effect of High Environmental rating on stock volatility for the period 2000-2019**

| VARIABLES | (1) OLS | (2) TE-OLS | (3) DiD-OLS | (4) DiD-OLS* |
|---|---|---|---|---|
| lqi1(α') | 0.79*** | 0.80*** | 0.80*** | 0.80*** |
| | (0.155) | (0.156) | (0.156) | (0.156) |
| r_RONA($\beta_4$) | -0.96 | -0.90 | -0.89 | -0.89 |
| | (0.670) | (0.623) | (0.606) | (0.606) |
| r_mgr($\beta_3$) | -0.16 | -0.16 | -0.15 | -0.15 |
| | (0.141) | (0.136) | (0.136) | (0.136) |
| r_int($\alpha_2$) | 1.10 | 3.67* | 3.67* | 3.67* |
| | (2.634) | (1.944) | (1.942) | (1.942) |
| INFL($\alpha_3$) | 4.18 | 1.03 | 1.04 | 1.04 |
| | (3.185) | (2.654) | (2.653) | (2.653) |
| rgdpgrowth($\beta_2$) | 3.02 | 3.85 | 3.84 | 3.84 |
| | (2.447) | (3.073) | (3.057) | (3.057) |
| Env. dummy($\beta_2$) | -0.07 | -0.07 | -0.04 | -0.04 |
| | (0.051) | (0.050) | (0.038) | (0.038) |
| Time dummy($\beta_1$) | | 0.12 | 0.14 | 0.14 |
| | | (0.016) | (0.146) | (0.019) |
| DiD coeff. (γ) | | | -0.05 | -0.029 |
| | | | (0.078) | (0.018) |
| Constant($\beta_0$) | 0.06 | -0.19 | -0.20 | 0.270*** |
| | (0.184) | (0.410) | (0.424) | (0.041) |
| Observations | 1,041 | 1,041 | 1,041 | 1,041 |
| R-squared | 0.492 | 0.493 | 0.493 | 0.193 |

Robust standard errors and standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1) for regression 1, 2,3 and 4, respectively. Pooled cross-section with micro-economic effects (OLS) in column (1), including time-variable effect (TE-OLS) in (2), then difference-in-difference effects (DiD-OLS*) in (3) with robust standard errors clustered by the stock, and (DiD-OLS) without robust standard errors clustered by stock in (4).

***Table 4.10 Summary of the DiD-OLS regression coefficients for a sample including banks***

| **Period** | **Treatment Group (Low Environmental rating firms affected by disclosure)** | **Control Group (High Environmental rating firms)** |
|---|---|---|
| Period 0 | -0.203 | -0.244 |
| Period 1 | -0.113 | -0.203 |
| **Change in Stock Volatility** | **0.09** | **0.041** |

The above table indicates that, prior to disclosure period the treatment and control groups mean estimate for standard deviation was -0.203 and -0.244, respectively. The net change post-disclosure amounts to 0.09 and 0.041 for the treatment and control groups, respectively. This change indicates that stocks with high environmental ratings display lower volatility than stocks with low environmental ratings. The difference in the change is 0.049, as indicated by DiD-coefficient in Table 4.10 above. However, this coefficient is statistically insignificant to confirm the hypothesis that stocks with low environmental performance have higher stock volatility on the returns.

# CHAPTER 5: CONCLUSION

This research envisages to examine the impact of climate risk disclosure on market performance and stability in South Africa, based on a sample from JSE listed firms. The study uses stock returns and standard deviation as market performance and stability proxies. Climate risk is explained using two variables: GHG emission intensity and environmental performance rating. Environmental ratings of firms taking part in the CDP disclosure program are based on (1) effective company governance structure to manage climate risk, (2) management of climate risks and opportunities, (3) climate risk targets and initiatives, and GHG emissions accounting for scope 1, scope 2 and scope 3. Panel data collected is analysed using pooled OLS regression analysis, and difference-in-difference method is used to isolate the effect of disclosure on the treatment samples. The model is augmented with real market capitalization growth rate and real return on net assets as firm specific control variables. In contrast, real GDP growth rate, real interest rates, and inflation are used to control for macroeconomic variables applicable to both population groups.

Firstly, we investigate the effect of GHG emission intensity on stock returns and volatility. The control and treatment samples are constructed with low GHG emitting firms (classified as scope 1-3 emissions < 0.5 MT pa) and firms with higher emission inventory, respectively. The original disclosure of climate risk through the CDP started in 2007, but to accommodate a gradual uptake, the disclosure period for this study starts from 1st January 2010. The DiD regression results show high GHG emitting firms to have -0.028% returns than low GHG emitters. The results are valid at the 10% significance level. These results contradict the findings of Bhima and Nhamo (2017) on a sample of JSE listed firms that could not establish this relationship. However, their study found that stock volatility increased in 2013 when the government announced plans to introduce carbon tax. Our findings suggest noted volatility readjusted and normalized as soon as the market disseminated the new information.

Secondly, we investigate the impact of disclosure on stock volatility of high GHG emitting firms. Although the volatility stocks increased post-disclosure, results are not statistically significant to draw any conclusion. This finding contradicts evidence from (Krishnamurti & Velayuthamb, 2018; Hapsoro & Ambarwati, 2018; Bhima & Nhamo, 2017) studies that found stock volatility to often be triggered by policy changes compared to stock returns. Bhima and Nhamo (2017) noted increased stock volatility of high GHG firms upon the government's announcement to introduce carbon tax. The market could have factored in this risk as the new information emerged. With our understanding of the complexity of climate risk, any announcement is expected to create panic in the market before gradually adjusting as clarity increases. Polzin et al. (2019) argue that reducing this ambiguity increases investor confidence about expected returns. As the information asymmetry, knowledge, and understanding of the impact of carbon tax improve investor confidence and forecasting (Buhr, 2017) is expected to mature as the tools to quantify the risk improve (Thomä et al., 2019). This finding explains contradictory findings in this research.

Thirdly, we investigate the impact of high environmental performance on stock returns. This study's control and treatment samples are made of firms with "A and B" and below CDP ratings, respectively. The sample size for this investigation was limited to 55 firms due to available data from the CDP. The DiD mean results of the two groups were -0.029 at 10% significance level. Therefore, the effect of disclosure on firms with low environmental performance resulted in a mean decline in returns of 0.029%, significant at a 10% significance level. Although the results are not highly significant, they seem consistent with previous findings (Huang et al., 2020; Kumar & Firoz, 2022) that both found a positive relationship between environmental disclosure and stock prices in developed and developing countries.

Finally, we investigate the effect of environmental performance on the volatility of stock returns post-disclosure period. The results indicate that although the mean estimate of stock volatility for lowly rated firms increases post-disclosure, the results are not statistically significant enough to draw a conclusive inference. In other studies, although Liu et al. (2021) found that environmental stewardship helps in building strong relationships and brand equity with key stakeholders, the efforts are often not compensated by the market. Hence, there is a weaker correlation between environmental performance and stock prices. The market appreciates increased disclosure but is indifferent about pricing unless brand equity is damaged. Findings are also consistent with Lu and

Taylor's (2016) results, which found a good correlation between environmental disclosure and stock performance but no correlation between a high rating and stock performance.

In conclusion, studies on climate risk disclosure and its associated impact on stock market performance and stability have yielded contradictory outcomes using various research methods. Results have been positive in developed markets with clear and well-defined policies, as the existing climate risk policies and guidelines provide clarity to the investor community. In developing countries where policies are evolving, contradictory outcomes are possible. In South Africa, implementing carbon tax caused market uncertainty before implementation. Therefore, the conclusion drawn from this study is that market stability and performance react to information that has a potential or direct impact on investments.

# CHAPTER 6: POLICY RECOMMENDATIONS

The findings from this study have implications on policy making, funding decisions, insurance pricing, investment decisions, and capital allocation by firms. For policymakers, reduced ambiguity policies reduce market uncertainty and provide investors with adequate information for price changes. In South Africa announcing of a possible carbon tax law in 2013 gave the capital market enough information to process the potential impact on market performance and stability. Hence, firms’ disclosure of climate risk in 2007 had a muted effect on the market stability though returns responded moderately. For insurers, understanding the impact of a high climate risk profile on a firm’s returns help manage and forecast clients’ risk profiles. For managers and boards, the results will guide capital allocation towards climate risk mitigation. Due to a weak link between returns and climate risk in South Africa, managers and boards should optimize capital allocation towards value accretive initiatives to achieve sustainable financial performance.

For the banks and debt financiers, the results guide funding decisions for capital investments. Pricing of the funding for expansionary investment should incorporate the downside risk of a future decline in returns if more stringent climate risk policies are implemented. For example, the withdrawal of carbon tax allowance by the government will sharply increase costs for high GHG emitters with a potential value erosion and increasing risk of default if the credit terms are not adequately adjusted.

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