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Stock return co-movements in ESG investing: An African context

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SCHOOL OF ECONOMICS AND FINANCE
FACULTY OF COMMERCE, LAW AND MANAGEMENT



Stock return co-movements in ESG investing: An African context

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A research report submitted to the Faculty of Law, Commerce and Management, University of the Witwatersrand in partial fulfilment of the requirements for the degree of Master of Commerce (50%) in Finance.

Johannesburg, South Africa

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Stock return co-movements in ESG investing: An African context

Abstract

This study investigates the relationship between Environmental, Social, and Governance (ESG) focused investments, driven by the growing emphasis on ESG within financial markets. The study considers three African markets, which are the only African markets that currently offer dedicated ESG indices. The markets considered are: South Africa, Egypt, and Morocco. The analysis is conducted by examining co-movements between the ESG indices of the selected markets – the FTSE/JSE Top 30 Responsible (J110EP) Index for South Africa, the S&P/EGX ESG (SPEGESGE) Index for Egypt, and lastly the ESG 10 (ESGI) Index (recently named “MASI ESG”) for Morocco. The ESG 10 Index was formed in September 2018 and for that reason, this study considers a sample period ranging from January 2019 to December 2023. Total index return data is extracted from Bloomberg and the Moroccan Stock Exchange. The study tests co-movement through Principal Components Analysis (PCA), using the whole sample, and 12-month rolling window periods to uncover the largest proportion of variation in returns. Secondly, the study examines instances of structural breaks, using the Bai and Perron (2003a) multiple structural breaks tests, aiming to analyse the dynamics in co-movements in these markets. Lastly, the study tests for dynamic co-movement by pairing the indices and estimating the product of their z-scores, with the aim of identifying index pairs with a high number of positive estimates. The results of this study suggest no significant co-movement between the indices, with the exception of critical global crises such as the COVID-19 pandemic and the Ukraine-Russia war. During these events, the indices exhibited extreme co-movement, as expected, due to market downturns. Outside of these crises, no notable co-movement was observed, suggesting that ESG investors are not disadvantaged by focussing on ESG stocks.

Declaration

I, Chuma Mpelane, declare that this research paper is my own work and that I have correctly acknowledged the work of others. It is submitted to fulfil the requirements for the degree of Master of Commerce in Finance at the University of the Witwatersrand, Johannesburg. I declare that this research paper has not been submitted for any other degree or examination in this or any other institution.

Chuma Mpelane

February 2025

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Definition of abbreviations, terms and symbols

Ceres : Coalition for Environmentally Responsible Economies

CFP: Corporate Financial Performance

CSR: Corporate Social Responsibility

EGX: The Egyptian Exchange

EPS: Earnings Per Share

ESG: Environmental, Social and Governance

ESGI: MASI ESG Index

GRI: Global Reporting Initiative

IPCC: Intergovernmental Panel on Climate Change

IWF: Investible Weight Factor

J110EP: FTSE/JSE Responsible Top 30 Index (J110)

JSE: The Johannesburg Stock Exchange

MODWT: Maximal Overlap Discrete Wavelet Transform

MPT: Modern Portfolio Theory

PRI: Principles for Responsible Investment

ROA: Return on Assets

SASB: Sustainable Accounting Standards Board

SPEGESGE: S&P/EGX ESG Index

SRI: Socially Responsible Investing

UNEP: United Nations Environment Program

WMC: Wavelet Multiple Correlation

1. | INTRODUCTION

1.1 | Background

In the last few years, the performance of companies on ESG metrics has garnered global attention across investors, researchers, finance professionals and policymakers. According to Koundouri, Pittis, and Plataniotis (2022), business leaders worldwide have begun to recognize that beyond effectively managing their capital, it is necessary to implement transparency regarding internal governance, and to increase business responsibility and accountability to society. Environmental factors pertain to an organization's environmental impact and risk mitigation practices, the social factor refers to a company's relationship with its stakeholders, including the community in which it operates. Governance factors look at how the firm is led and managed, and consider corporate governance factors such as shareholder rights, board management practices and executive compensation. Investing with ESG considerations is often referred to as responsible investing, or impact investing. ESG involves the integration of non-financial elements into corporate strategy and decision-making, and Koundouri, Pittis, and Plataniotis (2022) further argue that while ESG factors are non-financial, they can have major financial implications.

The increasing interest towards ESG has led to a vast amount of research¹ on the impact of ESG considerations on firm performance, in an effort to examine the validity of the concerns around a tradeoff between ESG investing and profitability (McWilliams & Siegel, 2000). Despite this growing body of literature, there generally has been no consensus on the relationship between ESG and firm financial performance - some studies such as Nollet, Filis, and Mitrokostas (2016), and Garcia and Orsato (2020) argue that ESG hinders financial performance, whereas the likes of Eccles, Ioannou, and Serafeim (2014) suggest that it enhances firm performance. Hornuf and Yüksel (2023) report that ESG has no influence whatsoever on firm performance. This is one component of the literature on ESG. This study builds on the ongoing ESG research by considering another component that has not garnered as much traction. This study examines the interrelations between the returns of ESG stocks,

¹ For instance, McWilliams and Siegel (2000), Caplan, Griswold, and Jarvis (2013), Friede, Busch, and Bassen (2015), Velte (2017), Xie, Nozawa, Yagi, and Fujii (2019), Chen, Song, and Gao (2023). These studies are elaborated upon in the literature review in Section 2.

and the implications thereof. Understanding the co-movements in stock returns is crucial for investors as this has implications for their portfolio risk. Portfolio theory asserts that the benefits of diversification are realized only if the assets in a portfolio have negative or near-zero correlations with each other. Therefore, if ESG stock returns demonstrate high correlations, investors may face challenges obtaining optimal diversification, leading to increased portfolio risk.

Literature that examines co-movements of stock returns from the lens of ESG is generally almost non-existent. A study relating to the co-movements of ESG stock returns was conducted by Kacperczyk, Lin, and Jing (2023) in the United States of America. They investigated whether the increased focus on ESG by leading asset managers would create a clientele effect, and whether it influences the co-movement of stock returns. They hypothesized that the diversity in investors' motives for ESG investing leads to a clientele effect, which in turn results in higher return co-movements among stocks with similar ESG characteristics. The finding was that the stock returns of firms with improved ESG scores exhibited significantly greater co-movement with the returns of other high ESG-stocks, and less co-movement with low-ESG stocks.

The phenomenon of ESG has been studied to a much greater extent in South Africa. Erasmus, Viviers, and Mans-Kemp (2017) found that there was a significant positive relationship between corporate social responsibility (CSR) and accounting-based earnings per share (EPS) and return on assets (ROA). A significant negative correlation was also found between CSR and market-based total shareholder return. Muzanya (2022) found a statistically significant negative relationship between ESG and corporate financial metrics in South Africa. Evans, Kramer, Lanfranchi, and Brijlal (2023) examined the relationship between ESG factors and the performance of mining companies in South Africa, they found that there was no statistically significant relationship between the total ESG score and firm performance – only the Governance score had a statistically significant relationship with firm performance. Different sub-components of the governance factor were significantly positively and negatively related to firm performance. On the other hand, Chininga, Alhassan, and Zeka (2023) found that investment in ESG initiatives enhances both accounting-and-market-based indicators of financial performance, with the environmental pillar being the most effective. Therefore, the valuation of ESG and firm financial performance in South Africa, similar to rest of the world, has not produced conclusive results.

1.2 | Research gap and objectives

This study examines the relationship in the returns of ESG-focused investments in three African markets, namely; South Africa, Egypt, and Morocco. These are the only African markets with dedicated ESG indices currently. By identifying potential co-movements, this study aims to assess the implications for portfolio diversification among ESG investors in Africa. Specifically, the research determines whether the returns of ESG indices move together, potentially limiting the diversification benefits for investors in ESG-focused portfolios.

Investors worldwide are becoming increasingly interested in aligning their portfolios to their beliefs and norms. Some investors desire to drive social and environmental change through their capital (Giese, Lee, Melas, Nagy, & Nishikawa, 2019). This study therefore seeks to answer the following question: If an ESG investor desired to invest their funds across African markets, would they have a diversification problem? High co-movements will imply that there is a diversification problem for ESG investors in Africa, which further implies increased portfolio risk for these investors.

1.2.1 | Motivation of the study

According to Auer and Schuhmacher (2016), investors are increasingly concerned not only with the monetary gain on their investment, but they also seek non-financial satisfaction derived from holding portfolios that align with their personal and societal values. While socially responsible investing (SRI) has long been established, the growing attention to environmental, social, and governance (ESG) factors is shaping investment decisions. This study considers the relationship between the returns of ESG stocks and seeks to investigate whether there are any co-movements in these returns. Co-movements in these returns imply that ESG-focused investors have a diversification problem (i.e., if returns move in lockstep, spreading investments across these markets could be to the investors' detriment). This study therefore examines whether ESG-focused investors face such a diversification challenge within an African context. Investors who seek to optimize risk-adjusted returns should ideally choose from the broad universe of assets. However, ESG investing does not include assets that fail to meet the required sustainability criteria, leaving ESG investors with only a fraction of the universe of assets to include in their portfolios (Hornuf & Yüksel, 2023). This assumes that ESG-focused investors restrict themselves to ESG-compliant stocks, driven by their commitment to

sustainable and socially responsible investing. Under these conditions, it is therefore critical to have an understanding of the relationship between the returns of these assets.

1.2.2 | The knowledge gap

As highlighted earlier, existing literature has devoted significant attention to the financial performance of socially responsible investments. A vast amount of literature (such as Barberis, Shleifer, and Wurgler (2005), Morgado and Tavares (2006) and Bekaert, Hodrick, and Zhang (2009)) has also examined the general co-movements in stock returns. There is a notable gap in literature linking the two components, that is, research regarding the interrelationships between the stock returns of socially responsible investments, which has propelled this study. With the accelerated popularity of ESG over the recent years, and the well-known importance of diversification to investors, one would expect the topic of co-movements in the stock returns of ESG adhering firms to be of particular interest. The relationship between these stock returns has significant implications for socially responsible investors. This study therefore fills the knowledge gap in literature by extensively examining this relationship in three African stock markets, for ESG investors who wish to invest their funds across African markets.

1.2.3 | Potential benefits

The results of the study have major implications for finance professionals and researchers alike. The study aids ESG investors who wish to invest in African markets, by providing clarity on whether they will be increasing their portfolio risk by investing in these markets. This study will be beneficial to the body of knowledge in that it will open room for further research on the relationship between the returns of ESG stocks. Future researchers can delve deeper into the extent of the co-movements between these returns and potential implications for diversification. Portfolio managers who look after ESG portfolios can be enlightened on the interrelationships between the returns of the assets they manage, thereby enabling them to make better investment decisions.

The importance of diversification is well-known in the field of finance. In his foundational paper, Markowitz (1952) highlights how diversification can reduce the risk of a portfolio – by holding a diversified portfolio, investors can achieve a desired return with the least amount of risk. This study has diversification implications for socially responsible investors. If the study

finds that ESG investors indeed face a diversification problem in Africa, it suggests a need for new portfolio strategies or broader asset inclusion to achieve effective diversification, especially as sustainable investing continues to grow globally.

1.2.4 | Hypothesis testing

The hypotheses pertaining to the objectives of this study are stated below:

H0: *There is no statistically significant co-movement between the returns of South African, Moroccan, and Egyptian ESG indices.*

The null hypothesis implies that there are diversification opportunities for ESG investors interested in investing across African markets. It suggests that the returns of stocks or portfolios in these markets are not highly correlated, and combining investments from these markets does not result in increased portfolio risk.

H1: *There is a statistically significant co-movement between the returns of South African, Moroccan, and Egyptian ESG indices.*

The alternative hypothesis in this study suggests that the returns of ESG stocks in the markets considered are highly correlated and exhibit high co-movements, implying that ESG investors looking to invest in African markets have limited diversification opportunities and increased portfolio risk.

1.3 | Structure of the study

The remainder of this report is structured as follows: Chapter 2 provides a review of the literature on ESG, Chapter 3 describes the data and methodology to be used in the study, Chapter 4 provides and discusses the results of the study, and Chapter 5 concludes the study.

2. | LITERATURE REVIEW

This chapter explores the evolution of ESG, beginning with its origins in SRI, a value-driven approach that laid the foundation for today's data-centric ESG frameworks. Following this historical overview, the review examines the relationship between ESG and firm financial performance, shedding light on the financial implications of adopting sustainable practices by exploring literature that reports a neutral relationship, a negative relationship, and a positive relationship between the two concepts. Finally, the chapter reviews literature that has examined co-movements in stock returns, aiming to highlight factors that the observed co-movement has been attributed to.

2.1 | From SRI to ESG

Caplan, Griswold, and Jarvis (2013) state that responsible investing can be broadly categorized into three main types; the first of which is traditional SRI, which is a portfolio construction approach that excludes certain stocks or industries using negative screening based on specific ethical criteria. The second category is Impact Investing, which is focused on directing investments into projects or companies with the explicit aim of driving social or environmental change aligned with a mission. The last is ESG investing, which involves incorporating ESG factors into fundamental investment analysis, prioritizing their relevance to investment performance. For a significant period, SRI was the most commonly adopted approach among the three.

The origins of socially responsible investing trace back to the colonial era in the U.S., when certain religious groups chose not to invest their endowment funds in the slave trade. However, it wasn't until the 20th century that SRI emerged as a distinct investment philosophy. In 1921, the Pioneer Group launched the first mutual fund to exclude investment in tobacco, alcohol and gambling (Caplan, Griswold, & Jarvis, 2013). Traditional SRI was significantly shaped by the transformative 1960s and 1970s, a period that is marked by the growth of anti-war movement and the establishment of movements focused on racial equality, women's rights, consumer protection, and environmental issues.² Townsend (2020) states that a combination of religious

² Activists began advocating for divestment from companies involved in the production of weapons and military supplies, particularly those tied to the Vietnam war.

values with these progressive ideals laid the foundation for socially responsible investing, and by the 1970s, this fusion resulted in the establishment of the first mutual funds that embodied religious values, civil rights perspectives, and environmental concerns.³ Investors started actively excluding companies associated with activities they considered unethical, such as tobacco, firearms, or companies that operated in apartheid South Africa. According to Caplan, Griswold, and Jarvis (2013), the fight against apartheid in South Africa gave rise to the first investment funds that excluded companies operating in specific countries. This approach sparked an ongoing debate about whether exclusionary investing accelerates the downfall of unjust systems or hinders progress by prompting companies to withdraw, potentially slowing economic growth and impeding the progress of reform.

SRI was originally driven purely by individual investor principles and values, and not by quantitative validation as it has evolved to be. The core principle of traditional faith-based investing, and to some extent traditional socially responsible investing, was to exclude products or industries that contradicted specific moral values. As would one would expect, by 1970, incorporating any “social” criteria into investing was widely considered contrary to conventional wisdom, and traditional socially responsible investing faced more criticism than support (Townsend, 2020). Many scholars adopted the perspective by Friedman in his 1970 article, *The Social Responsibility of Business is to Increase its Profits* – this has resulted in the ongoing debate about whether ESG investing hinders the financial performance of a firm. This perspective aligned with Modern Portfolio Theory (MPT) of Markowitz (1952); a core principle of MPT was that restricting the investment universe for any reason was fundamentally opposed to rational investing practices.

Over time, SRI focus shifted from simply avoiding investments in industries or companies that did not align with moral and ethical standards, to a more comprehensive approach that considers a broader range of factors. The emergence of ESG as distinct from SRI can be understood through the financial market dynamics outlined in the work of Heinkel, Kraus, and Zechner (2001). Their study offers a theoretical model that demonstrates the effects of

³ In 1971, the Pax World Balanced Fund was established, the fund offered religiously motivated investors an opportunity to avoid direct investment in the supply chains associated with “Agent Orange”, a chemical weapon used during the Vietnam War to destroy forests and crops, causing severe environmental health impacts.

exclusionary screening by investors on stock prices, expected returns, and corporate behaviour. The authors find that when a significant proportion of investors exclude polluting companies, the reduced demand for these firms' shares leads to a decline in their stock prices. This decline raises the cost of capital for the excluded companies, requiring them to offer higher expected returns to attract conventional investors. Conversely, "green" companies that meet environmental standards benefit from increased demand for their stocks, which results in lower expected returns due to higher stock prices. Through their study, Heinkel, Kraus, and Zechner (2001) highlighted the mechanisms through which responsible investing can influence corporate behaviour. By the mid-2000s, there were three primary factors that fuelled the demand for analysis on ESG issues by large investors, which Townsend (2020) refers to as "catalysts". The author states that innovation in the SRI market is typically driven firstly by a strong intellectual and legal discussion regarding the connection between fiduciary duty and sustainability issues, the second catalyst is climate change, and the last is an acceptance of the idea that inadequate corporate governance negatively impacts markets.

2.1.1 | Corporate governance

The subprime mortgage crisis and the subsequent global financial crisis (GFC), alongside climate change, were key catalysts that highlighted the importance of ESG research. Poor governance and unethical behaviour, such as those seen in the subprime mortgage market, had devastating financial consequences. The complexity and opacity of capital markets, along with a lack of oversight, led to widespread financial damage. This crisis, like previous ones such as the Enron and WorldCom scandals,⁴ exposed the need for transparency, accountability, and better risk assessment frameworks. The fallout from the crisis, including massive losses and government intervention, emphasised the need for ESG analysis to address risks related to corporate behaviour and governance. The crash also showed that traditional investment analysis was inadequate for assessing such risks. The global pandemic further underscored the

⁴ In 2001, Enron Corporation, a major energy company, filed for bankruptcy after it was revealed that the company had engaged in massive accounting fraud. The company used complex financial structures to hide debt and inflate profits, misleading investors and regulators, leading to significant financial losses. Similarly, in 2002, WorldCom, a telecommunications giant, collapsed after it was discovered that the company had overstated its assets by over \$11 billion through accounting fraud, i.e., misclassifying expenses as capital investments to inflate earnings. This scandal resulted in one of the largest bankruptcies in U.S history and further emphasized the need for corporate governance reforms.

need for companies to consider their roles and responsibilities beyond just shareholders, emphasizing the continued relevance of ESG in evaluating long-term investment performance.

Today, investors have access to more advanced tools for evaluating corporate disclosure, corporate governance practices and environmental risks, and this broadens the appeal of modern SRI. Townsend (2020) states that ESG has achieved what SRI could not: it has bridged the gap between mainstream investing and socially responsible approaches. The modern SRI process is built on three foundational pillars that combine traditional and contemporary elements: values-based exclusionary screens, reflecting the principles of traditional North American SRI; proactive analytics centred on sustainability, aligning with the principles of ESG investing; and corporate engagement and impact investing, focusing on driving measurable social and environmental change.

2.1.2 | Climate change

The second major driver of ESG investing – climate change – gained attention as early as the 1980s when climate scientists raised alarms about rising global temperatures caused by fossil fuel emissions. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established to address these concerns. That same year, NASA scientist James Hansen testified to the U.S. Congress, linking greenhouse gases to global warming. The 1989 Exxon Valdez oil spill acted as a turning point, sparking collaboration between environmental groups and socially responsible investors. Joan Bavaria, an SRI advocate, spearheaded the formation of the Coalition for Environmentally Responsible Economies (Ceres), which introduced the Valdez Principles – later simply known as Ceres Principles – promoting corporate environmental accountability. Ceres brought together NGOs, institutional investors, and SRI advocates to push for increased transparency on environmental impacts. This laid the foundation for frameworks like the Global Reporting Initiative (GRI) and the 2018 Sustainable Accounting Standards Board (SASB) standards, which emphasised both transparency and industry-relative performance (Townsend, 2020). Today, sustainability reporting is mainstream, with 93% of the world's largest 250 companies disclosing information on their environmental practices, reflecting the growing influence of ESG principles in addressing climate change.

2.1.3 | Fiduciary duty

According to Townsend (2020), the United Nations Environment Program (UNEP) collaborated with the financial services sector to promote “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. This concept had been evolving for decades, reflecting themes echoed earlier in U.S. President Dwight Eisenhower’s 1961 farewell address, where he urged society to resist the temptation to prioritize immediate convenience at the expense of depleting future resources. In 2005, UNEP commissioned a groundbreaking report from the London-based law firm Freshfields Bruckhaus Deringer to address whether incorporating ESG factors into investment decisions was voluntarily allowed, legally mandated, or restricted by existing laws and regulations. The report examined the standardised fiduciary duty laws across seven major developed markets, including the U.S, the UK, Germany and France. It was determined that integrating ESG factors was not only aligned with fiduciary duty but that failing to address these long-term risks could potentially constitute a breach of it. This finding eliminated a significant barrier to the expansion of ESG investing.

2.2 | ESG and firm financial performance

Caplan, Griswold, and Jarvis (2013) state that the connection between ESG factors and investment performance was formally established by the United Nations in 2006 by introducing the Principles for Responsible Investment (PRI), a voluntary framework for investors. Unlike approaches that exclude companies with subpar environmental, social, or governance practices, the PRI encourages investors to consider ESG factors when they are relevant to the financial performance of a portfolio. Investors are advised to evaluate ESG issues alongside traditional risk and opportunity indicators during the investment decision-making process and to actively engage with companies and managers post-investment to address important ESG risks and opportunities. The PRI highlights that the impact of ESG considerations on a firm’s investment process is constantly changing, noting that ESG issues can affect the performance of investment portfolios to different magnitudes across companies, sectors, regions, asset classes, and over time.⁵ It also emphasizes that incorporating ESG considerations into core investment analysis aligns with traditional investment principles.

⁵ See Principles For Responsible Investment (n.d.). Retrieved December 19, 2024, from <https://www.unpri.org/about-us/what-are-the-principles-for-responsible-investment>.

Early research indicates that incorporating ESG considerations into fundamental investment analysis may enhance performance, though definitive conclusions have yet to be established. Critics of ESG integration often reference the efficient market hypothesis, which suggests that all available information about prospective investments is quickly absorbed and incorporated in asset prices. The argument is that if ESG factors were genuinely significant, they would already be a standard component of most investors' evaluation processes. Proponents of ESG argue that if the efficient markets hypothesis functioned as its advocates suggest, there would be no advantage in selecting companies with strong ESG attributes. They contend that the current opportunity lies in the fact that ESG analysis has yet to be fully incorporated into mainstream investment practices. As techniques for determining which ESG factors are genuinely material to specific investments become more sophisticated, more insightful studies on the effects of integrating ESG considerations into portfolios are expected to emerge.

Friede, Busch, and Bassen (2015) state that the investigation of the link between SRI and corporate financial performance (CFP) traces as far back as the 1970s during the emergence of SRI. According to Giese, Lee, Melas, Nagy, and Nishikawa (2019), existing literature on this relationship has been inconclusive – researchers have found non-existent, positive and negative correlations between ESG and financial performance as will be outlined in this subsection. Whelan, Atz, and Clark (2022) suggest that these inconclusive results may be largely due to the lack of standardization with ESG data - Caplan, Griswold, and Jarvis (2013) attest to this, stating that the relatively poor quality of ESG data reported by companies is a challenge. They state that the lack of consistent standards and uniform reporting methods makes it challenging for investors to confidently compare different investments. Standardized reporting frameworks are increasingly being advocated for, to enhance the reliability and quality of the data, which is essential for assessing risk and materiality. McWilliams and Siegel (2000) attribute the inconsistency in findings to flawed empirical analysis.

2.2.1 | Neutral relationship

In their model, McWilliams and Siegel (2000) control for investment in Research and Development (R&D) and find that when the model is properly specified, corporate social responsibility has a neutral impact on financial performance. Schroder (2004) investigated the performance of socially responsible investment equity funds in the United States, Germany, and Switzerland, as well as the performance of prominent SRI equity indices such as the Domini 400 Index (now known as the MSCI KLD 400 Social Index). The study found that

socially responsible investments exhibit no clear disadvantage regarding their performance in comparison to conventional investments, their risk-adjusted performance is comparable to conventional assets. Renneboog, Te Horst, and Zhang (2008) proceed to compare the alphas of SRI funds with those of corresponding conventional funds, and they also find that there is no statistically significant evidence to suggest that SRI funds underperform their conventional counterparts in most countries. This view is shared by Auer and Schuhmacher (2016) in their study that investigated the performance of socially (ir)responsible investments in the Asia-Pacific region, Europe and the United States. They found that regardless of geographic location, industry sector or specific ESG criteria, actively selecting high or low ESG rated stocks does not generate superior risk-adjusted performance when compared to passive stock market investments. Europe being the only exception, they also found that investors who wish to derive ethical satisfaction from their portfolios can adopt an ESG-focused investment approach and still obtain a comparable performance to the overall broad market. Xie, Nozawa, Yagi, and Fujii (2019) also report a nonnegative relationship between ESG and corporate financial performance. A study by Hornuf and Yüksel (2023), which conducted a meta analysis to investigate the performance of SRI, incorporating the most recent publications, found that SRI neither outperforms nor underperforms the market portfolio, further supporting the idea that socially responsible investing does not impact firm financial performance.

2.2.2 | Positive relationship

Despite findings of a neutral relationship between ESG and firm financial performance, a significant number of studies have reported a positive relationship between ESG and financial performance. Eccles, Ioannou, and Serafeim (2014) examine the long-run effects of corporate sustainability on organizational processes and performance, they find that high sustainability companies show significant outperformance in comparison to their counterparts over the long-term, both in accounting and stock market performance. This result is of the view that ESG compliant stocks demonstrate considerable outperformance. The finding is corroborated by Friede, Busch, and Bassen (2015), who in their academic review of 2200 studies find that a significant number of these studies report a positive relation between ESG and firm financial performance. Velte (2017) studies the relation on a sample selection of companies listed on the

German Prime Standard⁶, the study finds that ESG has a positive impact on ROA, further supporting the idea of a positive relationship between ESG and financial performance. Ahmad, Mobarek, and Roshni (2021) revisit the impact of ESG on the financial performance of UK firms. Their findings show that high ESG firms demonstrate high financial performance compared to low ESG firms. In their review of over 1000 studies published between 2015 – 2020, Whelan, Atz, and Clark (2022) found that majority of the studies found persistent positive correlations between ESG and corporate financial performance. Bruna, Loprevite, Raucci, Ricca, and Rupo (2022) use a time-lagged panel regression model to examine the effect of ESG on firm financial performance, their study finds evidence for a positive and significant effect. Chen, Song, and Gao (2023) also report that ESG performance is positively correlated to corporate financial performance.

2.2.3 | Negative relationship

Among studies that have uncovered a negative relationship between ESG and financial performance, Lee, Faff, and Langfield-Smith (2009) reported a negative association between corporate social performance (CSP) and corporate financial performance (CFP) in their market-based tests, while accounting-based tests indicated no significant relationship. They suggested that the negative market-based CSP/CFP relationship might reflect that leading CSP firms trade at a price premium, signalling that financial markets value CSP and are prepared to accept lower returns. In contrast, Nollet, Filis, and Mitrokostas (2016) found a negative relationship between corporate social responsibility (CSR) and CFP based on accounting measures. In developing markets, Garcia and Orsato (2020) observed that ESG negatively impacts key financial indicators such as Return on Assets (ROA) and Free Cash Flow. Giannopoulos, Kihle-Fagernes, Elmarzouky, and Afzal-Hossain (2022) also identified a significant negative relationship between ESG initiatives and ROA in Norwegian listed firms. According to Whelan, Atz, and Clark (2022), such findings have led to arguments that ESG is, at best, a distraction to the primary goal of generating profits.

⁶ The German Prime Standard is a market segment of the Frankfurt Stock Exchange (FSE) that requires companies to meet stricter transparency and disclosure requirements compared to the General Standard. These enhanced standards aim to attract international investors by ensuring greater accountability and more comprehensive reporting.

In the context of South Africa, Nkomani (2013) conducted a comparative analysis of the financial performance of companies that were either members or non-members of the Socially Responsible Investment Index from 2002 to 2011. The findings of the study suggested a significant negative relationship between membership in the SRI Index and accounting-based ROA. Chetty, Naidoo, and Seetharam (2015) found no significant difference in firm financial performance as a result of CSR activities. Sayed (2018) also found no significant correlation between ESG compliance and financial performance. Johnson, Mans-Kemp, and Erasmus (2019) found that most of the significant relationships between ESG and CFP became evident only after the composite ESG disclosure score was separated into its individual components (E-, S-, and G-scores) and distinctions between sectors were accounted for. Their study found no significant relationship between the composite ESG disclosure score and accounting-based earnings per share (EPS), however, a statistically significant negative relationship was found between the E-scores and EPS, and a significant positive relationship between the S-scores and EPS. They found no significant relationship between the G-scores and CFP. This implies that the different ESG components interact with CFP in unique ways, and that the impact of ESG initiatives varies depending on the specific industry and the distinct ESG factors considered. As outlined above, majority of the focus on ESG literature has been on the relationship between ESG and firm financial performance, none of the literature has delved into the interrelationships between ESG stock returns, which is what this study aims to highlight.

2.3 | Co-movements in stock returns

The analysis of co-movements between stock returns is central to finance and has recently garnered significant attention across various disciplines, particularly in international finance. In their study which aimed to investigate the observed increase in co-movement across national stock markets since the mid-1990s, Brooks and Del Negro (2004) found that the increased co-movement was a temporary phenomenon linked to the dot-com bubble, rather than a permanent shift caused by global integration. They suggested that diversifying across countries would therefore still remain an effective strategy for reducing portfolio risk. However, Morana and Beltratti (2008) conducted an empirical evaluation of the interconnectedness among the major global stock markets: the United States, the United Kingdom, Japan and Germany. Their findings indicate a gradual integration of the four stock markets, resulting in heightened co-movements in prices, returns, volatilities, and correlations. A positive relationship between volatility and correlation is observed, along with a consistent upward trend in correlation

coefficients over time. The co-movement appeared particularly strong between the US and European markets, whereas Japan's stock market showed more unique behaviour, potentially due to the prolonged stagnation and weak fundamentals during the 1990s. Bekaert, Hodrick, and Zhang (2009) investigate international stock return co-movements using country-industry and country-style portfolios, and their results reveal no general upward trend in return correlations, apart from European markets, and show that the dominance of industry factors over country factors was short-lived. Additionally, they observe that large growth stocks exhibit higher cross-country correlations than small value stocks, with this difference increasing over time. Rua and Nunes (2009) examine international co-movement of stock returns using wavelet analysis. They consider the United States, Germany, United Kingdom and Japan. A key insight from their study is that the intensity of international stock return co-movements varies with frequency. Specifically, co-movements are stronger at lower frequencies, indicating that the advantages of international diversification may be significant over the long term compared to the short term. Consequently, they suggest that an investor's time horizon - whether short-term or long-term – should be considered when addressing the challenges of international portfolio diversification. Inaba (2020) investigates the trends and factors influencing the reliance of stock returns on underlying global factors across 37 advanced and emerging countries between 1996 and 2015, the author found increasing timetrends in dependence for most countries and globally, indicating a steady rise in international stock market integration and a gradual reduction in the potential benefits of international portfolio diversification. They also found that integration was higher in advanced countries compared to emerging countries but progressed more rapidly in emerging markets, highlighting their growing appeal for investment. These findings on international stock return co-movements suggest that the co-movement is complex and varies across contexts. The variation in co-movements across frequencies indicates that the benefits of international diversification are time-sensitive, offering greater advantages to long-term investors. Additionally, the observed co-movement of large growth stocks across countries implies that stock characteristics also play a significant role. While co-movements are more pronounced in certain regions, particularly between the U.S and Europe, they have become more widespread across major global markets. This trend suggests that the potential benefits of international diversification have diminished as markets have become more interconnected.

Siyou and Bene (2023) identify two main strands of co-movement theory in finance literature, since the recent financial crises. One line of research has concentrated on economic and financial events, investigating whether these are transmitted from one country's stock market to another, and how they are transmitted. In-line with this first strand of literature, studies such as that of Siyou and Bene (2023) have examined the co-movement in the returns of six African stock markets, including South Africa. Their results show strong co-movement among the selected African markets, with South Africa and Botswana exhibiting the highest co-movement. The other line of literature focuses on portfolio diversification. In South Africa, studies in this line of research include a study by Ocran and Mlambo (2009), who studied excess co-movement in asset prices between 1995 and 2005. They found that there were co-movements in the returns of equities and bonds, suggesting a significant presence of noise traders in the South African market. Their findings support the idea that market volatility in the two asset classes may be influenced by fad behaviour or crowd psychology. These findings have implications for institutional investors in South Africa, as most of their asset allocation is between equities and bonds. This study follows the two lines of literature by examining co-movements in stock returns in Africa, particularly in ESG indices, as these co-movements have major implications for portfolio diversification.

Literature has attributed the observed co-movements in stock returns to various factors. According to Barberis, Shleifer, and Wurgler (2005), the correlation between stocks may be induced by behavioural factors. Morgado and Tavares (2006) examined the determinants of stock return co-movements across 40 developed and emerging markets. They found that trade intensity results in an increased correlation between stock returns, whereas real exchange rate volatility, output growth asymmetry, and differences in export patterns reduce it. Zebedeea and Kasch-Haroutounian (2009) analysed the conditions that lead to intra-day co-movements of asset returns. Their findings suggest that these co-movements are a function of asymmetric information. According to Coleman, Vitor, and de Medeiros (2018), in the existing literature, factors such as geographical proximity, financial connections, and trade relationships have been identified as possible reasons for the co-movement of stock markets. In their analysis of intra-market return co-movements, Parsley and Popper (2020) find that intra-market return co-movements can be attributed to the stability of international macroeconomic trilemma

policies⁷, the frequency of crises and the level of turnover, as opposed to factors such as country risk, investor policies and investor protection. This study examines the existence (or lack of) co-movements between ESG indices in Africa, and whether these co-movements can be attributed to ESG-related factors.

⁷ The “international macroeconomic trilemma” refers to the economic principle that a country cannot simultaneously achieve free capital mobility, a fixed exchange rate, and independent monetary policy. It must forgo one, as pursuing all three is impossible. Policies addressing this trilemma play a significant role in shaping international macroeconomic stability, influencing exchange rates, capital flows and financial crises.

3. | DATA AND METHODOLOGY

3.1 | Data

The three African stock markets considered in this study are the only markets with dedicated ESG indices currently, these are also in the top 10 African markets ranked by market capitalization as of May 2024.⁸ The stock markets considered are the Johannesburg Stock Exchange (JSE) located in South Africa, the Casablanca Stock Exchange (MASI) in Morocco, and the Egyptian Exchange (EGX) in Egypt. Total monthly return index values with gross dividends for the South African and Egyptian ESG indices are obtained from Bloomberg for the period January 2019 to December 2023, resulting in a total of 60 observations for each index. Total return index values with gross dividends and closing prices in this study are used interchangeably going forward. The data for the Moroccan ESG index is obtained from the Moroccan Stock Exchange, as it is unavailable on the Bloomberg database. Total return data is used because it provides a more comprehensive and accurate view of an investment's performance, as it accounts for all sources of return. This is important for this study as the study is a comparative analysis - total return data results in more accurate comparisons. The data is extracted from January 2019 due to the Moroccan ESG Index only being introduced in 2018.

For South Africa, the study extracts total return index values of the FTSE/JSE Responsible Top 30 Index (J110)⁹. The FTSE/JSE Responsible Top 30 Index is an equally-weighted index on the Johannesburg Stock Exchange (JSE), that consists of the top 30 companies as ranked by the FTSE Russell ESG rating. The constituents of the index are primarily determined by the total score of FTSE Russell's ESG Data Model. The ESG scores evaluate firm ESG risk and performance by assessing both its impact on the external environment and its vulnerability or ability to withstand ESG-related risks. Each firm is given a total ESG score that is between 0 and 5, where 5 represents the maximum score. This index serves as a valuable tool for investors to identify companies who demonstrate strong ESG practices, and acts as a benchmark for

⁸Daba Finance (2024). Retrieved July 13, 2024, from <https://dabafinance.com/en/learn/blogs/the-largest-stock-exchanges-in-africa-by-market-capitalization>.

Daba Finance is an investment platform that allows users to invest in Africa and emerging markets. It offers a variety of investment options, including stocks, bonds, private credit, and venture investments. The platform also provides tools to help users discover, track, and analyse investment opportunities.

⁹ J110 is the ticker symbol for the FTSE/JSE Responsible Top 30 Index on the Johannesburg Stock Exchange.

companies that seek to enhance their ESG efforts. According to the Johannesburg Stock Exchange (2024), the index was created in 2015, along with the FTSE/JSE Responsible Investment Index (J113) through a collaboration of the JSE with the FTSE Russell to advance the JSE's efforts in advocating for corporate sustainability activities. Before the index was created, the JSE had already been actively involved in encouraging sustainable and transparent business practices, through the Socially Responsible Investment Index (SRI Index) which then evolved into the two indices mentioned.

The Moroccan ESG index considered is the ESG 10 Index (ESGI), introduced in September 2018. This index is ESG score weighted, and previously consisted of 10 stocks with the highest ESG rating as ranked by Moody's ESG Solutions to companies listed in MASI. The index has recently adjusted its stock composition to 15 stocks with the highest total scores published by the agency (Yonga, 2023). This index is also called the "MASI ESG" index. The ESG index considered for Egypt is the EGX ESG Index, referred to as the S&P/EGX ESG Index (SPEGESGE)¹⁰ formed in 2010. The index constituents are also ESG score weighted, i.e., each company's weight in the index is determined by dividing its ESG score by the total sum of ESG scores for all the index constituents. The index was formed through a collaboration of S&P Dow Jones Indices with EGX and consists of 30 companies listed on the Egyptian Exchange. According to S&P Global (2024), in order for a company to be included in the index, it must meet the following criteria: 1, The company must be based in Egypt. 2, The company must achieve a minimum ESG qualitative score of 90. 3, The company is also required to have an Investible Weight Factor (IWF) that is greater than zero. EGX conducts the research, calculation and management of the ESG scores, while the S&P Dow Jones Indices provides the framework for defining the relevant ESG criteria, as well as the development and calculation of the index (S&P Global, 2024)

The size and liquidity of these ESG indices should be carefully considered when interpreting the results of this study. The South African and Egyptian ESG indices benefit from a larger number of constituents compared to the Moroccan ESG index, and therefore greater sectoral diversity. This constraint may increase sensitivity to individual securities, affecting observed correlations and structural breaks. Future studies may consider aggregating smaller indices or incorporating additional sectoral metrics to enhance robustness.

¹⁰ SPEGESGE is the ticker symbol for the S&P/EGX ESG Index.

3.2 | Methodology

The first method used in the study is the Principal Components Analysis (PCA). The entire sample is examined using the PCA, and thereafter, 12-month rolling window periods are used, this allows the capturing of both the monthly dynamics, as well as more extended co-movement patterns. Using rolling window periods tests whether convergence is specific to certain periods or increasing over time. The total monthly returns for the indices are calculated using the Gross Total Return (TR) index data, which includes both price changes and reinvested dividends. The total monthly return for index i at time t is calculated as:

$$R_{it} = \frac{TR_{it} - TR_{it-1}}{TR_{it-1}} \quad (1)$$

Where TR_{it} is the total return index value at time t , and TR_{it-1} is the total return index return value at time $t-1$. Equation (1) defines simple returns, which were chosen for their intuitive interpretability.

For each variable, total monthly return data is normalized by subtracting the mean and dividing by its standard deviation. This is done to ensure that the data has a uniform scale, as the PCA is sensitive to the scale of the variables used. The PCA is then applied on the normalized monthly returns to test for convergence over the sample period. The study then determines the overall variation in returns accounted for by the first principal component. If a single factor explains a large proportion of return variances, the indices converge as they are influenced by a common factor.

The PCA has been widely used in financial research to measure co-movement among various financial markets and assets, some of the studies that have utilized the PCA in this context are Coleman, Vitor and de Medeiros (2018), Beckmann, Belke and Dobnik (2012), Esmaeili and Shokoohi (2011), Modi, Patel and Patel (2010), Gilmore, Lucey and McManus (2008). The PCA is appropriate for this study due to the high-dimensionality of the dataset, a high-dimensional dataset is likely to result in correlated variables. The PCA reduces the dimensionality of the dataset by transforming these variables into a smaller set of uncorrelated variables, known as principal components, which allows the study to focus on the most significant patterns in the data without losing important information. By transforming the data

into a set of linearly uncorrelated principal components, the PCA eliminates multicollinearity in the ESG indices, ensuring that the subsequent analysis is not distorted by redundant information.

The study then tests for structural breaks using the Multiple Structural Break Test – individual index returns are tested for multiple structural breaks and similarity in the number of breaks and time periods of the breaks across the indices is then explored. Structural break analysis is critical for determining whether observed convergence patterns are influenced by external shocks or are consistent over time. The inclusion of structural breaks in this particular study serves to investigate whether the ESG indices exhibit breaks at similar time points, particularly in the absence of significant market events. If such breaks align across the indices, it could suggest a shared underlying behaviour or response potentially driven by ESG-specific factors. This would necessitate a deeper examination to distinguish whether these breaks are attributable to ESG characteristics, or external influences. Conversely, if no similar breaks are observed, it would indicate that from the lens of structural breaks, the indices do not exhibit co-movement. Lastly, to add depth to analysis of convergence, the three indices are paired to test for co-movements within each index pair. Co-movement between the index pairs is examined by computing the product of their z-scores.

3.2.1 | Testing for co-movement through the PCA

The PCA, developed by Hotelling (1933), is a statistical technique used to reduce the complexity of a dataset while maintaining as much variance as possible. This is achieved through a conversion of the initial set of variables into a new set of uncorrelated variables, and these are referred to as “principal components”. This method has two main objectives; data reduction and data interpretation. PCA has often been considered as a specific form of factor analysis, but Coleman, Vitor, and de Medeiros (2018) make the distinction between the PCA and factor analysis, stating that although both methods seek to reduce the complexity of a dataset, the techniques utilized in each method are different. PCA focuses on describing the relationships and variability within the data by using a small number of linear combinations of the original variables. Even though the original dataset has m variables, most of the variability is often captured by a smaller number p of principal components. The p principal components contain nearly as much information as the original m variables. According to Tsay (2005) the

initial m variables can then be replaced by the p principal components, reducing the initial dataset to a dataset with n measurements on p principal components.

Let $x = \{x_{it}\}$ be a vector of stock market indicators for country $i = 1, \dots, n$ for period $t = 1, \dots, T$ which are decided by a group of components f :

$$x_{it} = \sum_{j=1}^Y \lambda_{ij} f_{jt} + \epsilon_{it} \quad x_{it} = \lambda_i f_{it} + \epsilon_{it} \quad , \quad (2)$$

Where λ_i is the factor loading coefficient related to each one of the f shared factors and ϵ_{it} represents a white noise error term that is identically and independently distributed. As shown in Becker and Hall (2009) a group of variables is considered to be converging if the generic factor model described by Equation (2) can be limited to one factor. The Y shared factors are derived by PCAs that represent the highest amount of variance for the selected indices. Utilizing the computed monthly returns, the study applies a PCA test to examine convergence over the sample period. The study considers convergence as described in Coleman, Vitor, and de Medeiros (2018), which bases convergence on the value of the R^2 of the first principal component; the figure reflects the overall variation in returns accounted for by the first factor. Values closer to one indicate a higher level of convergence between the returns, signifying stronger co-movement. Such increased co-movement suggests that the returns behave more similarly, reducing the potential for effective portfolio diversification. Moreover, if the R^2 for the first period is lower than that for a later Period 2, it indicates that convergence has increased during the chosen interval. Convergence is therefore used as a measure of co-movement in this study.

3.2.2 | Testing for structural breaks

Parameter testing and structural change in regression models has been an essential element of econometric work. This dates back to Chow (1960), who examined regime change at known dates by employing an F-statistic. In an attempt to test for structural change where potential break dates are unknown, Quandt (1960) builds on Chow's work by considering the F-statistic with the greatest value over all probable break dates. Notable contributions on structural change include Andrews (1993), and Andrews and Ploberger (1994), who derived the limiting distribution for the Quandt test statistics and similar measures. Building on these methodologies, Bai and Perron (1998, 2003a, 2003b) expanded the Quandt-Andrews framework by enabling the testing for multiple unknown break dates. This study considers a

pure structural change regression model consisting of T periods and m possible breaks for observations $T_j, T_j+1, \dots, T_{j+1}-1$ for regimes $j = 0, \dots, m$ given by:

$$x_t = Z'_t \delta_j + \epsilon_t \quad (3)$$

Where the coefficients of the Z variables are regime-specific. In such instances, the estimates of equation (3) can be calculated by use of the ordinary least squares approach, segment by segment and with no constraints. According to Coleman, Vitor and de Medeiros (2018), the multiple breakpoint tests can be categorised as follows: (a) tests that employ global maximisers for breakpoints; (b) tests that utilize breakpoints that are sequentially defined; (c) tests that integrate the two approaches. This study applies the global maximizer approach as recommended by Bai and Perron (2003a, p15): “The problem is that, in the presence of multiple breaks, certain configurations of changes are such that it is difficult to reject the null hypothesis of 0 versus 1 break, but it is not difficult to reject the null hypothesis of 0 versus a higher number of breaks (this occurs, for example, when 2 changes are present and the value of the coefficient returns to its original value after the second break).” The sequential procedure breaks down in such instances.

For a specific set of m breakpoints, such as $\{T\}_m = (T_1, \dots, T_m)$, the following is minimised:

$$S(\beta, \delta | \{T\}) = \sum_{j=0}^m \{ \sum_{t=T_j}^{T_{j+1}-1} x_t - X'_t \beta - Z'_t \delta_j \} \quad (4)$$

utilizing standard least squares regression to calculate the estimates $\hat{\beta}, \hat{\delta}$ in the context of a partial structural model, or $\hat{\delta}$ for a pure structural change model. Bai and Perron (1998, 2003a) demonstrate that the number of comparison models grows rapidly with both m and T , and they developed practical algorithms to efficiently estimate the global optimizers for models with multiple breakpoints. These estimates are subsequently used as the basis for multiple breakpoint tests.

In most cases, the exact number of structural breaks is unknown. The Bai and Perron (1998, 2003a) method addresses this uncertainty by proposing double maximum tests to evaluate the null hypothesis of no structural breaks against an alternative of an unknown number of breaks, up to a specified upper limit M . The first test, UDmax is an equal-weighted approach that selects the alternative with the highest test statistic across the potential break points. The

second, WDmax, adjusts the test by applying weights to ensure consistent marginal p-values across different values of M . Bai and Perron (2003a, 2003b) suggest that considering up to five breaks is sufficient for most empirical studies and provide critical values for $M = 5$, along with options for 5%, 10%, and 15% sample trimming. They also note that critical values show minimal variation when M exceeds five. This study tests each of the indices for multiple structural breaks using the “Global L breaks versus None” approach and investigates the similarities in the number of breaks, thereby inferring potential evidence of co-movements across these markets. A 15% trimming level is applied to ensure that each segment contains sufficient observations (at least 9) to estimate parameters reliably, given the sample size of 60 monthly observations. This level balances sensitivity to detect structural breaks with robustness against overfitting or the identification of spurious changes. Lower trimming levels, while more sensitive, increase the likelihood of capturing noise as structural breaks.

3.2.3 | Z-score

In this study, dynamic co-movement between the selected markets is examined by use of a z-score, following Yetman (2011b) and diverging from the commonly used Pearson correlation coefficient, which, although straightforward, has significant drawbacks particularly due to the limited time-specific information it offers (Coleman, Vitor, & de Medeiros, 2018).¹¹ Pearson correlation provides only a static, linear measure of association at a single point in time and does not capture the evolving nature of market co-movement. In contrast, the z-score approach allows for a standardized comparison of deviations from the mean, making it more suitable in analysing temporal dynamics in market behaviour. The co-movements in the returns R of indices i and j are estimated by multiplying their z scores :

$$\rho_t^{ij} = \frac{(R_{it} - \bar{R}_i)}{\sqrt{\frac{1}{T-1} \sum_{t=1}^T (R_{it} - \bar{R}_i)^2}} \frac{(R_{jt} - \bar{R}_j)}{\sqrt{\frac{1}{T-1} \sum_{t=1}^T (R_{jt} - \bar{R}_j)^2}} \quad (5)$$

Equation (5) is estimated for each of the 3 possible pairings across the 60 monthly observations. To summarize this sequence of 60 values, the study reports the percentage of months in which $\rho_t^{ij} > 0$. This summary statistic provides a simple and interpretable measure of the proportion of time the returns of the two indices moved in the same direction. A positive estimate indicates

¹¹ See Yetman (2011a) for a theoretical background, and Bin, Chen, and Chiu (2012), Sirichand and Coleman (2015) for some empirical applications.

co-movement between the two markets, whereas a negative estimate suggests movement in opposite directions. In each case, the relative magnitude of the z-score reflects the strength of the co-movements.

3.3 | Robustness checks

To examine the robustness of the results, the study will use copulas and wavelet multiple analysis on the same dataset to determine whether the results correspond across methodologies. This subsection provides a brief explanation of the two methods.

3.3.1 | Copula analysis

The study extends its analysis to investigate the dependence structure among the three ESG indices using copulas. Diversification benefits decrease when assets exhibit strong co-movement during extreme events (i.e., high tail dependence), as this reduces the effectiveness of risk mitigation strategies. Copula tail-dependence coefficients quantify the likelihood of the indices moving together in the tails of their distributions. A variety of copula models, incorporating diverse conditional dependence structures and dynamic dependence parameters are explored. The Clayton and Gumbel copulas focus on lower and upper tail dependence, respectively, while the Student-t copula captures symmetric tail dependence. The SJC copula models asymmetric tail behaviour, and the Gaussian copula serves as a baseline for linear dependence. This approach allows the study to comprehensively assess the co-movement dynamics relevant to diversification across ESG indices. The copulas can be derived through the inversion method, which replaces the variables in the original joint distribution with marginal quantile functions. This approach isolates the influence of marginal distributions from the dependence relationship:

$$C(u, v) = F_{XY}(F_X^{-1}(u), F_Y^{-1}(v)) \quad (6)$$

Where F_X^{-1} and F_Y^{-1} represent the marginal quantile functions and u and v the probabilities. The bivariate Gaussian copula (N) is expressed as $C_N(u, v; p) = \Phi(\Phi^{-1}(u), \Phi^{-1}(v))$, where Φ represents the cumulative distribution of the bivariate standard normal distribution with a correlation p between X and Y , and $\Phi^{-1}(u)$ and $\Phi^{-1}(v)$ are the quantile functions of the standard normal distribution. The Student-t copula is defined as $C_{ST}(u, v; p, \nu) = T(t_\nu^{-1}(u), t_\nu^{-1}(v))$, where T represents the bivariate Student-t cumulative distribution function, with ν as the degrees of

freedom parameter and ρ as the correlation. $t_v^{-1}(u)$ and $t_v^{-1}(v)$ are the quantile functions of the univariate Student-t distribution, with v as the parameter for degrees of freedom. Unlike the Gaussian copula, the Student-t copula allows for non-symmetric dependence in the tails (Embrechts, Lindskog, & McNeil, 2003). This is useful for modelling extreme co-movements.

To account for likely asymmetric tail dependence, the Clayton, Gumbel and SJC copulas are examined. The Clayton copula exhibits asymmetry, with a higher degree of dependence in the lower tail and no dependence in the upper tail. It is defined as $C_{CL}(u, v; a) = \max\{(u^{-a} + v^{-a} - 1)^{-1/a}, 0\}$. The Gumbel copula is also asymmetric but shows a greater degree of dependence in the upper tail, while the lower tail has no dependence. It is given by $C_G(u, v; \delta) = \exp(-[-\log(u)]^\delta + [-\log(v)]^\delta)^{1/\delta}$. Lastly, the SJC copula, which states is a modification of the original Joe-Clayton copula, accommodates both upper and lower tail dependence, with symmetric dependence as a special case when $\lambda_U = \lambda_L$. This copula is defined as:

$$C_{SJC}(u, v; \lambda_U, \lambda_L) = 0.5 * C_{JC}(u, v; \lambda_U, \lambda_L) + C_{JC}(1-u, 1-v; \lambda_U, \lambda_L) + u + v - 1, \quad (7)$$

where $C_{SJC}(u, v; \lambda_U, \lambda_L)$ is the Joe-Clayton copula, defined as:

$$C_{JC}(u, v; \lambda_U, \lambda_L) = 1 - (1 - \{[1-u]^k\}^{-\gamma} + [1-(1-v)^k]^{-\gamma} - 1)^{1/\gamma} \quad (8)$$

where $k = 1/\log_2(2-\lambda_U)$, $\gamma = -1/\log_2(\lambda_L)$ and $\lambda_L \in (0,1)$, $\lambda_U \in (0,1)$.

3.3.2 | Wavelet Multiple Correlation

Various studies¹² have used Wavelet Multiple Correlation (WMC) to assess the interdependence between stock exchanges. This study applies WMC as a robustness check to verify if the results align with the results derived from the above tests, the PCA, structural breaks tests and correlation analysis. The WMC coefficient measure allows the estimation of the strength of co-movement among a multivariate time series across different timescales, such that one could distinguish between the short-run, medium-run and long-run relationship.

¹² For instance, Tiwari, Dar, Bhanja, and Shah (2013), Fernandez-Macho (2012), Nyakurukwa and Seetharam (2023).

Let $\{X_t\}$ be a multivariate stochastic process and let $\{W_{jt}\}$ be the respective j^{th} level wavelet coefficients from the application of maximal overlap discrete wavelet transform (MODWT). The WMC $\phi_X(\lambda_j)$ can be defined as one single set of multi scale correlations calculated from X_t as follows:

At each wavelet scale λ_j , the study computes the square root of the regression coefficient of determination in the linear combination of variables w_{ijt} , $i=1,2,\dots,n$, for which the coefficient of determination is a maximum. The coefficient of determination corresponding to the regression of a variable Z_i on a set of regressors $\{Z_k, k \neq i\}$, could be obtained as $R_i^2 = 1 - (1/p^{ii})$, where p^{ii} is the i^{th} diagonal element of the inverse of the complete correlation matrix P . The WMC $\phi_X(\lambda_j)$ is given by:

$$\phi_X(\lambda_j) = \sqrt{1 - \frac{1}{\max \text{diag } P_j^{-1}}} \quad (9)$$

Where P is the $N \times N$ correlation matrix of $\{W_{jt}\}$, and the $\max \text{diag}(\cdot)$ operator selects the largest element in the diagonal of the argument.

4. | RESULTS AND DISCUSSION

4.1 | Summary statistics

The summary statistics of the data is reported in Table 1. The Egyptian ESG Index (SPEGESGE) has the highest monthly average return of 1.47%. This is followed by the South African ESG Index (J110EP) at 1.09%, the Moroccan ESG Index (ESGI) appears to have the lowest average return at 0.1%. Volatility, measured by the monthly standard deviation, is the highest in Egypt at 7.6%, while the lowest volatility is observed in Morocco at 4.4%. South Africa shows moderate volatility at 6.1%. In terms of price movement, the SPEGESGE Index carries the most risk, while ESGI is the least risky. This suggests that the ESGI could act as a stabilizing asset in a portfolio containing the three indices, particularly during periods of high market volatility. However, the ESGI can increase portfolio fragility during market downturns, as it has strong negative skewness. The indices are all negatively skewed, indicating more small negative returns or a few extreme negative outliers. All the markets present leptokurtotic distributions, with ESGI being extremely leptokurtic, indicating significant tail events compared to the other two indices. The Jarque-Bera test indicates that none of the indices follow a normal distribution ($p = 0.00027$, 0.0107 and 0 for the J110EP, SPEGESGE and ESGI respectively).

Lastly, the correlation matrix is reported in Table 2. The results reported show that there is diversification potential with the ESGI as it has weaker correlations with the J110EP and SPEGESGE indices. ESGI's unique risk-return profile as shown by the descriptive statistics and its low correlation suggest that it can reduce overall portfolio risk. The moderate relationship between J110EP and SPEGESGE indicates that they share some common risk factors, therefore, including both in a portfolio offers less diversification compared to pairing either with ESGI.

TABLE 1 Descriptive statistics for the total monthly returns of the South African, Egyptian, and Moroccan ESG index respectively

Statistic	J110EP Index total return	SPEGESGE Index total return	ESGI Index total return
Mean	0.0108645	0.01469754	0.001017268
Median	0.01478346	0.006416023	0.0115545
Maximum	0.2152266	0.203343	0.06969076
Minimum	-0.1980651	-0.2592087	-0.2146037
Standard deviation	0.06135755	0.07603171	0.04393575
Skewness	-0.1586997	-0.2237054	-2.040828
Kurtosis	5.544123	4.852048	10.76532
Jarque-Bera	16.43326	9.075641	192.4002
Probability	0.0002701239	0.01069669	0
Sum	0.6518700	0.8818521	0.0610361
Sum Sq. Dev	0.2221202	0.3410684	0.1138907
Observations	60	60	60

TABLE 2 Correlation matrix

	J110EP Index total return	SPEGESGE Index total return	ESGI Index total return
J110EP Index total return	1.0000000	0.5288055	0.2189463
SPEGESGE Index total return	0.5288055	1.0000000	0.2805649
ESGI Index total return	0.2189463	0.2805649	1.0000000

4.2 | Principal Component Analysis

4.2.1 | Full sample

PCA results for the full sample are reported in Table 3. It can be noted that for the full sample, the first principal component can explain approximately 56.86% of the variance in the data, making it the most significant. This suggests that a substantial portion of the variance in the ESG indices can be explained by a single factor across the sample period. This result differs slightly to that of Coleman, Vitor, and de Medeiros (2018), who find that in seven Latin American stock markets, only 49.79% of the variance in the data is explained by the first principal component. With PC1 explaining 56.86% of the variance, the results indicate partial but incomplete convergence – the remaining variance in the indices (43.14%) is spread across the other two components PC2 (27.58%) and PC3 (15.55%), highlighting the presence of additional independent or divergent behaviours among the indices. The incomplete dominance of PC1 (less than 80-90% variance explained) suggests that the indices retain unique characteristics, which could provide diversification benefits – while the indices share some common risks, their movements are not fully synchronised, meaning they can still serve as useful tools for reducing portfolio risk. As a result of the incomplete convergence over the sample period, the study proceeds to assess if convergence is period-specific or increasing over time by applying the PCA to 12-month rolling window periods. By applying rolling PCA, the study examines how the variance explained by PC1 changes across 12-month periods. If PC1's explanatory power fluctuates, it suggests that convergence varies over time. The PCA results

for the full sample support the hypothesis of no significant co-movement in the indices. This aligns with the possibility of ESG indices reflecting a mix of shared global ESG trends captured by PC1, and idiosyncratic dynamics captured by PC2 and PC3. Figure 1 visualises the percentage of the variance explained by the principal components over the full sample period.

TABLE 3 summary of PCA results for the full sample (2019 – 2023)

Importance of components:			
	Comp.1	Comp.2	Comp.3
Standard deviation	1.2951785	0.9020309	0.6773868
Proportion of Variance	0.5686398	0.2758169	0.1555434
Cumulative Proportion	0.5686398	0.8444566	1.0000000

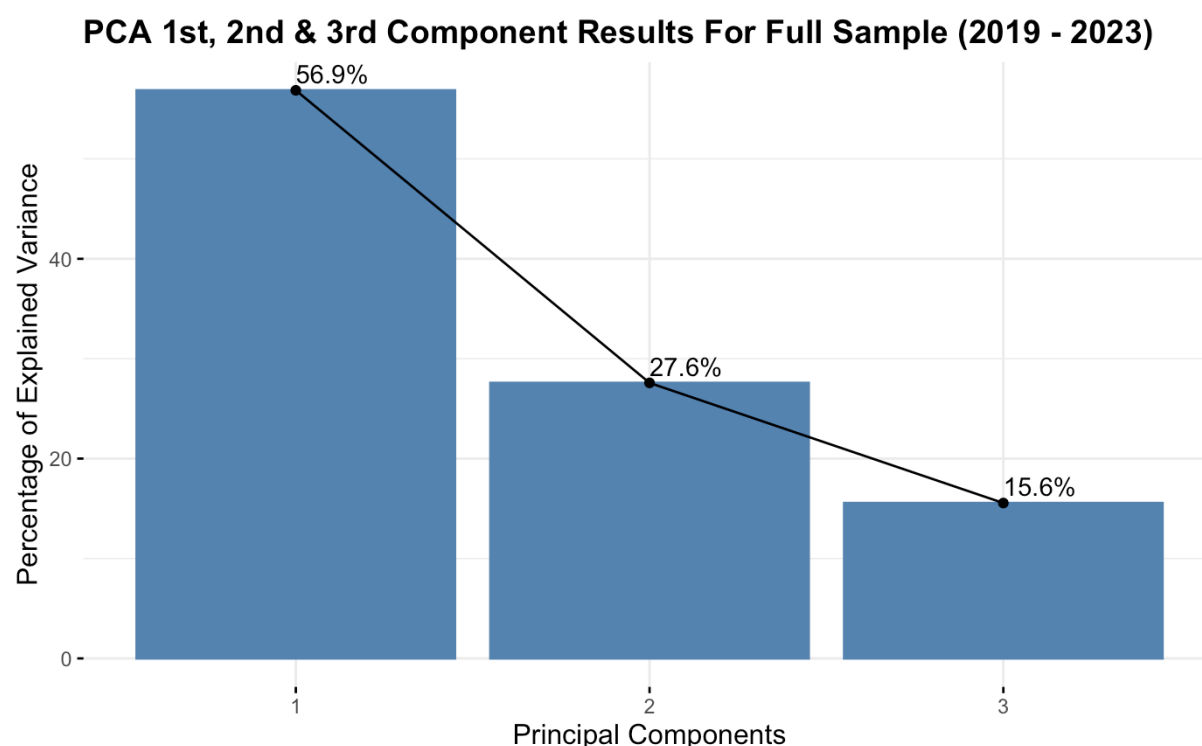


FIGURE 1 PCA results for the 1st, 2nd and 3rd principal components for the full sample (2019 -2023)

4.2.2 | 12-month rolling window-periods

The results for the rolling PCA are reported in Table 4 and Figure 2. The results show that PC1 values fluctuate over time, peaking at 86.11% (2019-04-30 to 2020-03-31) and dropping as low as 39.34% (2022-11-30 to 2023-10-31). This variability suggests that convergence is not constant but period-specific, likely influenced by external factors, such as market conditions or macroeconomic events. For instance, the peak observed from April 2019-March 2020 aligns with the onset of the COVID-19 pandemic, which caused significant global market turmoil and synchronized movements in stock returns. During this time, PC1 rose sharply from an average of approximately 44% in earlier periods to 86.11%, marking an increase of 42.11 percentage points. This spike underscores the extreme nature of market co-movement during the pandemic's early stages, driven by synchronised responses to a global crisis. This is consistent with Athari and Hung (2022) whose findings indicated that interdependence between asset classes had increased significantly during the COVID-19 crisis. Similarly, studies such as Brooks and Del Negro (2004) and Jiang, Yu, and Hashmi (2017) state that there generally is a pattern of increasing co-movement in returns during periods of financial distress. Conversely, from mid-2021 onward, PC1 values generally decline, frequently falling below 50%. This indicates weaker co-movement, suggesting that ESG indices began exhibiting more independent behaviours, such as divergence in recovery trajectories, influenced by each country's varying levels of inflation and monetary policy adjustments. Overall, the results confirm that convergence among these African ESG indices is not uniform over time but is influenced by external factors and market conditions. The declining PC1 values after 2021 indicate declining co-movement between the ESG indices, which is consistent with H0. This observation suggests that there are opportunities for diversification for ESG investors in African markets.

TABLE 4 Variance Explained by the First Principal Component (PC1) for Each 12-Month Period

Start date	End date	PC1
2019-01-31	2019-12-31	44.43656
2019-02-28	2020-01-31	44.15796
2019-03-29	2020-02-28	55.36147
2019-04-30	2020-03-31	86.10567
2019-05-31	2020-04-30	76.24556
2019-06-28	2020-05-29	75.36254
2019-07-31	2020-06-30	76.03451
2019-08-30	2020-07-31	77.79006
2019-09-30	2020-08-31	77.20403
2019-10-31	2020-09-30	77.39895
2019-11-29	2020-10-30	74.26722
2019-12-31	2020-11-30	76.61357
2020-01-31	2020-12-31	77.03406
2020-02-28	2021-01-29	78.04136
2020-03-31	2021-02-26	77.32698
2020-04-30	2021-03-31	61.91344
2020-05-29	2021-04-30	47.92740
2020-06-30	2021-05-31	47.79592
2020-07-31	2021-06-30	43.64364
2020-08-31	2021-07-30	44.66769
2020-09-30	2021-08-31	50.17578
2020-10-30	2021-09-30	55.36995
2020-11-30	2021-10-29	50.84098
2020-12-31	2021-11-30	47.76775
2021-01-29	2021-12-31	51.29709
2021-02-26	2022-01-31	53.41715
2021-03-31	2022-02-28	50.76668
2021-04-30	2022-03-31	50.01887
2021-05-31	2022-04-29	50.49312
2021-06-30	2022-05-31	45.86468
2021-07-30	2022-06-30	54.76583
2021-08-31	2022-07-29	52.54601
2021-09-30	2022-08-31	47.99009
2021-10-29	2022-09-30	51.75146
2021-11-30	2022-10-31	46.73196
2021-12-31	2022-11-30	52.03339
2022-01-31	2022-12-30	43.97935
2022-02-28	2023-01-31	48.06580
2022-03-31	2023-02-28	49.98968
2022-04-29	2023-03-31	50.90466
2022-05-31	2023-04-28	54.33666
2022-06-30	2023-05-31	52.81461
2022-07-29	2023-06-30	52.33513
2022-08-31	2023-07-31	50.18045
2022-09-30	2023-08-31	47.53201
2022-10-31	2023-09-29	49.19046
2022-11-30	2023-10-31	39.34423
2022-12-30	2023-11-30	49.18573
2023-01-31	2023-12-29	48.58591

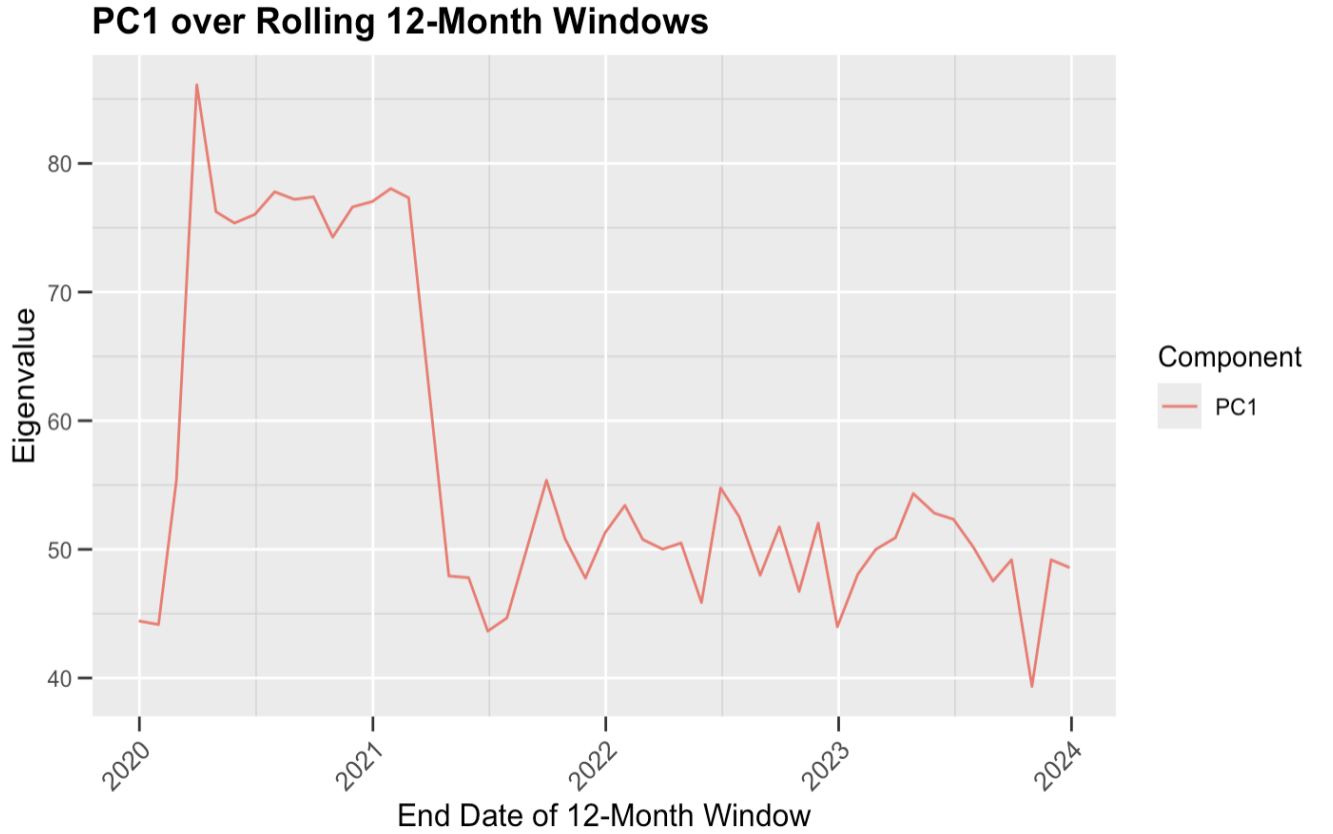


FIGURE 2 PCA results for the 12-month rolling window periods

4.3 | Multiple structural breaks

To conduct the tests for Multiple Structural Breaks through Bai and Perron (2003a, 2003b), the following multiple regression equation was applied on each of the three ESG indices over the entire sample:

$$Y_{jt} = \alpha_t + \sum_{k=1}^3 \beta_{kt} X_{kt} + \varepsilon_t \quad (10)$$

Where Y_j refers to the return of index j in which the multiple structural breaks test is applied, and X_k is the return of the other indices $k = 1, 2, 3$. To mitigate the possible problems associated with heteroskedasticity and serial correlation, the Newey-West (1987) estimator is applied to the covariance matrix. As outlined in the previous section, the Global L breaks versus None approach is utilised, applying an F statistic and double maximum test, which involves maximization both for a given number of breaks l across various values of the test statistic for l . Results of the multiple structural breaks tests estimated are reported in Tables 5 and 6. It can be noted that for all three indices considered, the F-statistics for 1 to 5 breaks exceed critical

values, indicating strong evidence of significant breaks. The UDMAX and WDMAX values are also well above the critical thresholds, confirming significant structural changes in the indices. The South African ESG index (J110EP) exhibits substantial shifts particularly around 2019 – 2022, which is a period that incorporates the COVID-19 pandemic and Ukraine-Russia war. The Egyptian ESG index (SPEGESGE) experienced significant structural changes particularly in the 2020 – 2022 period, similar to the Moroccan ESG index (ESGI). Overlapping structural break dates among the three indices align with critical periods of global market instability (such as the COVID-19 pandemic), supporting the PCA findings of increased co-movements during these periods. While breaks appear in 2020 for all indices, the exact timing varies (April, August, December), which likely reflects local market reactions to the global event. Similarly, breaks in 2022 are evident across all indices, occurring in February, March and July. Outside of these critical periods, the break dates across the indices do not exhibit a consistent pattern of similarity. This lack of persistent similarity in break dates beyond periods of global instability suggests that the co-movements among the indices are not pervasive or sustained over time – both the PCA and structural breaks tests indicate that significant co-movements in the three African ESG indices is episodic and event-driven. Consequently, this result supports the null hypothesis of no significant co-movement as a result of ESG factors among the indices over the sample period.

TABLE 5 Bai and Perron (2003a) Multiple breakpoint test results

Index	Breaks	F-statistic	Critical value	UDMAX	UDMAX critical value	WDMAX	WDMAX critical value
J110EP	1*	5.822951	13.98	56.34910*	14.23	75.13898*	15.59
	2*	18.78303	11.99				
	3*	18.61455	10.39				
	4*	13.50284	9.05				
	5*	11.19332	7.46				
SPEGESGE	1*	8.458643	13.98	40.15894*	14.23	46.82419*	15.59
	2*	13.38631	11.99				
	3*	9.955806	10.39				
	4*	7.344983	9.05				
	5*	6.688596	7.46				
ESGI	1*	5.512913	13.98	24.97490*	14.23	34.77222*	15.59
	2*	4.100800	11.99				
	3*	8.324968	10.39				
	4*	7.503304	9.05				
	5*	4.231430	7.46				

Note: Maximum Breaks = 5= m; Trimming Percentage = 15 = critical number of observations as defined in the model; Significance Level = 0.05.

TABLE 6 Estimated break dates

Index	Estimated break dates
J110EP	1: 2021(3) 2: 2019(10), 2020(8) 3: 2019(10), 2020(8), 2022(4) 4: 2019(10), 2020(8), 2022(3), 2022(12) 5: 2019(10), 2020(8), 2021(6), 2022(3), 2022(12)
SPEGESGE	1: 2022(7) 2: 2022(6), 2023(4) 3: 2020(1), 2022(6), 2023(4) 4: 2020(1), 2020(12), 2022(7), 2023(4) 5: 2020(1), 2020(12), 2021(9), 2022(7), 2023(4)
ESGI	1: 2020(4) 2: 2020(4), 2022(2) 3: 2020(4), 2022(2), 2023(4) 4: 2020(4), 2021(2), 2022(2), 2023(4) 5: 2020(4), 2021(1), 2021(10), 2022(7), 2023(4)

4.4 | Correlation dynamics

This study uses Equation (4) to compute all possible pairings of the ρ_t^{ij} for the three ESG indices over time. The results are presented in Table 5 and graphically illustrated in Figure 3. Positive estimates of ρ_t^{ij} indicate co-movement, while negative estimates suggest that the indices move in opposite directions. From the results in Table 5, South Africa and Egypt exhibited the highest number of positive estimates (60%), indicating high co-movement between the markets. This complements the results from the correlation matrix in Table 2. It can be seen from Figure 3 that the estimated z-scores exhibit stronger co-movement during periods of economic crises, which corroborates the results from the rolling PCA analysis above. Across all three index-pairs, the highest co-movement is observed in the 2020-2021 period, which is a period that is representative of the COVID-19 pandemic. This result is consistent with the findings of Junior, Tetteh, Nkrumah-Boadu, and Adjei (2024), who found co-

movements in African stock markets as a result of the impact of the COVID-19 Pandemic. Their results suggested that African stock markets exhibit some level of co-movement during periods of uncertainty. Coleman, Vitor, and de Medeiros (2018), also found a similar pattern of stronger comovements in the 1998 and 2007/2008 periods, which consist of the Russian crisis and the Global Financial Crisis respectively.

Figures 3, 4 and 5 further show that across the three index-pairings, ρ_t^{ij} seems to hover around the zero mark for majority of the periods, implying that there is generally low or negligible correlation between the three index pairings over the sample period. This suggests a lack of strong integration or dependency between the index pairs, which might allow for potential diversification benefits. These results do not warrant rejection of the null hypothesis, as high co-movement within the indices is only observed during periods of market stress, and does not seem to be consistent over the sample period.

TABLE 7 Percentage of positive ρ_t^{ij} values in the index pairs

Index pair	Positive estimates	No. observations	% positive estimates
South Africa & Egypt	36	60	60.00000
South Africa & Morocco	34	60	56.66667
Egypt & Morocco	30	60	50.00000

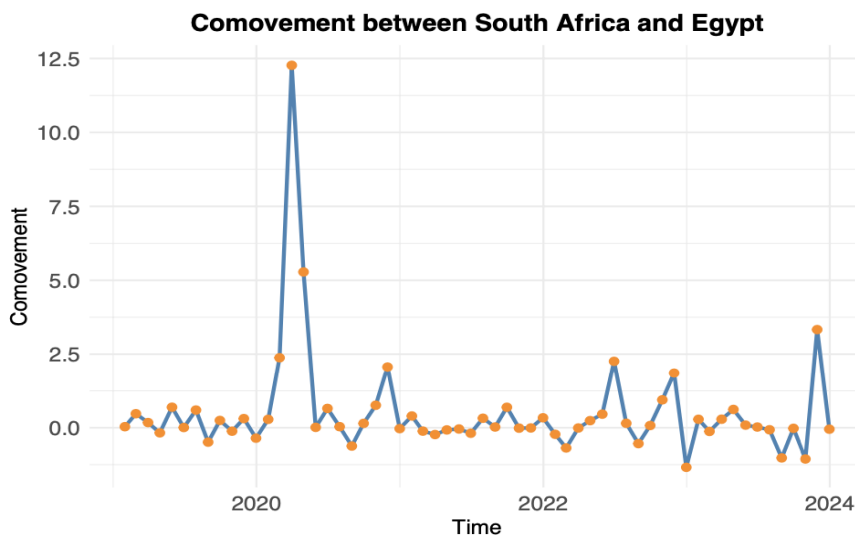


FIGURE 3 Co-movement estimates ρ_t^{ij} for the South Africa-Egypt index pair.

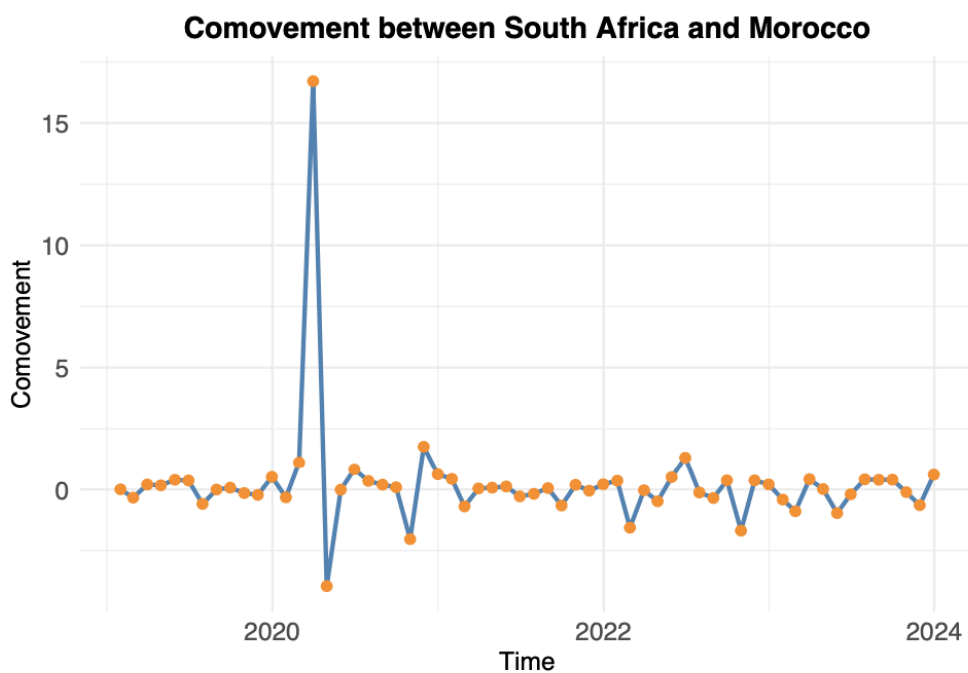


FIGURE 4 Co-movement estimates ρ_t^{ij} for the South Africa-Morocco index pair.

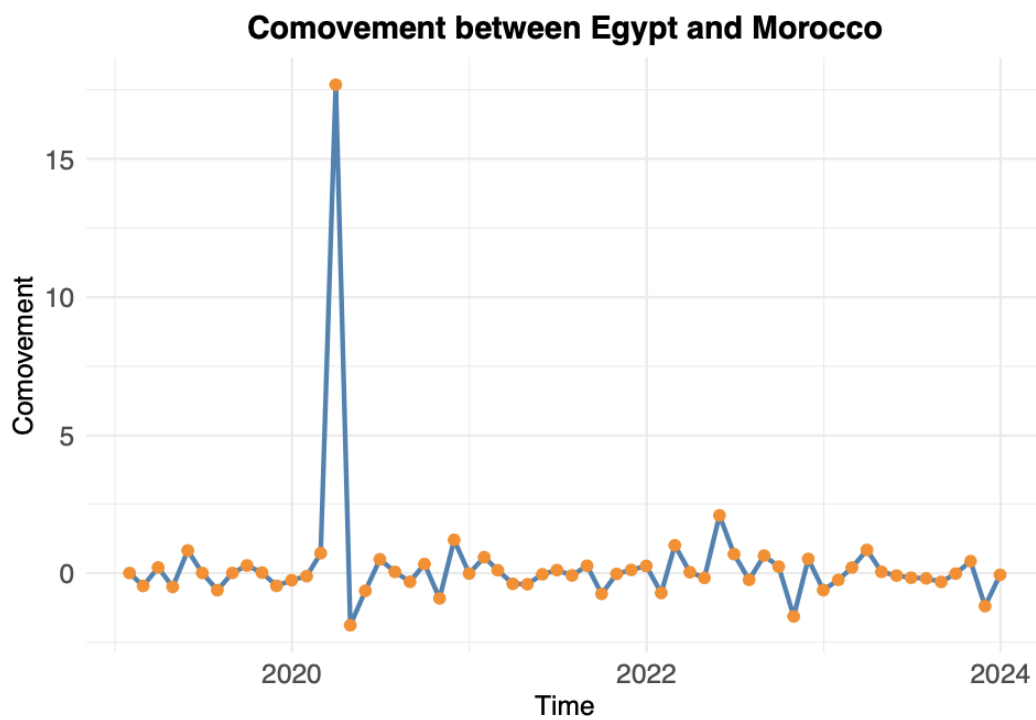


FIGURE 5 Co-movement estimates ρ_t^{ij} for the Egypt-Morocco index pair.

4.5 | Robustness checks

4.5.1 | Copulas

Table 8 gives a summary of the results for the copula models. The degrees of freedom for the Student-t copulas were all moderately low (between 2 and 7), suggesting extreme co-movements and tail dependence for all the index pairs. The AIC results show that the Gumbel copula performed significantly better for the South Africa- Egypt index pair (-11.96363), thereby rejecting the symmetric no-tail dependence implied by the Gaussian copula. It can be observed that there is moderate upper tail dependence for the South Africa-Egypt pair ($\delta = 1.44$), with the upper tail dependence parameter δ for two of the index being 1, indicating no upper tail dependence for South Africa and Morocco, and Egypt and Morocco. The lower ν (2.17) for the South Africa-Morocco pair suggests heavier tails (higher likelihood of extreme co-movements between the index pair). This result corroborates the results above from the PCA tests, Structural breaks and Correlation analyses, that dependence among the indices is observed only in the lower tails. As reported in the correlation analysis, South Africa and Egypt consistently show moderate dependence across all copula types, while all the Morocco index pairs show very low or no dependence. The consistent South Africa-Egypt co-dependency is an interesting dynamic that can be explored further in future research papers.

TABLE 8 Estimates for copula models

		South Africa & Egypt	South Africa & Morocco	Egypt & Morocco
Gaussian copula	ρ	0.487723	-0.003333	0.107797
	AIC	-11.72421	1.995751	1.422158
Student-t copula	ρ	0.4366	0.03053	0.08761
	ν	2.9467	2.17118	7.78043
	AIC	-11.74673	-1.916276	3.102861
Clayton copula	α	0.8641	0.1569	0.3782
	AIC	-10.93872	1.000274	-2.506296
Gumbel copula	δ	1.44	1	1
	AIC	-11.96363	1.99995	2
SJC copula	λ_U	-2.271121	-83.08678	-4.276183
	λ_L	0.266012	0.00138443	0.00138443
	AIC	-11.85573	3.01246	-0.4753035

4.5.2 | Wavelet Multiple Correlation analysis

Results of the WMC analysis are reported in Figure 4 below. It can be seen that the highest frequency has a coefficient of 0.7, and the lowest frequency has a coefficient slightly above 0.6. This brings a new perspective to the study, suggesting that co-movement among the indices is relatively high and similar across both shorter and longer time periods. Studies such as Rua and Nunes (2009), and Kiviaho, Nikkinen, Piljak, and Rothovius (2012) have found co-movement to be stronger at lower frequencies (longer horizons). The WMC result indicates that the interrelationship between the indices is stable across different market conditions, regardless of the time scale. From a time-frequency perspective, the higher frequencies typically capture more immediate, volatile interactions, while lower frequencies reflect broader, more persistent trends. The relatively uniform correlation displayed in Figure 4 across these scales implies that co-movement between the indices is not solely driven by short-term market noise or long-term structural factors, instead, it suggests that the factors influencing the co-movement of these indices are present at multiple time scales. This result differs from the findings of PCA, Structural Breaks and Correlation Dynamics above, which suggest that co-movement among the indices is not consistent over time, instead it is highly present during high frequency events or crises. It is important to note that the shorter sample period used in this study limits the wavelet scale to 4, which inhibits the ability to see the WMC graph over prolonged periods. From the below graph, it is unclear that the relationship continues to follow the same pattern over lower frequencies. Therefore, although the result does not support the methods above, it is insufficient to reject the null hypothesis of no significant co-movement over time.

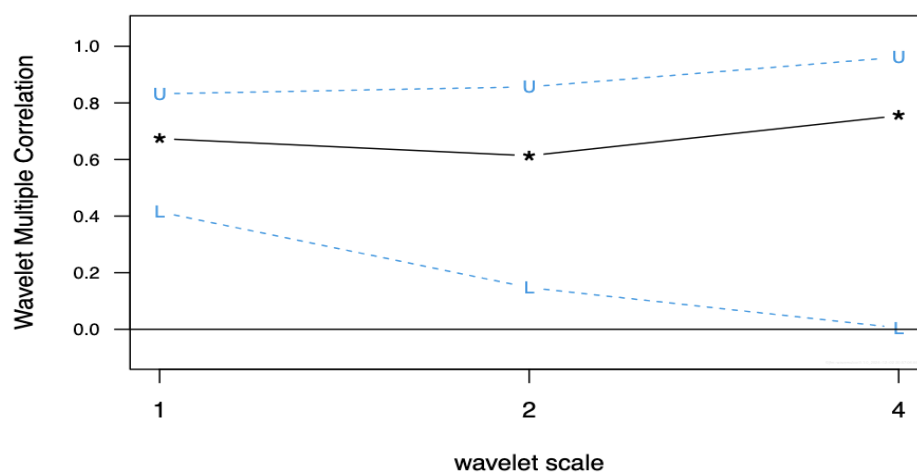


FIGURE 6 WMC graph of the ESG indices. Scale 2 = 2–4 months, scale 4 = 8–16 months. The dotted lines correspond to the upper and lower bounds of the relevant 95% confidence interval.

The copulas robustness check reinforces the core findings of the study: ESG indices exhibit low co-movements under normal market conditions, supporting their diversification potential. However, during major market events, co-movement increases significantly. This suggests that while ESG investments may reduce risk in stable markets, their diversification benefits diminish during periods of market stress.

5. | CONCLUSION

The study investigated the interrelations in ESG stocks in Africa, with the aim of examining whether these stocks exhibit any co-movements, which would then imply that ESG investors seeking to invest in Africa will have a diversification problem. This was carried out by analysing three African ESG indices, the FTSE/JSE Responsible Top 30 Index (J110) from South Africa, the ESG 10 Index from Morocco, and the S&P/EGX ESG Index from Egypt. These indices are the only indices formed solely on ESG criteria in the African markets, hence they were chosen for this study. To test for co-movement, the study employed the PCA to uncover variations in returns over the whole sample and 12-month rolling window periods to capture temporal dynamics. Structural breaks were then identified using the Multiple Structural Break Test to explore common break periods across the indices. Pairwise co-movement was assessed using z-score products, and robustness checks were conducted using Copula models and Wavelet Multiple Correlation (WMC).

The findings reveal no significant co-movement among the indices over prolonged periods, indicating that ESG-focused investors are not forfeiting diversification benefits by investing in African ESG stocks. Results from PCA showed that 56.86% of the variation was explained by PC1, with remaining variance distributed across PC2 (27.58%) and PC3 (15.55%). Rolling PCA demonstrated that convergence is period-specific, with PC1 peaking at 86.11% during the early stages of the COVID-19 pandemic and dropping to 39.34% by late 2023. The Multiple Structural Break Test identified significant breaks across all indices, with common break periods observed between 2020 and 2022, likely reflecting global crises such as the COVID-19 pandemic and the Ukraine-Russia war. Z-score product estimates indicated limited co-movement between South Africa and Egypt (60%), South Africa and Morocco (56.7%), and Egypt and Morocco (50%). Copula tests corroborated these findings, showing extreme co-movement only during crises and weak dependence outside of these periods. The WMC, however, revealed that co-movement remains stable across all horizons, suggesting that certain aspects of co-movement dynamics warrant further investigation. In conclusion, the study provides empirical evidence that African ESG indices exhibit limited co-movement during stable periods, preserving diversification opportunities for ESG-focused investors. Morocco's ESG index, in particular, demonstrates weak dependence with other indices, making it a valuable tool for diversification. These findings contribute to the literature on ESG investing

by offering the first comprehensive analysis of African ESG index co-movements, combining innovative methods such as PCA, structural breaks, and copulas.

The primary limitation of this study, as with many ESG-focused analyses is the availability of ESG data. In particular, the ESG 10 index, which forms the basis of this study, has data available only from 2018. Consequently, the analysis spans a relatively short 5-year period. This limited timeframe may not be sufficient to fully capture the long-term interrelations in ESG stock returns, especially given that the effects of ESG factors often manifest over extended periods. Moreover, long-term co-movements and structural breaks, which are critical to understanding market dynamics, often require a longer dataset to identify meaningful patterns. This limitation is particularly evident in the Wavelet Multiple Correlation analysis, where the shorter sample period (and consequently the number of observations) resulted in fewer wavelet scales. The reduced number of scales restricts the ability to observe co-movements over prolonged periods, potentially limiting the robustness of conclusions regarding the temporal dynamics of ESG stock returns. Another limitation pertains to the scope of the markets included in the sample. ESG investing is still in its developmental stage across African markets, and many stock exchanges have yet to establish indices dedicated specifically to ESG. This study, therefore, focuses on a small subset of markets with available ESG indices, which may not fully represent the diversity and complexity of ESG investing across the continent. Differences in ESG ratings are a limitation implicit in all studies that involve ESG data, and this study is not immune. Variations in how ESG scores are assigned across rating agencies can introduce inconsistencies in index construction, which may affect the measurement and interpretation of co-movement patterns. Lastly, as described in Section 3, the ESG indices analysed in this study differ in size and weighting methodology. The South African ESG index comprises 30 equally weighted companies, providing a relatively balanced representation of its sustainable investment landscape. Similarly, the Egyptian ESG index includes 30 companies, but these are ESG-score weighted, which introduces a bias towards companies with higher ESG scores, potentially amplifying their influence on the index's performance. In contrast, the Moroccan ESG index is smaller, consisting of 15 companies that are also ESG-score weighted. The smaller size of the Moroccan index makes it more susceptible to idiosyncratic risks and sector-specific shocks, as fewer companies are available to offset these effects.

Despite these limitations, the study provides valuable insights into the dynamics of ESG investing in African markets, uncovering interesting co-movement patterns dependencies. The study lays a foundation for future researchers who can address these limitations by incorporating longer time horizons, a broader range of markets, and more granular ESG data as it becomes available.

Future researchers with an interest in the concept of ESG investing in Africa can delve deeper and expand into the factors influencing co-movement of ESG stocks. This can be explored in various ways, one of which is possibly integrating frameworks like the Fama-French model, incorporating ESG metrics as factors to determine whether these contribute to explaining stock returns and their correlations. Studies of this nature could provide valuable insights into whether ESG is a priced factor in African markets. Additionally, this study uncovered an interest dynamic of co-dependency between South Africa and Egypt, which warrants further investigation. Researchers could explore whether this dependence is driven by shared economic policies, trade linkages or similar ESG investment behaviours. Identifying and addressing these drivers could help shed light on how regional interconnections affect ESG dynamics. Moreover, the wavelet multiple correlation analysis suggests stable co-movement among indices across both shorter and longer time horizons. Future researchers could examine the time-varying nature of ESG stock correlations using advanced time series models. To enhance this study, future researchers could explore methodologies that integrate spillover effects into structural break analysis for a more comprehensive understanding of the potential endogeneity between indices.

Other potential areas include a comparative analysis across regions, where researchers could compare ESG co-movements in Africa with those in developed markets to assess whether African markets are converging toward global ESG trends or exhibiting unique patterns. Researchers could also conduct a sector-specific ESG analysis, exploring whether certain sectors (e.g., renewable energy or agriculture) exhibit stronger ESG integration or co-movement compared to others in African markets. Lastly, researchers could explore the role of government policies, such as incentives for ESG investments, in shaping the dynamics of these markets. By addressing these areas, future studies can build on the current findings and contribute to a richer understanding of ESG investing in Africa, aiding policymakers, investors, and other stakeholders in making informed decisions.

References

- Ahmad, N., Mobarek, A., & Roshni, N. N. (2021). Revisiting the impact of ESG on financial performance of FTSE350 UK firms: Static and dynamic panel data analysis. *Cogent Business & Management*, 8(1).
- Andrews, D. W. (1993). Tests for parameter instability and structural change with unknown change point. *Econometrica*, 61(4), 821-856.
- Andrews, D. W., & Ploberger, W. (1994). Optimal tests when a nuisance parameter is present only under the alternative. *Econometrica*, 62(6), 1383 - 1414.
- Athari, S. A., & Hung, N. T. (2022). Time–frequency return co-movement among asset classes around the COVID-19 outbreak: portfolio implications. *Journal of Economics and Finance*, 46, 736-756.
- Auer, B. R., & Schuhmacher, F. (2016). Do socially (ir)responsible investments pay? New evidence from international ESG data. *The Quarterly Review of Economics and Finance*, 59, 51-62.
- Bai, J. (1997). Estimating multiple breaks one at a time. *Econometric Theory*, 13, 315 -352.
- Bai, J., & Perron, P. (1998). Estimating and testing linear models with multiple structural changes. *Econometrica*, 66, 47-78.
- Bai, J., & Perron, P. (2003a). Computation and analysis of multiple structural change models. *Journal of Applied Econometrics*, 6, 72-78.
- Bai, J., & Perron, P. (2003a). Computation and analysis of multiple structural change models. *Journal of Applied Econometrics*, 6, 72-78.
- Bai, J., & Perron, P. (2003b). Critical values for multiple structural change tests. *The Econometrics Journal*, 18, 1-22.
- Barberis, N., Shleifer, A., & Wurgler, J. (2005). Comovement. *Journal of Financial Economics*, 283-317.
- Becker, B., & Hall, S. (2009). A new look at economic convergence in Europe: A common factor approach. *International Journal of Finance and Economics*, 14, 85-97.

- Beckmann, J., Belke, A., & Dobnik, F. (2012, January). Cross-section dependence and the monetary exchange rate model - A panel analysis. *The North American Journal of Economics and Finance*, 23(1), 38-53.
- Bekaert, G., Hodrick, R. J., & Zhang, X. (2009). International Stock Return Comovements. *The Journal of Finance*.
- Bin, F., Chen, D., & Chiu, P. (2012). The nonlinear dynamic spot-futures relationship surrounding the tick size reduction on the Taiwan stock exchange: A threshold VECM approach. *Journal of Money, Investment and Banking*, 24, 27-38.
- Brooks, R., & Del Negro, M. (2004). The rise in comovement across national stock markets: market integration or IT bubble? *Journal of Empirical Finance*, 11(5), 659-680.
- Bruna, G. M., Loprevite, S., Raucci, D., Ricca, B., & Rupo, D. (2022). Investigating the marginal impact of ESG results on corporate financial performance. *Finance Research Letters*, 47.
- Caplan, L., Griswold, J. S., & Jarvis, W. F. (2013). From SRI to ESG: The Changing World of Responsible Investing. *Commonfund Institute*.
- Chen, S., Song, Y., & Gao, P. (2023). Environmental, social, and governance (ESG) performance and financial outcomes: Analyzing the impact of ESG on financial performance. *Journal of Environmental Management*, 345.
- Chetty, S., Naidoo, R., & Seetharam, Y. (2015). The Impact of Corporate Social Responsibility on Firms' Financial Performance in South Africa. *Contemporary Economics*, 9(2), 193-214.
- Chininga, E., Alhassan, A. L., & Zeka, B. (2023). ESG ratings and corporate financial performance in South Africa. *Journal of Accounting in Emerging Economies*, 692-713.
- Chow, G. C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica*, 28(3), 591-605.
- Coleman, S., Vitor, L., & de Medeiros, O. R. (2018). Latin American stock market dynamics and comovement. *International Journal of Finance & Economics*, 24(3), 1109 -1129.

- Daba Finance. (2024, June 3). *The Largest Stock Exchanges in Africa by Market Capitalization*. Retrieved from Daba Finance: <https://dabafinance.com/en/learn/blogs/the-largest-stock-exchanges-in-africa-by-market-capitalization>
- Eccles, R. G., Ioannou, I., & Serafeim, G. (2014). The Impact of Corporate Sustainability on Organizational Processes and Performance. *Management Science*, 60(11), 2835-2857.
- Embrechts, P., Lindskog, F., & McNeil, A. (2003). Modelling dependence with copulas and applications to risk management. .
- Erasmus, P., Viviers, S., & Mans-Kemp, N. (2017). Does investing in sound corporate governance pay? a South African study. *South African Journal of Business Management*, 48(2).
- Esmaeili, A., & Shokoohi, Z. (2011, February). Assessing the effect of oil price on world food prices: Application of principal component analysis. *Energy Policy*, 39(2), 1022-1025.
- Evans, D., Kramer, A. G., Lanfranchi, M., & Brijlal, P. (2023). Environmental, social and corporate governance (ESG) on the financial performance of listed mining firms in South Africa. *International Journal of Business and Economic Sciences Applied Research (IJBESAR)*, 16(2), 42-52.
- Fernandez-Macho, J. (2012, February 15). Wavelet multiple correlation and cross-correlation: A multiscale analysis of Eurozone stock markets. *Physica A: Statistical Mechanics and its Applications*, 391(4), 1097-1104.
- Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, 5(4), 210-233.
- Friedman, M. (1970, September 13). The Social Responsibility of Business is to Increase its Profits. *The New York Times Magazine*.
- Garcia, A. S., & Orsato, R. J. (2020). Testing the institutional difference hypothesis: A study about environmental, social, governance, and financial performance. *Business Strategy and the Environment*, 29(8), 2939-3722.

- Giannopoulos, G., Kihle-Fagernes, R. V., Elmarzouky, M., & Afzal-Hossain, K. A. (2022). The ESG Disclosure and the Financial Performance of Norwegian Listed Firms. *Journal of Risk and Financial Management*, 15.
- Giese, G., Lee, L.-E., Melas, D., Nagy, Z., & Nishikawa, L. (2019). Foundations of ESG Investing: How ESG Affects Equity Valuation, Risk, and Performance. *The Journal of Portfolio Management*, 45(5).
- Gilmore, C. G., & Lucey, B. m. (n.d.). The dynamics of Central European equity market comovements.
- Gilmore, C. G., Lucey, B. M., & Mcmanus, G. M. (2008). The dynamics of Central European equity market comovements. *The Quarterly Review of Economics and Finance*, 48(3), 605 - 622.
- Gilmore, C. G., Lucey, B. M., & McManus, G. M. (2008). The dynamics of Central European equity market comovements. *The Quarterly Review of Economics and Finance*, 48(3), 605-622.
- Heinkel, R., Kraus, A., & Zechner, J. (2001, December). The Effect of Green Investment on Corporate Behavior. *Journal of Financial and Quantitative Analysis*, 36(4), 431 - 449.
- Hornuf, L., & Yüksel, G. (2023). The performance of socially responsible investments: A meta-analysis. *European Financial Management*, 30(2).
- Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. *Journal of Educational Psychology*, 24, 417-441 and 498-520.
- Inaba, K.-I. (2020). A global look into stock market comovements. *Review of World Economics*, 156:517-555.
- Jiang, Y., Yu, M., & Hashmi, S. M. (2017). The Financial Crisis and Co-Movement of Global Stock Markets—A Case of Six Major Economies. *Sustainability*, 9(2), 260.
- Johannesburg Stock Exchange. (2024). *FTSE/JSE Responsible Investment Index*. Retrieved from Johannesburg Stock Exchange Web site: <https://www.jse.co.za/services/indices/ftsejse-responsible-investment-index>

- Johnson, R., Mans-Kemp, N., & Erasmus, P. D. (2019). Assessing the business case for environmental, social and corporate governance practices in South Africa. *South African Journal of Economic and Management Sciences*, 22(1).
- Junior, P. O., Tetteh, J. E., Nkrumah-Boadu, B., & Adjei, A. N. (2024, May 15). Comovement of african stock markets: Any influence from the COVID-19 pandemic? *Heliyon*, 10(9).
- Kacperczyk, M., Lin, P., & Jing, X. (2023). ESG Investing and Stock Return Comovements.
- Kiviaho, J., Nikkinen, J., Piljak, V., & Rothovius, T. (2012). The Co-movement Dynamics of European Frontier Stock Markets. *European Financial Management*, 20(3), 574-595.
- Koundouri, P., Pittis, N., & Plataniotis, A. (2022). The Impact of ESG Performance on the Financial Performance of European Area Companies: An Empirical Examination. *Environmental Sciences Proceedings*, 15(13).
- Lee, D. D., Faff, R. W., & Langfield-Smith, K. (2009). Revisiting the Vexing Question: Does Superior Corporate Social Performance Lead to Improved Financial Performance? *Australian Journal of Management*, 34(1).
- Markowitz, H. (1952, March). Portfolio Selection. *The Journal of Finance*, 7(1), 77-91.
- McWilliams, A., & Siegel, D. (2000). Corporate Social Responsibility and Financial Performance: Correlation or Misspecification? *Strategic Management Journal*, 21, 603-609.
- Modi, A. G., Patel, B. K., & Patel, N. N. (2010). The Study on Co-Movement of Selected Stock Markets. *International Research Journal of Finance and Economics*, 47, 170-185.
- Morana, C., & Beltratti, A. (2008). Comovements in international stock markets. *Journal of International Financial Markets, Institutions and Money*, 31-45.
- Morgado, P., & Tavares, J. (2006). Economic Integration and the Co-Movement of Stock Returns.
- Muzanya, S. (2022). ESG and Corporate Financial Performance: Evidence from JSE- listed firms.
- Nkomani, S. (2013). Nkomani, Sibusiso. Corporate social responsibility and financial performance: The Johannesburg Stock Exchange top 100.

- Nollet, J., Filis, G., & Mitrokostas, E. (2016). Corporate social responsibility and financial performance: A non-linear and disaggregated approach. *Economic Modelling*, 400-407.
- Nyakurukwa, K., & Seetharam, Y. (2023). Stock market integration in Africa: Further evidence from an information-theoretic framework. *International Finance*, 26(1), 2-18.
- Ocran, M., & Mlambo, C. (2009). Excess Co-Movement in Asset Prices: The Case of South Africa. *Studies in Economics and Econometrics*, 33(1), 25-39.
- Parsley, D., & Popper, H. (2020). Return comovement. *Journal of Banking and Finance*, 112.
- Principles For Responsible Investment. (n.d.). *What are the Principles for Responsible Investment?* Retrieved from Principles For Responsible Investment: <https://www.unpri.org/about-us/what-are-the-principles-for-responsible-investment>
- Quandt, R. E. (1960). Tests of the hypothesis that a linear regression system obeys two separate regimes. *Journal of the American Statistical Association*, 55(290), 324-330.
- Renneboog, L., Te Horst, J., & Zhang, C. (2008). The price of ethics and stakeholder governance: The performance of socially responsible mutual funds. *Journal of Corporate Finance*, 14(3), 302-322.
- Rua, A., & Nunes, L. C. (2009). International comovement of stock market returns: A wavelet analysis. *Journal of Empirical Finance*, 632-639.
- S&P Global. (2024, March). *S&P Global*. Retrieved from S&P Global: <https://www.spglobal.com/spdji/en/documents/methodologies/methodology-sp-egx-esg-index.pdf>
- Sayed, A. (2018). The impact of ESG compliance on the Financial Performance of JSE-listed firms.
- Schroder, M. (2004). The performance of socially responsible investments: Investment funds and indices. *Swiss Society for Financial Market Research*, 18(2), 122-142.
- Sirichand, K., & Coleman, S. (2015). International yield curve co-movements: Impact of the recent financial crisis. *Applied Economics*, 47(43), 4561-4573.
- Siyou, R. N., & Bene, M. A. (2023). African Stock Market Dynamics and Comovement. *African Development Finance Journal*, 5(3).

- Tiwari, A. K., Dar, A. B., Bhanja, N., & Shah, A. (2013, September). Stock Market Integration in Asian Countries: evidence from Wavelet multiple correlations. *Journal of Economic Integration*, 28(3), 441-456.
- Townsend, B. (2020). From SRI to ESG: The origins of socially responsible and sustainable investing. *The Journal of Impact and ESG Investing*, 1(1), 10-25.
- Tsay, R. (2005). Analysis of financial time series (2nd ed.).
- Velte, P. (2017). Does ESG performance have an impact on financial performance? Evidence from Germany. *Journal of Global Responsibility*, 8(2).
- Whelan, T., Atz, U., & Clark, C. (2022). Uncovering the Relationship by Aggregating Evidence from 1,000 Plus Studies Published between 2015 – 2020. *ESG and Performance*.
- Xie, J., Nozawa, W., Yagi, M., & Fujii, H. (2019). Do environmental, social, and governance activities improve corporate financial performance? *Business Strategy and the Environment*, 28(2), 286-300.
- Yetman, J. (2011a). The Decoupling of Asia-Pacific? In Y.-W. Cheung, V. Kakkar, & G. Ma (Eds.). *The evolving role of Asia in global finance (frontiers of economics and globalization)*, 235-253.
- Yetman, J. (2011b). Exporting recessions: International links and the business cycle. *Economics Letters*, 110, 12-14.
- Yonga, R. (2023, January 24). *African Markets*. Retrieved from African Markets Web site: <https://www.african-markets.com/en/stock-markets/bvc/the-casablanca-stock-exchange-revamps-its-range-of-indices>
- Zebedeaa, A. A., & Kasch-Haroutounian, M. (2009). A closer look at co-movements among stock returns. *Journal of Economics and Business*, 61(4), 279-294.