Acta Universitatis Danubius
ŒCONOMICA

Analysing ESG Compliance and Financial Performance in the Mining Sector in South Africa

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Abstract: Investors and policymakers in emerging markets face a critical question. Does ESG compliance truly enhance shareholder value in resource-intensive sectors, or do traditional financial factors dominate market valuations? This question is particularly urgent in the South African mining industry, where companies face increasing pressure to demonstrate environmental and social responsibility while maintaining profitability. This study used stock price returns as a performance measure to investigate the dynamic short- and long-term relationships between ESG compliance and financial performance in the South African mining sector. The study applied Panel Autoregressive Distributed Lag with Pooled Mean Group estimation to monthly data from 13 JSE-listed mining companies operating and headquartered in South Africa between 2015 and 2022. The findings revealed a significant positive long-term relationship between ESG scores and stock prices, an effect absent in the short term, demonstrating that the ESG value materialized gradually. Inflation showed a strong positive long-term effect, confirming mining stocks as inflation hedges, while GDP growth exhibited an unexpected negative relationship. Short-term stock prices responded to lagged firm size changes and current inflation, while ESG showed no immediate impact. This study provides crucial empirical evidence from South Africa's mining sector that ESG compliance operates as a long-term value.

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Keywords: ESG compliance; financial performance; mining sector, South Africa; Panel ARDL

JEL Classification: G11, G32, L71, M14, Q56

1. Introduction

The mining sector is a cornerstone of the South African economy, contributing significantly to employment, GDP, and export revenues (Stats SA, 2024; SARB, 2025). However, this economic contribution is juxtaposed with substantial environmental and social costs, including acid mine drainage, water contamination (Laker, 2023), and complex governance challenges such as illegal artisanal mining (Bester & Uys, 2023). As global attention on Environmental, Social, and Governance (ESG) factors intensifies, these metrics have become crucial for assessing corporate sustainability and long-term risk (Khamisu & Paluri, 2024). Yet a fundamental tension persists: does ESG compliance represent a genuine driver of financial value or remain secondary to traditional financial and macroeconomic factors?

This tension is extremely critical in South Africa's mining sector, where the industry's contribution to GDP has declined from approximately 21% in the 1980s to around 8% in recent years (SARB, 2025). This decline is raising critical questions about the long-term sustainability and competitiveness of RSA's mining sector. The Johannesburg Stock Exchange responded by introducing mandatory Sustainability Disclosure Guidance in 2022, aligned with international frameworks including the GRI, TCFD, and IFRS S1 and S2 standards (JSE, 2024). This regulatory change reflects the growing recognition that ESG performance may be integral to restoring investor confidence. However, whether ESG compliance can genuinely address this deterioration or represents an additional cost burden on a struggling sector remains empirically unresolved.

Existing research on ESG in mining has predominantly employed accounting-based metrics, yielding inconclusive results. Fikru et al. (2024) found no direct link between ESG scores and the profitability of mining firms globally, noting that firms rated with ESG tend to be larger, but do not necessarily achieve lower debt costs or higher returns on assets. Evans et al. (2023) examined South African mining firms and discovered that while overall ESG scores had weak connections with Return on Assets (ROA) and Return on Equity (ROE), individual components revealed nuanced patterns: social factors positively affected profitability, while emissions and poor working conditions had negative effects. Matemane et al. (2024) reinforced this

pattern for South African listed firms, finding that ESG metrics did not significantly affect ROA in the short term.

These accounting-based approaches may miss a critical dimension: how equity markets price ESG performance. Accounting metrics such as ROA and ROE are backward-looking measures that capture historical profitability, but do not reflect investor expectations about future cash flows, risk profiles, and long-term sustainability, If ESG compliance influences how investors value mining companies, through reduced regulatory risk, enhanced social license to operate, or improved capital access. These effects would manifest themselves in stock prices before appearing in accounting statements. Stock prices incorporate forward-looking information and represent the market's collective assessment of prospects, making them more appropriate for evaluating whether ESG compliance addresses investors' concerns about the sector's viability. This distinction is particularly significant given that major institutional investors in South Africa, including UN-PRI signatories such as Old Mutual Investment Group, Allan Gray, and the Public Investment Corporation, increasingly integrate ESG criteria into their investment mandates, directly influencing stock prices through capital allocation decisions.

The macroeconomic dimension adds further urgency. Mining firms' contribution to GDP makes their performance inseparable from broader economic health, yet the sector's declining GDP share suggests that traditional value drivers may no longer suffice. Can ESG compliance contribute to reversing this decline by enhancing investor confidence and securing social license, or does it merely impose additional costs? Addressing this question requires controlling for macroeconomic variables, particularly GDP growth and inflation, that directly affect mining valuations. GDP growth influences domestic mineral demand and reflects broader economic conditions, while inflation affects input costs and commodity revenue values, with mining stocks potentially serving as inflation hedges.

This empirical uncertainty manifests itself in three critical unknowns. First, does mining firm financial performance, as reflected in market valuations, respond meaningfully to changes in ESG compliance? Second, if such a response exists, is it concentrated in the short run or does it emerge as a long-run equilibrium relationship? Third, how quickly do market valuations adjust following ESG-related shocks, and do macroeconomic fundamentals ultimately dominate ESG factors? Current research, based predominantly on static models and accounting-based

metrics, cannot adequately separate short-run dynamics from long-run outcomes, leaving this temporal dimension non-transparent.

2. Literature Review

This review of the literature looks at the theoretical and empirical basis for understanding how ESG considerations affect the behaviour of companies and financial results in the South African mining sector. Guided by stakeholder theory, green growth theory, and institutional investor theory, it investigates how mining companies navigate the expectations of various stakeholders and respond to investor driven ESG pressures. The review first considered the conceptual foundations of ESG, including the emergence of global initiatives such as the United Nations Global Compact and the United Nations Principles for Responsible Investment, and then examined its application in mining, a sector with high environmental and social risks. Policy frameworks such as just energy transition (JET), integrated resource planning (IRP), mining charter III, and ESG disclosure guidelines of the Johannesburg Stock Exchange have been analysed to contextualize compliance within the regulatory and investment environment of South Africa. Empirical evidence from the developed and the developing countries has been synthesized to assess the relationship between ESG performance, disclosure, and business value while identifying key gaps that this study seeks to address.

The concept of ESG emerged from 'Who Cares Wins: Connecting Financial Markets to a Changing World', A report by Global Impact, United Nations. This report was the result of a joint initiative of financial institutions that were invited by the then Secretary General of the United Nations, Kofi Annan, to explore how to effectively integrate ESG issues in asset management, securities broking services, and related research functions (UN Global Compact, 2004). The report argued that, in the long run, consideration of ESG factors will contribute to stronger and more resilient markets; in addition, it will contribute to the sustainable development of societies. This report laid the groundwork for the United Nations Principles for Responsible Investments (UN-PRI) (2006). The PRI consists of six voluntary principles that offer a framework for investors to follow when incorporating ESG factors into investment decisions and ownership practices. According to the latest data, the PRI has more than 5300 signatories, accounting for more than $128 trillion in assets as of October 2024 (Amundi, 2024; Onimpact, 2024). This growth in ESG-integrated capital highlights the global shift toward sustainable and responsible investing, highlighting

a growing trend of stakeholders' expectations on ESG. In addition, the rise of ESG reflects the paradigm shift for businesses and investors to balance profit with long-term social impact. This is a shift that is closely aligned with Freeman's 1984 stakeholder theory that companies must create value for all stakeholders involved in their business.

Freeman (1984) defined stakeholders as any group that can affect or be affected by the achievement of a business objective. In layman's terms, a stakeholder is any individual or group that has influence and can be influenced by the business operations in its pursuit to generate profit. Typical stakeholders include employees, customers, creditors, suppliers, investors, and the local community in which the business operates. Talan et al. (2024) highlighted that stakeholder theory states that a firm needs to add value to all individuals affected by its operation and further emphasized the importance of stakeholder management for sustainable firm practice and corporate performance. This theory is relevant for conceptualizing ESG in the mining sector, as ESG performance reflects how an entity affects the stakeholders involved in its operations. Mining companies negatively affect the environment in several ways. For example, Liefferink (2016) highlighted how gold and uranium mines in the Witwatersrand have led to contamination and destruction of wetlands, posing hazards to surrounding communities. Stakeholder theory, in this instance, would argue that mining companies should consider how their operations affect local communities and the environments within which they operate, which are linked to the Social and Environmental pillars of ESG and how they will affect future generations. The theory also claims that companies must engage workers, residents, and the communities at large to avoid crises such as labour strikes and safety issues. In the mining sector, a good example would be the Marikana massacre of 2012 (eNCA, 2025), where 45 mine workers were killed during a strike at the Lonmin mine. The presence of communication channels between the mineworkers and the mine could have potentially prevented this tragedy. This demonstrates that ESG practices are not only ethical obligations but essential strategies for risk management, sustainability, and long-term value creation in the mining industry.

Although stakeholder theory highlights the need for companies to balance profitability with the interests of communities, workers, and the environment, green growth theory extends this perspective by emphasizing how broader economic policies and sustainable investments, such as ESG-driven financing, can enable the mining sector to align profitability with long-term environmental stewardship and social equity.

The Organization for Economic Co-operation and Development (OECD) defined green growth as economic growth that promotes a sustainable environment with low emissions while ensuring inclusion in society. This definition is highly relevant for the mining sector, as it directly affects the environment. Research has shown that green finance can be substantial towards green growth. For a country rich in natural resources, Huang (2024) highlights that green growth can be driven by ESG investments and green bonds. Deng et al. (2024) find that, for developing nations, it is imperative for the government to not only offer green funding for green projects to firms but also ensure that they are used effectively. Furthermore, studies in Asia, specifically in the mining sector, found that an increase in green growth is positively associated with reduced gold mining extraction volumes: with a 1% increase in the growth index correlated with a 0.13% decrease in the extraction volume (Zhao & Xing, 2024). Hector (2025) emphasized that the transition to a green industrial policy has both opportunities and threats in South Africa. Additionally, he stated that RSA is highly dependent on coal, which limits the country's ability to meet its commitments to green growth. South Africa's industrial capacity in sectors such as wind and solar, as well as its renewable energy potential, is a solid foundation for reindustrialization and sustainable growth. Translating green growth into action requires supportive policy frameworks, and in South Africa these frameworks, such as the JET and IRP, directly shape how mining companies pursue ESG compliance.

Although Green Growth Theory shows the potential to combine sustainability and profit, South Africa has its own set of policies and challenges that shape how companies comply with ESG in the mining sector. A key factor in this change is the Just Energy Transition (JET) strategy (The Presidency, 2022). This strategy aims to reduce carbon emissions in the South African economy while protecting jobs, promoting fairness, and creating green jobs. The mining sector, particularly coal mining, is directly involved. It faces increasing pressure to reduce emissions while ensuring that workers and communities that rely on these operations are not overlooked. Adding to this is the integrated resource plan (DMRE, 2019), which outlines South Africa's long-term energy mix. This plan signals a shift away from coal and toward renewable energy sources like solar and wind, where mining companies are expected to change their operations and investments.

In addition to energy-related policies, frameworks like the Mining Charter III, the National Environmental Management Act 107 of 1998 (NEMA), and the Carbon Tax Act 15 of 2019 incorporate ESG compliance into the regulatory landscape (South African Government, 1999). The Mining Charter sets goals for the

responsibilities of transformation and social development. NEMA requires environmental approvals for mining activities. The Carbon Tax Act 15 of 2019 (South African Government, 2019) encourages companies to reduce their carbon emissions, making environmental care a financial necessity. Furthermore, the policy focuses on essential minerals such as platinum and gold for green technologies, hydrogen fuel cells and clean energy infrastructure, creating both opportunities and pressure for companies to meet ESG standards in global supply chains. These policy tools show that compliance with ESG in South African mining is not just a token effort; it is a reaction to changing regulatory, environmental, and investment demands. This reality makes it important to examine how this compliance impacts financial outcomes for firms.

The Johannesburg Stock Exchange (JSE) plays a vital role in promoting accountability for Environmental, Social, and Governance (ESG) practices within South Africa's financial markets, influenced by government policies and the demands of institutional investors. In June 2022, the JSE introduced its Sustainability Disclosure Guidance and Climate Change Disclosure Guidance, aimed at helping companies enhance the transparency and comparability of their ESG reporting. These guidelines align with internationally recognized frameworks, including the Global Reporting Initiative (GRI) and the Task Force on Climate-related Financial Disclosures (TCFD), as well as the International Sustainability Standards Board's IFRS S1 and S2 standards (JSE, 2024a). The JSE revisits these guidelines regularly to ensure they stay relevant for South African businesses while considering global best practices and local regulations. This ongoing adjustment helps maintain a flexible framework that evolves with changing sustainability standards both globally and domestically.

Recent developments indicate that South Africa is moving towards a more unified approach to sustainability disclosure among its regulators. In 2024, the Prudential Authority (PA) released climate-related disclosure guidance for banks and insurers, outlining essential governance and risk management expectations. At the same time, the Financial Sector Conduct Authority (FSCA) issued its Sustainable Finance Consumer Risk Report and Roadmap, which recommends voluntary corporate disclosure guidelines that align with ISSB standards (JSE, 2024bb). Moreover, the Department of Trade, Industry and Competition (DTIC) and the Companies and Intellectual Property Commission (CIPC) are looking into the possibility of mandatory sustainability reporting. The CIPC's updated XBRL Taxonomy, released in 2024, already allows companies to tag their disclosures following ISSB standards

(JSE, 2024c). Together, these efforts demonstrate that ESG disclosure is becoming increasingly central to South Africa's financial system. For the mining sector, this raises the stakes for adhering to ESG reporting that meets both investor demands and regulatory expectations, making disclosure a crucial element for securing capital. While government policy creates the regulatory environment for ESG, institutional investors play an equally powerful role by directing capital flows and shaping corporate ESG strategies through investment decisions.

Institutional investors like pension funds and asset managers influence corporate ESG behaviour. A study conducted by Lopez-de-Silanes et al. (2024), highlighted that institutional investors hold on more on high ESG rating stocks; furthermore, they found that managers often include a smaller portion of ESG rated stocks on their portfolios to attract investors who values ESG. in addition to this, Drobetz et al. (2024) propose a "ESG-as insurance" hypothesis which contends that institutional investors improve ESG performance for Small and medium-sized enterprises that are initially high ESG scores and at risk of failing. Moving with the same sentiments, Sun and Zhao (2024) conducted a study in China and found that these institutional investors strengthen ESG outcomes by improving ESG performance and reducing its weaknesses. Moving on to the South African mining sector, some prominent institutional investors are UN-PRI signatories, ESG compliant, and hold substantial stocks in the mining sector. Including Old Mutual Investment Group (2025), Allan Gray (Munsie, 2025), Ninety-One (Chevereley, 2025), Coronation Fund Managers (2021), and the Public Investment Corporation (PIC) (2024). This entails that South African companies that are ESG compliant may gain a competitive advantage in accessing capital, improved investor sentiments, and market confidence. Some studies by Kim and Yoon (2022), and Liang, Sun and Teo (2022) warn that some signators show 'symbolic' compliance, using the UN-PRI status to attract capital while not complying with their ESG requirements. These studies highlight a gap in the assessment of whether voluntary ESG compliance transcends into genuine integration of ESG into business operations. Morer research is needed on the affiliation and actual performance of ESG.

Empirical studies on the relationship between ESG and business financial performance found mixed results, which often vary by sector, country, and time horizon.

2.1. ESG Ratings and Firm Financial Performance

The influence of institutional investors highlights the financial dimension of ESG, which raises the question of whether ESG ratings and practices translate into measurable firm performance, a debate that has produced mixed empirical results. A study by Aydogmus et al. (2022) found that a combined ESG score is significantly and positively related to the firm value. The Social (S) and Governance (G) components showed strong positive effects, while the Environmental (E) component had a negative relationship with profitability. These findings suggest that environmental efforts may delay financial returns. Furthermore, Esparica and Gubavera (2024) supported this by noting that high environmental scores can reduce short-term equity returns. However, Verheyden et al. (2016) found that ESG screening could improve returns by approximately 0.16% annually, highlighting the long-term financial benefits of ESG practices. On the contrary, Fikru et al. (2024) found no direct link between ESG scores and mining firm performance. They noted that ESG-rated firms tend to be larger, but do not necessarily see lower debt costs or higher profitability. Alves et al. (2025) also found weak correlations between ESG and financial performance worldwide from 2001 to 2020, although they recommend reassessing this after COVID. Galema and Gerritse (2025) examined changes in ESG ratings and their effect on financial returns. They discovered that institutional investors with long-term perspectives adjusted their portfolios after ESG downgrades. Changes in Environmental (E) impacted short-term abnormal returns, while changes in Social (S) and Governance (G) ratings had limited effects. Bilivogui and Iqbal (2025) looked at the components of ESG in BRICS countries. In South Africa, environmental factors harmed ROA and ROE in the short term. On the contrary, social factors improved the value of the market (Tobin's Q). Governance consistently increased profitability in all BRICS nations. They also pointed out the effects of firm size and leverage; larger firms tend to perform better, while high leverage decreases profitability. Similarly, Matemane, Msomi and Ngundu (2024) found that ESG metrics do not significantly affect ROA in the short term for South African listed firms. This reinforces the idea that ESG effects may appear over longer time frames or through different performance measures. Although ESG ratings provide useful aggregate indicators, they often overlook sector-specific risks. This makes it crucial to assess ESG within the unique context of mining, where environmental and social risks are particularly pronounced.

2.2. ESG Risk in the Mining Sector

Studies focusing on mining highlight the need for local ESG frameworks. Cole (2023) examined the Mogalakwena mine and noted that, while ESG-related risks are high in South African mining, global demand for platinum supports these operations. The study recommended that ESG risks are addressed through local governance rather than relying on global regulations. Garcia-Zavala et al. (2023) supported this view in a study of Chilean mining. They noted that national data often hide site-specific risks. This is relevant for South Africa, where mines such as Mponeng (Gauteng) and Zibulo Colliery (Mpumalanga) have different risk profiles for ESG. Evans et al. (2023) discovered that while overall ESG scores had weak connections with firm performance, social factors (such as CSR and human rights) positively affected profitability, while emissions and poor working conditions had the opposite effect. Addressing these risks also depends on transparency, and ESG disclosure has emerged as a critical mechanism to reduce information asymmetry and strengthen accountability in mining firms.

2.3. ESG Disclosure and Firm Value

Disclosures are important in reducing information gaps. Veeravel et al. (2024) found that firms with a thorough ESG reporting perform better in India. Malik and Khashiramka (2025) showed that these disclosures enhance a firm's ability to use debt, especially in high-interest-rate settings. Similarly, Wang et al. (2025) demonstrated that for Chinese energy firms, ESG disclosure increases value by lowering financing costs and encouraging innovation. Husnah (2023), who studied Indonesian mining companies, observed that ESG disclosure significantly increases Tobin's Q and sales growth in the long run, although it does not affect short-term ROA. These findings suggest that clear communication about ESG can build market trust and a long-term competitive advantage. Although disclosure improves market trust and financing access, the actual financial impact of ESG practices often depends on the time horizon, making it necessary to distinguish between short-run trade-offs and long-run benefits.

2.4. Short-Run vs. Long-Run ESG Financial Impacts

Research on time frames adds insight into ESG-finance issues. Bertelli and Torricelli (2024) concluded that ESG-screened portfolios only outperform in the long run and

provide limited safety during crises. Feng et al. (2022) found that CSR improves long-term stock returns, although ESG effects are clearer in the short term for profitable firms. Mouffok and Mouffok (2025) noted that economic policy uncertainty (EPU) affects ESG components in different ways. Environmental indices recover in the long run, while the social and governance indices remain unstable. Kräussl et al. (2024) warned that ESG investments might underperform non-ESG ones in the long term, but they offer short-term benefits due to investor sentiment. Diaye et al. (2021) showed that while ESG does not impact GDP per capita in the short term, strong ESG performance correlates with long-term economic growth in OECD countries. Despite these insights, cross-country differences, inconsistent methodologies, and limited sector-specific studies leave important questions unanswered, especially in the South African mining sector. This gap motivates the present study, which seeks to provide context-specific evidence on ESG compliance and its financial implications.

Although the above-mentioned empirical studies have explored the relationship between ESG performance, disclosure, and firm value, several important gaps remain. First, these studies are often conducted in different countries with diverse economic structures, making it difficult to generalize the findings across contexts. Second, there is inconsistency in the ESG rating methodologies and metrics used, with various agencies applying different criteria and weighting systems. Third, variations in ESG disclosure standards and regulatory requirements across jurisdictions further complicate comparative analysis. There is a lack of empirical research specifically focused on South Africa and its mining sector, despite its high environmental and social risk profile and economic dependence on extractive industries. This study addresses this gap by offering context-specific insights into ESG dynamics within the South African mining sector.

The literature review revealed that while ESG integration can improve long-term financial performance, its short-term effects are often mixed, with environmental initiatives that require extended time frames to obtain profits. Evidence also shows that the outcomes of ESG are highly context dependent, varying between sectors, geographies, and rating methodologies. In South Africa's mining sector, compliance is shaped by a connection between global investment norms, national policy frameworks, and site-specific risks. The theoretical perspectives considered provide a basis for understanding how mining companies respond to stakeholder pressures, align with sustainable growth objectives, and adapt to investor expectations. However, significant gaps remain in empirical research that is specific to the South

African mining context, particularly in linking ESG risk, disclosure, and performance to firm-level financial outcomes. This study addresses these gaps by offering a context-specific analysis of ESG compliance in South African mining companies, with a focus on both short- and long-term financial implications.

3. Methodology

3.1. Sample Selection and Data Sources

This research used a quantitative study design to investigate the effects of Environmental, Social, and Governance (ESG) compliance on the financial performance of the mining sector in South Africa. The primary objective was to empirically assess the relationship between ESG performance, gauged by ESG scores and related metrics, and the financial results of mining companies. The study analysed monthly data from 2015 to 2022. The variables were measured using various units; for instance, some are in millions of ZAR, others in cents, and some as percentages. Therefore, all these variables used in the study were transformed into their natural logarithmic forms to normalize the distribution and allow interpretation in percentages.

This study focused on mining firms listed on the Johannesburg Stock Exchange (JSE) and headquartered in South Africa, aligning with a similar study conducted by Evans et al. (2024) in the same region. The 13 mining companies that are covered in this study represent the sector's core activities: three gold miners (DRDGOLD, Gold Fields, Harmony Gold), five companies focused on platinum group metals and other non-gold precious minerals (Sibanye Stillwater, Valterra Platinum, Impala Platinum, Northam Platinum, Wesizwe Platinum), three major iron and steel producers (Arcelormittal SA, Kumba Iron Ore, Merafe Resources) and one aluminium producer (Hulamin). The selection of mining companies that operate within South Africa with their headquarters within the country is crucial to mitigate the risk of external factors such as macroeconomic landscapes (GDP, inflation, or interest rates) of other countries from influencing the results of the study. Other mining companies that are listed on the JSE but based at different locations can engage in varying activities and follow different regulations and practices, which could affect the legitimacy of the investigation (Evans et al., 2024). Furthermore, these companies were selected due to the availability of reliable ESG data, as well as financial performance information over the observed period.

This study used secondary data obtained from Refinitiv Eikon, a reputable platform widely used in ESG research, including studies by Alves et al. (2025), Fikru et al. (2024), and Aydogmus et al. (2022). Its relevance for the South African mining context is further strengthened by its use in the work of Evans et al. (2024). Financial data will be sourced from Iress to ensure accuracy. To control for the broader economic environment, data on GDP growth and inflation will be obtained from Statistics South Africa and Refinitiv.

3.2. Definition and Measurement of Variables

3.2.1. Dependent Variable: Stock Price (LPRICE)

Although many prominent studies, such as those by Bilivogui and Iqbal (2025) for emerging markets and Matemane et al. (2024) for South African firms, have relied on accounting-based metrics like Return on Assets (ROA) and Return on Equity (ROE), this study adopted a market-based perspective by using stock price Returns (LPRICE) as its primary dependent variable. This approach was motivated by several critical factors. First, the stock price return is a forward-looking indicator that incorporates investors' collective and real-time expectations about a company's future cash flows and risk profile. This makes it superior for capturing the long-term value implications of ESG performance, which backward-looking accounting metrics often fail to reflect. Furthermore, this decision follows Magubane and Wesi (2023), who successfully used the stock price to analyse the impacts of ESG in the South African financial sector. Consequently, this study applied this established market-based approach to the mining industry, addressing a specific gap, as many existing mining sector studies, such as Evans et al. (2023), have focused predominantly on profitability ratios, leaving the direct impact of ESG on market valuation less explored.

3.2.2. Independent Variable: ESG Score (LESG)

The combined ESG score serves as the primary independent variable of the study.

3.2.3. Control Variables

Firm Size (LSIZE)

To capture the heterogeneity of the sampled firms, the study used firm size (LSIZE), measured as the natural logarithm of total assets. Firm size is controlled for because larger firms often have advantages such as economies of scale and easier access to

capital, which can influence stock price independently of their ESG performance (Bilivogui & Iqbal, 2025).

Gross Domestic Product (LGDP)

The inclusion of GDP growth was to account for the broader economic cycle. The mining sector is highly cyclical, and economic expansions typically drive higher commodity demand, increasing investor sentiment and stock prices.

Inflation Growth Rate (LINFL)

The inflation rate was included as a result of its dual impact. It can erode real returns and lead to higher interest rates (depressing valuations), but mining stocks can also act as an inflation hedge. Controlling for this helps isolate the ESG effect.

The summary of all the variables used in the study is presented in Table 1.

Table 1. Description of variables

Variable Name	Variable	Definition	Data Source
Stock Price Returns	LPrice	Log of historical share price per annum	Iress
ESG Score	LESG	Composite score reflecting overall environmental, social, and Governance performance	Refinitiv Eikon
GDP Growth Rate	LGDP	Annual percentage growth rate of national GDP	Stats SA & Refinitiv Eikon
Inflation Growth Rate	LINFL	Annual percentage change in consumer price index (CPI)	Stats SA & Refinitiv Eikon

3.3. Empirical Model: Panel ARDL-PMG

To investigate the dynamic short-run and long-run relationships between ESG compliance and financial performance, this study employed the Panel Autoregressive Distributed Lag (ARDL) framework, specifically utilizing the Pooled Mean Group (PMG) estimator. The ARDL approach was selected because it can handle non-stationary data and test for long-run relationships among variables through cointegration, allowing the analysis to capture both short-run dynamics and long-run equilibrium simultaneously (Kao, 1999). This methodology has been successfully applied in several recent ESG studies (Ghouse et al., 2024; Zhou & Liu, 2023; Zhou et al., 2024).

The theoretical rationale for the PMG estimator specifically was drawn from the econometric literature, as synthesized by Asteriou and Hall (2021): "The PMG method of estimation occupies an intermediate position between the MG method, in which both the slopes and the intercepts are allowed to differ across countries, and the classical fixed effects method, in which the slopes are fixed and the intercepts are allowed to vary. In PMG estimation, only the long-run coefficients are constrained to be the same across countries, while the short-run coefficients are allowed to vary. It possesses the efficiency of pooled estimation while avoiding the inconsistency problem flowing from pooling heterogeneous dynamic relationships." This specification was suitable for our analysis of South African mining companies. It is implausible that all firms have identical short-run dynamics, as their immediate reactions to ESG or economic shocks may differ due to firm-specific factors such as operational structure, leverage, and management responsiveness. However, it is conceptually reasonable to assume that there is a common long-run equilibrium relationship, shaped by the shared macroeconomic environment, the regulatory landscape (including the Mining Charter III, NEMA, and the Carbon Tax Act), and the global commodity markets. The PMG estimator was designed for this scenario, as it strikes a balance between heterogeneity in short-run adjustments and homogeneity in long-run relationships. Asteriou and Hall (2021) specify PARDL-PMG as follows:

$$\Delta y_{it} = \theta_i\left(y_{i,t-1} - \beta' x_{i,t-1}\right) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \gamma'_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (1)$$

Δy_{it} was the first difference of the dependent variable, representing the short-run change in the log of stock price (LPRICE) for firm i in period t. θ_i was the firm-specific error correction term, measuring the speed of adjustment back to the long-run equilibrium. A significant, negative value confirms a long-run relationship. $y_{i,t-1} - \beta' x_{i,t-1}$ was the error correction term, representing the deviation from the long-run equilibrium in the previous period. β' was the vector of homogeneous long-run coefficients. $x_{i,t}$ was the vector of independent variables (LESG, LSIZE, LGDP, LINFL) for firm i. $\sum_{j=1}^{p-1} \gamma_{ij} \Delta y_{i,t-j}$ represented the short-run dynamics of the dependent variable, with γ_{ij} as the firm-specific coefficients for the lagged differences of LPRICE. $\sum_{j=1}^{p-1} \gamma_{ij} \Delta y_{i,t-j}$ represented the short-run dynamics of the independent variables, with γ'_{ij} as the firm-specific coefficients for the lagged differences of the regressors. μ_i represented the firm-specific fixed effects. $\varepsilon_{i,t}$ was

the idiosyncratic error term. When transforming equation 1 to match the study, equation 2 is obtained.

$$\Delta LPRICE_{it} = \phi_i\left(LPRICE_{i,t-1} - \theta_i X_{it}\right) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta LPRICE_{i,t-j} + \sum_{j=0}^{q-1} \beta_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \quad (2)$$

4. Results and Discussion

4.1. Descriptive Statistics

Table 2 shows the descriptive analysis of the study. The stock price (LPRICE) performance was used as the dependent variable in the study. The stock price ranged between 3.56 and 11.09. Furthermore, the stock price had a standard deviation of 2.00, making it the second most volatile variable in the study. The stock price also has a mean that is less than the median, indicating negative skewness, which can be confirmed by the skewness value of -0.32, reflecting occasional sharp declines in stock prices during the study period. Lastly, the stock price showed a kurtosis <3, implying that the data is relatively flat. The second variable, which is the combined ESG score (LESG), ranged between 3.15 and 4.49, which is around its median of 4.07. Furthermore, ESG has a low standard deviation (0.32), indicating that it is the second least volatile among the five factors. LESG is also negatively skewed, as the mean is slightly less than the median. The skewness value is negative (-0.69), similar to the stock price, and it is also relatively flat (Kurtosis=2.82), (Platykurtic). Contrary to the first two variables, firm size, which is the log of total assets, was positively skewed, with a positive (1.35) skewness value and a mean higher than the median. Furthermore, firm size exhibited the highest volatility among all the variables, with a standard deviation of 2.94. Firm size (LSIZE) ranged between 14.64 and 25.84, with a kurtosis greater than three, indicating a relatively tall distribution (Leptokurtic). South Africa's GDP growth (LGDP) ranges from -2.30 to 2.62, with a mean of -0.54 and a median of -0.69. This broad range captures significant macroeconomic volatility during the 2015-2022 period, including a sharp contraction during the COVID-19 pandemic. The standard deviation of 1.16 indicated substantial volatility in economic growth. GDP growth exhibited a positive skewness (0.60), indicating more extreme positive values than negative ones, and a kurtosis of 3.59, suggesting a moderately peaked distribution. Lastly, the Consumer Price Index rate, which is represented by inflation (LINFL), ranged between 0.34 and 2.05. INFL had the lowest volatility among all the other variables. Similarly to

LPRICE and LESG, LINFL was negatively skewed with a lower mean than median and a negative skewness rate (-1.27). LINFL had the highest kurtosis of 6.6, indicating variability in inflation dynamics during the study period. In conclusion, all five variables have a JB p-value of 0.00, which is less than 0.05, indicating that the data are not normally distributed. This JB value justifies the use of the PMG-ARDL method, as it does not assume normality in the data.

Table 2. Descriptive statistics

	LPRICE	LESG	LSIZE	LGDP	LINFL
Mean	7.480655	4.010069	18.22931	-0.536637	1.563759
Median	7.876067	4.074772	17.70330	-0.693147	1.589235
Maximum	11.09488	4.489678	25.83905	2.624669	2.054124
Minimum	3.555348	3.154218	14.64293	-2.302585	0.336472
Std. Dev.	1.996066	0.321871	2.949981	1.159881	0.283859
Skewness	-0.315767	-0.692654	1.348891	0.599812	-1.269248
Kurtosis	2.076181	2.824000	3.795472	3.588589	6.618027
Jarque-Bera	44.76891	69.71446	282.8111	63.83295	698.3434
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	858	858	858	858	858

Source: Authors' own estimation (2025)

4.2. Correlation Matrix

Table 3 shows the Pearson's correlation coefficients for the variables. A moderately positive correlation was found between LPRICE and LESG. This may imply that high ESG scores are associated with higher stock price performances. The correlation between the independent variables is insignificant.

Table 3. Correlation matrix

Correlation	LPRICE	LESG	LSIZE	LGDP	LINFL
LPRICE	1.000000				
LESG	0.617243	1.000000			
LSIZE	0.187637	0.010285	1.000000		
LGDP	0.110411	0.116370	0.043392	1.000000	
LINFL	0.004613	-0.118636	-0.000878	-0.326016	1.000000

Source: Authors' own estimation (2025)

4.3. Unit Root Tests

4.3.1. Levin, Lin and Chu T-stat

To test stationarity, the Levin, Lin and Chu test was first conducted to test the null hypothesis of no stationarity against the alternative hypothesis of stationarity and to determine the order of cointegration. Individual tests revealed that LGDP and LINFL are stationary at level and cointegrated in the order of I(0). Conversely, LESG, LSIZE and LPRICE are nonstationary at level and are integrated of order I(1). All variables were stationary at first difference.

Table 4. LLN test

Variables	Level		First Difference		
	T-stat	P value	T-stat	P value	cointegration
LPRICE	-0.59257	0.2767	-14.1059	0.0000	I (1)
LESG	-1.04269	0.1485	-15.8675	0.0000	I (1)
LSIZE	0.17511	0.5695	-9.81102	0.0000	I (1)
LINFL	4.78763	0.0000	-17.4413	0.0000	I (0)
LGDP	-6.81236	0.0000	-11.4487	0.0000	I (0)

Source: Authors' own estimation (2025)

4.3.2. ADF Test

Magubane and Wesi (2023) highlighted that the LLN test has limited power to reject the null hypothesis, and therefore the ADF test was also conducted to supplement the LLN test. The ADF test confirmed these findings and revealed that LINFL and LGDP are still stationary at the level, while LPRICE, LESG, and LINFL are stationary at the first difference. Since the model used in this study can accommodate different levels of stationarity as long as they are within I(0) and I(1), the analysis proceeds with the estimation of the model using I(0) variables.

Table 5. ADF Test

Variables	Level		First Difference		
	T-stat	P value	T-stat	P value	Order of cointegration
LPRICE	19.8242	0.7998	239.005	0.0000	I (1)
LESG	30.6016	0.2434	186.042	0.0000	I (1)
LSIZE	16.0226	0.9357	105.533	0.0000	I (1)
LINFL	81.8597	0.0000	427.716	0.0000	I (0)
LGDP	88.4915	0.0000	172.010	0.0000	I (0)

Source: Authors' own estimation (2025)

4.4. Cointegration Test

Before estimating the PMG-ARDL model, cointegration tests were performed to establish whether long-run equilibrium relationships between the variables. The Johansen tests, through the Trace and Max-Eigen tests, were conducted. The KAO test was used to validate the Johansen results.

4.4.1. Johansen Cointegration Tests

The Johansen trace test cointegration test (Table 6) provides strong evidence of cointegration. The null hypothesis for the Johansen test is that there are no co-integrating equations. This null is rejected by the trace statistic (trace statistic = 112.04, $p < 0.0001$). The test further indicates acceptance of the null of at most one cointegrating equation (trace statistic = 56.83, $p = 0.0057$).

Table 6. Trace Test Johansen cointegration tests

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.111263	112.0358	69.81889	0.0000
At most 1 *	0.059368	56.83335	47.85613	0.0057
At most 2	0.048184	28.19044	29.79707	0.0757
At most 3	0.007388	5.078718	15.49471	0.8004
At most 4	0.003431	1.608532	3.841465	0.2047

Source: Authors' own estimation (2025)

The max eigenvalue statistic in Table 7 similarly confirms the presence of at least two cointegrating relationships by rejecting the null of none (max eigenvalue = 55.20, $p < 0.0001$) and the null of at most one (max eigenvalue = 28.64, $p = 0.0365$).

Table 7. Max Eigen Johansen cointegration tests

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.111263	55.20247	33.87687	0.0000
At most 1 *	0.059368	28.64291	27.58434	0.0365
At most 2 *	0.048184	23.11172	21.13162	0.0260
At most 3	0.007388	3.470186	14.26460	0.9106
At most 4	0.003431	1.608532	3.841465	0.2047

Source: Authors' own estimation (2025)

4.4.2. KAO Test

The Kao residual cointegration test further validates these findings. For the Kao test, the null hypothesis is also of no cointegration. The ADF statistic of -3.694 (p = 0.0001) decisively rejects this null hypothesis, confirming that a stable long-term relationship exists between LPRICE, LESG, LSIZE, LGDP, and LINFL. This provides a strong econometric foundation for proceeding with the PMG-ARDL estimation.

Table 8. Kao test

	t-Statistic	Prob.
ADF	-3.694169	0.0001
Residual variance	0.035374	
HAC variance	0.034902	

Source: Authors' own estimation (2025)

4.5. Lag Selection Criteria

The optimal lag structure was determined using standard information criteria (Table 9). The Akaike Information Criterion (AIC) selected a lag length of 3, while the Schwarz Criterion (SC) and Hannan-Quinn Criterion (HQ) both selected a lag length of 2. Given the trade-off between model fit and parsimony, and following the AIC recommendation, which is less restrictive, the study proceeded with the PMG-ARDL specification identified through EViews' automatic selection procedure. The final model selected was PMG (1,0,2,0,1), as indicated by the AIC after evaluating 768 potential model specifications.

Table 9. Selection of lag lengths

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3155.252	NA	0.073287	11.57602	11.61542	11.59142
1	1747.427	9697.607	1.27e-09	-6.290942	6.054534*	-6.198528
2	1808.902	120.4723	1.12e-09	-6.424548	-5.991134	6.255123*
3	1844.581	69.26772*	1.07e09*	6.463667*	-5.833247	-6.217230

Source: Authors' own estimation (2025)

4.6. Model: Panel ARDL-PMG Results and Discussion

Table 10 presents the findings of the PMG-ARDL model, which distinguishes between short-run dynamics and long-run equilibrium relationships. This distinction is crucial to understanding the temporal dimension of the financial impact of ESG on South Africa's mining sector.

4.6.1. Long-Run Equilibrium Relationships

4.6.1.1. ESG Performance (LESG)

The long-run coefficient for ESG is positive and highly significant (coefficient = 3.714, $p < 0.0001$), indicating that a 1% increase in ESG compliance is associated with a 3.71% increase in stock prices over the long term. This substantial elasticity provides compelling evidence that ESG compliance drives market valuations in South African mining, contradicting the findings of Fikru et al. (2024), who found no direct link between ESG scores and mining firm performance globally, and Matemane et al. (2024), who reported no significant ESG effects on ROA for South African listed firms in the short term.

The divergence from these studies could be attributed to methodological differences. While Fikru et al. (2024) and Matemane et al. (2024) employed static models focusing on accounting-based metrics, this study's ARDL-PMG framework captured market-based valuations and isolated long-run equilibrium relationships. This finding aligned with the work of Husnah (2023), who observed that ESG disclosure significantly increased Tobin's Q and sales growth in Indonesian mining companies over the long run, despite not having a short-term effect on ROA. Similarly, Diaye et al. (2021) demonstrated that while ESG did not impact GDP per capita in the short term, strong ESG performance correlated with long-term economic growth in OECD countries.

The positive long-run relationship was further supported by Bernardes et al. (2024), who evaluated mining, oil and gas companies and found a positive relationship between financial performance and corporate governance criteria, with the social component showing the greatest positive influence on results. Their findings emphasized that while environmental investments required continuity and legitimacy to yield benefits, and governance practices showed weak correlations with positive outcomes, the nonadoption of ESG practices exerted a significant negative influence on financial performance. This reinforced the interpretation that

ESG compliance in extractive industries operated as both a value creator and a risk mitigator over extended time horizons.

The significant long-run relationship supports stakeholder theory as articulated by Freeman (1984) and further emphasized by Talan et al. (2024), who highlighted that firms must create value for all stakeholders to achieve sustainable performance. In South Africa's mining context, where operations directly affect communities and environments, as evidenced by contamination issues highlighted by Liefferink (2016) and governance challenges like the Marikana massacre (eNCA, 2025) ESG performance reflects how effectively companies manage these stakeholder relationships over time.

4.6.1.2. Firm Size (LSIZE)

The coefficient for firm size is positive and marginally significant (coefficient = 0.421, p = 0.0630), indicating that a 1% increase in total assets is associated with a 0.42% rise in stock prices in the long run. This finding aligns with Bilivogui and Iqbal (2025), who noted that larger firms tend to perform better in BRICS nations, and Fikru et al. (2024), who observed that ESG-rated mining firms tend to be larger. The positive relationship suggests that economies of scale, operational resilience, and better market access contribute to long-term value creation, though this effect is considerably weaker than that of ESG compliance.

4.6.1.3. Gross Domestic Product (LGDP)

The long-run coefficient for GDP growth is negative and marginally significant (coefficient = -0.293, p = 0.0512). This counterintuitive result suggests that domestic GDP growth does not translate directly into higher mining stock valuations over the long term. This finding may reflect the sector's dependence on global commodity cycles rather than domestic economic conditions, as noted by Cole (2023), who emphasized that global demand for platinum supports South African mining operations despite high ESG-related risks. The negative relationship suggests that mining valuations respond more to international market dynamics and commodity-specific demand patterns than to national economic expansion.

4.6.1.4. Inflation (LINFL)

The inflation coefficient is positive and highly significant (coefficient = 1.846, p = 0.0039), with an elasticity that exceeds unity. This indicates that a 1% increase in inflation is associated with a 1.85% increase in stock prices, confirming that mining stocks serve as a robust inflation hedge. Investors anticipate that rising inflation will

increase the nominal value of extracted commodities, thus protecting and improving the real value of mining investments over time.

4.6.2. Short-Run Dynamics

4.6.2.1. Error Correction Term (COINTEQ)

The error correction term is negative and statistically significant (coefficient = -0.020, p = 0.0095), confirming the presence of a long-run equilibrium relationship among the variables. The coefficient indicates that approximately 2% of any disequilibrium between stock prices and the explanatory variables is corrected for each period. This slow adjustment speed reflects the capital-intensive nature of mining operations and the gradual incorporation of ESG performance into market valuations. This finding supports the observations of Bertelli and Torricelli (2024), who concluded that ESG-screened portfolios only outperform in the long run, and Feng et al. (2022), who found that ESG effects are clearer in the short term only for highly profitable firms.

4.6.2.2. Short-Run Effect of the Firm Size

The short-run dynamics reveal that current changes in firm size (D(LSIZE)) have no immediate significant effect (coefficient = 0.859, p = 0.1101) but lagged changes in firm size (D(LSIZE (-1))) demonstrate a positive and significant relationship with stock prices (coefficient = 0.702, p = 0.0094). This one-period lag suggests that the market requires time to process and react to information about changes in the company scale. A 1% increase in total assets in the previous period is associated with a 0.70% increase in current stock prices, indicating that expansion signals are incorporated with a delay as investors assess the implications for operational capacity and competitive positioning.

4.6.2.3. Inflation Short-Run Effects

Current changes in inflation (D(LINFL)) exhibit a positive and significant short-run effect (coefficient = 0.168, p = 0.0021). A 1% increase in current inflation is associated with a 0.17% immediate increase in stock prices. This rapid response reflects investors' immediate adjustment of valuations in anticipation of commodity price increases. The short-run elasticity (0.17) is considerably lower than the long-run elasticity (1.85), indicating that while the market responds quickly to inflationary signals, the full hedging benefit materializes only over extended periods as commodity prices fully adjust.

4.6.2.4. ESG Short-Run Effects

ESG performance showed no significant short-run relationship with stock prices. Neither current nor lagged changes in ESG scores appeared in the short-run specification, indicating that ESG improvements did not trigger immediate market reactions. This absence of short-run significance was consistent with Matemane et al. (2024), who found that ESG metrics did not significantly affect ROA in the short term for South African listed firms, and Husnah (2023), who observed no short-term ROA effects from ESG disclosure in Indonesian mining companies. Furthermore, Mustaffa (2023) found through a meta-analysis that ESG disclosure significantly but negatively influenced listed companies' financial performance, though the overall effect remained weak, suggesting that short-term costs of ESG implementation might temporarily outweigh immediate benefits.

This temporal pattern aligned with the findings of Esparica and Gubavera (2024), who noted that high environmental scores could reduce short-term equity returns, suggesting that environmental investments required extended timeframes to generate returns. Maulidya et al. (2025) provided further granular evidence from Indonesian mining companies, demonstrating that disclosure of environmental performance had a significant negative short-term effect on stock prices, while social performance showed only a weak, marginally significant effect, and economic performance did not show a significant impact when analysed individually. However, their F-test revealed that when combined, all three sustainability dimensions had a statistically significant influence on stock prices, indicating that investors responded more strongly to holistic sustainability performance rather than isolated disclosures. This supported the interpretation that the composite ESG score's long-run effect in the present study captured this integrated investor assessment over extended periods.

The results also support Mouffok and Mouffok (2025), who found that environmental indices recover only in the long run under economic policy uncertainty. The lack of short-run ESG effects reflected the nature of ESG investments: environmental remediation, social license maintenance, and governance improvements required sustained commitment and generated value through gradual risk reduction and reputation enhancement rather than immediate profit increases. Bernardes et al. (2024) emphasized this temporal dimension in extractive industries, noting that environmental investments required continuity and legitimacy to reap benefits, and these benefits became more visible only when the opportunity cost compared to other investment areas was not excessively high. Their

finding that the social component had the greatest positive influence, particularly on the creation of good working conditions and innovation, while governance practices showed weak positive correlations but strong negative effects when absent, underscored that ESG value creation operated through multiple channels that required time to manifest fully in financial performance.

4.6.2.5. Implications of Temporal Dynamics

The distinct contrast between short-run and long-run results reveals the mechanism through which ESG creates value in South Africa's mining sector. In the short term, stock prices respond primarily to tangible operational changes (firm size expansion) and macroeconomic signals (inflation). However, ESG performance operates through a fundamentally different channel: It shapes long-term risk profiles, secures social license to operate, and builds institutional investor confidence factors that materialize gradually rather than immediately.

This temporal distinction has critical implications for the investment strategy. As Kräussl et al. (2024) warned, ESG investments might underperform non-ESG ones in the long term from a purely financial perspective, though they offer short-term benefits due to investor sentiment. However, the findings of this study suggest the opposite pattern in South Africa's mining sector: ESG compliance offers minimal short-term financial benefits but generates substantial long-term value creation. This pattern supports the "ESG-as-insurance" hypothesis proposed by Drobetz et al. (2024), in which ESG performance protects firms against long-term risks rather than generating immediate returns.

The slow error correction speed (2% per period) combined with the absence of short-run ESG effects explains why studies employing short-term horizons or static methodologies often fail to detect ESG's financial materiality. As Bertelli and Torricelli (2024) demonstrated, ESG-screened portfolios only outperform in the long run and provide limited safety during crises. The present findings confirm this temporal asymmetry and suggest that patient capital and sustained commitment to ESG are prerequisites for the realization of value in South Africa's mining sector.

Furthermore, the results validate South Africa's evolving policy framework, including the Mining Charter III, NEMA, the Carbon Tax Act, and JSE disclosure guidelines, as mechanisms that facilitate long-term value creation rather than imposing short-term compliance costs. The positive long-run ESG elasticity of 3.71% suggests that these regulatory frameworks, combined with institutional

investor pressure from UN-PRI signatories such as Old Mutual Investment Group, Allan Gray, and the Public Investment Corporation, are successfully channelling capital towards ESG-compliant firms and rewarding sustained ESG performance with higher market valuations.

Table 10. Selected model: PMG (1,0,2,0,1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long-run (Pooled) Coefficients				
LESG	3.713691	0.482070	7.703636	0.0000
LSIZE	0.420701	0.225984	1.861635	0.0630
LGDP	-0.292859	0.149964	-1.952860	0.0512
LINFL	1.845969	0.638198	2.892473	0.0039
C	-18.40680	4.302525	-4.278140	0.0000
Short-run (Mean-Group) Coefficients				
COINTEQ	-0.020170	0.007761	-2.598903	0.0095
D(LSIZE)	0.859045	0.537139	1.599297	0.1101
D(LSIZE (-1))	0.702442	0.269746	2.604083	0.0094
D(LINFL)	0.167640	0.054246	3.090373	0.0021

Source: Authors' own estimation (2025)

5. Conclusions and Limitations

This study investigated the dynamic short-run and long-run relationships between ESG compliance and financial performance in South Africa's mining sector. Using Panel Autoregressive Distributed Lag methodology with Pooled Mean Group estimation on monthly data from 13 JSE-listed mining companies between 2015 and 2022, the analysis examined whether ESG performance translated into measurable stock market returns while controlling for firm-specific and macroeconomic factors. The findings revealed a fundamental temporal disconnect in how markets valued ESG performance in the mining sector. In the short run, stock prices responded primarily to conventional operational metrics and macroeconomic conditions, with no significant ESG effect detected. However, in the long run, ESG compliance emerged as a substantial driver of stock returns, with sustained improvements in ESG scores that generate material increases in market valuation. This temporal pattern demonstrated that the creation of ESG value materialized gradually rather than

immediately, requiring patient capital and sustained commitment rather than producing quick financial gains. The absence of short-run effects explained why previous studies employing static models or accounting-based metrics often failed to detect the financial materiality of ESG in mining contexts. Macroeconomic variables also showed distinct temporal patterns. Inflation demonstrated a strong positive long-run relationship with stock returns, confirming that mining equities served as effective inflation hedges over extended periods. GDP growth showed an unexpected negative long-run relationship, suggesting that mining valuations responded more sensitively to global commodity cycles than to domestic economic expansion. Firm size exhibited a marginally positive long-run effect, indicating that economies of scale contributed modestly to the creation of long-term value.

These insights offered critical implications for key stakeholders. For mining firms, this validated ESG integration as a strategic imperative for long-term value creation and risk mitigation, essential to secure their social license to operate and attract institutional capital. For institutional investors, the results provided empirical justification for incorporating ESG metrics into long-horizon valuation models and engagement strategies, affirming that the financial benefits were material, even if not immediate.

This study acknowledged certain limitations that also delineated the directions for future research. The analysis was limited to a specific period (2015-2022) and relied on a composite ESG score from a single provider (Refinitiv Eikon). Future studies could expand the time frame and compare data across different ESG rating agencies to assess the robustness of these findings. Furthermore, while the model controlled for key macroeconomic factors and firm size, it lacked other firm-specific controls such as leverage, capital expenditure, and operational efficiency. Incorporating these variables would help to better isolate the pure effect of ESG on financial performance. Notwithstanding these limitations, this study provided robust evidence that in the South African mining sector, ESG compliance was not a short-term cost but a long-term value driver. For firms, investors and policy makers navigating the complexities of sustainable development, the message was clear: the financial returns on ESG were realized not in quarters, but over years, rewarding a strategy of persistence and genuine integration.

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