Board gender diversity, CEO overconfidence, and ESG risk in mining companies

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Abstract

Environmental, Social, and Governance (ESG) risk is critical to business resilience, yet it may be intensified by executive cognitive biases. This study examines the effect of CEO overconfidence on ESG risk and investigates board gender diversity as a moderating mechanism. CEO overconfidence is proxied by capital expenditure intensity (CAPEX), overinvestment, and the debt-to-equity ratio (DER). Using an explanatory quantitative design, this study analyzes 34 mining companies listed on the Indonesia Stock Exchange from 2021 to 2024. The data were analyzed using panel data regression with the Random Effect Model and Moderated Regression Analysis. The results indicate that, among the three proxies, only CAPEX significantly increases ESG risk, while the overinvestment and DER hypotheses are not supported. However, board gender diversity does not mitigate the effect of CEO overconfidence on ESG risk. Descriptive statistics further show that overinvestment and DER have mean values of 0.2500 and 0.0034, respectively, suggesting more conservative or underconfident CEO behavior. An interesting finding is that women's representation on the board is only 9%, indicating that their presence remains limited in strategic risk-taking decisions. These findings indicate that mining companies should strengthen gender-responsive governance by increasing women's representation in top leadership to enhance sustainability and reduce excessive executive risk-taking. These findings also imply that IDX, OJK, investors, and credit rating agencies should move beyond symbolic gender diversity by encouraging a critical mass of female directors and integrating board composition and CEO behavioral profiles into ESG risk assessment to support sustainable corporate governance.

Keywords: *Board gender diversity, CEO overconfidence, corporate governance, ESG risk, mining companies.*

Introduction

The modern corporate paradigm, firmly rooted in the Triple Bottom Line (TBL) theory, posits that the resilience of a business entity is no longer measured exclusively by short-term financial profitability. Instead, long-term survival depends on the reliable harmonization of economic performance, social empowerment, and ecological sustainability (Cabello et al., 2021; Zubeltzu-Jaka et al., 2024). In the contemporary business environment, robust ESG risk management has proven to be an essential strategic instrument. It serves not only to cushion the volatility of macroeconomic uncertainties but also to safeguard corporate legitimacy in the eyes of investors and regulatory stakeholders (Pamungkas & Risman, 2024). This fundamental shift is particularly critical for explorative industries, such as the mining sector in emerging markets, which inherently face intense public scrutiny due to their substantial ecological footprint and significant socio-

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environmental impacts. However, despite the growing urgency of sustainability, the theoretical framework of corporate governance reveals a complex reality in which strategic decision-making mechanisms are often substantially shaped by the psychological attributes of top executives (Zhang et al., 2024).

From the perspective of Behavioral Theory, an executive's rationality is not perfectly objective; rather, it is significantly constrained by subjective experience biases and cognitive distortions. One of the most prominent manifestations of this distortion in corporate leadership is CEO overconfidence which is a psychological condition in which top executives consistently overestimate their predictive abilities, exaggerate expected returns, and systematically underestimate the probability of long-term corporate threats (Lee & Kim, 2021; Yue et al., 2024). While overconfidence is inherently a psychological trait, it empirically manifests in observable, aggressive strategic financing and investment maneuvers. Specifically, in the context of capital-intensive industries like mining, overly confident CEOs tend to demonstrate high intensity in CAPEX, engage in inefficiencies through overinvestment, and accumulate extreme levels of external debt, reflected in a high DER (Ramchandani & Lilge, 2025; Tian et al., 2021).

The context of the Indonesian capital market, particularly the mining sector listed on the Indonesia Stock Exchange (IDX), provides a highly relevant testing ground for this behavioral governance phenomenon. The mining sector is inherently characterized by high capital intensity, significant ecological footprints, and profound social impacts on local communities. In recent years, the Indonesian Financial Services Authority (Otoritas Jasa Keuangan/OJK) has mandated strict sustainability reporting to foster a green economy transition. However, compliance remains highly variable, often treated as a peripheral administrative duty rather than a core strategic imperative. In such an environment, the psychological traits of top executives play a disproportionately large role in determining whether a firm genuinely integrates ESG principles or merely engages in superficial compliance. When CEOs in this sector exhibit overconfidence, the massive free cash flows generated during commodity price booms are frequently channeled into aggressive physical expansions and rigid debt structures rather than being reinvested into environmental reclamation or community development programs. This unique intersection of regulatory transition, high environmental sensitivity, and volatile commodity cycles makes the Indonesian mining sector an ideal empirical context to evaluate the destructive capacity of executive cognitive biases on sustainability profiles.

This managerial optimism bias significantly impacts the stability of corporate sustainability and escalates ESG risks. Executives exhibiting overconfidence persistently inject cash flows into massive physical expansion projects to pursue rapid, albeit sometimes illusory, growth. This intense ambition frequently triggers a resource diversion or "crowding-out effect," which significantly reduces the budget allocated for environmental protection, occupational safety, and social empowerment agendas (Qiao et al., 2025). Furthermore, the distortion of strategic capital allocation through overinvestment often ignores the prudent adoption of green technologies (Wang et al., 2023). When these aggressive investment maneuvers are combined with ballooning debt structures, it creates severe liquidity pressures (Mselmi et al., 2017; Rehman et al., 2023). To maintain short-term solvency, management is frequently forced to cut social responsibility initiatives and compliance governance standards (Scarpellini, 2021). Neglecting sustainable investment

values for short-term expansion ultimately increases the entity's vulnerability to non-financial risks (Liu & Song, 2025). Consequently, the following hypotheses are formulated:
H1a: CAPEX has a positive impact on the level of ESG risk.
H1b: Overinvestment has a positive impact on the level of ESG risk.
H1c: DER has a positive impact on the level of ESG risk.

To mitigate the negative impact of executive behavioral biases, Gender Theory offers a governance mechanism that relies on board structure inclusivity. The presence of women in board meetings introduces a cognitive dimension oriented toward risk-averse behavior, cross-sector collaboration, and rigorous ethical oversight (Kavanagh et al., 2023; Lindqvist et al., 2020). Gender diversity at the top management level functions as an effective check-and-balance mechanism when a CEO attempts to breach prudent tolerance limits through capital expenditure surges, impulsive overinvestment, or excessive debt accumulation. Female directors consistently advocate for transparency in disclosures, challenge overly optimistic projections, and review investment maneuvers that may threaten the entity's sustainability (Antonioli et al., 2022; Caputo et al., 2021; Nadeem, 2020). In the face of disruption risks caused by high debt ratios, female directors proactively advocate for environmental compliance budgets to ensure they are not sacrificed for debt repayment. Therefore, a board architecture that accommodates gender diversity is postulated to operate effectively as a moderating variable that dampens the adverse effects of CEO overconfidence on ESG risk (Al et al., 2025; Issa & Hanaysha, 2023; Sasidharan et al., 2024). The second hypotheses are formulated as follows:
H2a: Board gender diversity weakens the influence of CAPEX on ESG risk.
H2b: Board gender diversity weakens the influence of overinvestment on ESG risk.
H2c: Board gender diversity weakens the influence of DER on ESG risk.

Based on the theoretical and empirical elaboration above, the relationships among CEO overconfidence proxies, board gender diversity, and ESG risk are illustrated in the conceptual framework in Figure 1.

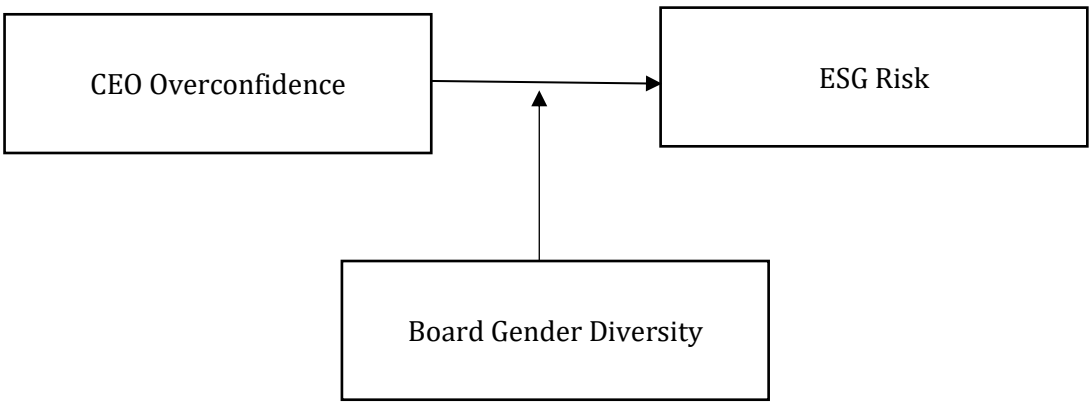

Figure 1. Conceptual Framework

Despite the growing literature on behavioral finance and corporate governance, there remains a significant gap regarding the detailed mechanisms by which specific CEO

overconfidence proxies such as CAPEX, overinvestment, and DER which is escalate non-financial risk vulnerabilities, particularly in extractive sectors like mining. Furthermore, empirical evidence validating whether board gender diversity can effectively counterbalance this executive aggressiveness remains limited and often contradictory in the context of emerging markets, where Tokenism Theory suggests that minority female representation may not yet possess the critical mass required to influence strategic vetoes. Filling this empirical gap, this research aims to precisely analyze the impact of CEO overconfidence on the level of ESG risk, while simultaneously proving the moderating capacity of board gender diversity in mitigating such risk anomalies among mining companies listed on the Indonesia Stock Exchange.

Methods

This study adopted a quantitative approach with an explanatory research design to systematically explore the causal relationships among the observed variables. The target population of this research includes all companies in the mining and extractive sector that are officially listed on the Indonesia Stock Exchange (IDX) during the four-year observation period of 2021–2024. The sampling technique was implemented using a stringent purposive sampling approach based on a set of specific criteria to ensure data robustness. The criteria require that the companies maintain continuous listing status throughout the observation period, have not undergone delisting or mergers that could distort the financial data, and provide complete publication of annual reports and sustainability reports containing the required variables. Through this rigorous data screening process, a final consistent sample of 33 mining companies over four consecutive years was obtained, yielding a total of 132 balanced panel data observations. All data elements used in this study are secondary data collected through documentation methods, primarily sourced from the companies' official annual and sustainability reports, as well as validated statistical data from capital market authorities and credible rating agencies.

In this study, ESG Risk is measured using the volatility of ESG scores over time. ESG volatility is calculated as the standard deviation of a firm's ESG scores over a rolling three-year window. The use of a three-year window is justified by the consideration that ESG scores reflect corporate sustainability policies and practices, which generally evolve gradually rather than fluctuate abruptly within a single year. Therefore, a sufficiently extended observation horizon is required to capture the instability of ESG scores across periods. In addition, a three-year window provides a more adequate minimum number of observations for estimating standard deviation compared with a two-year period. This approach is consistent with (Magnani et al., 2024). To address the psychological bias of top management, the independent variable, CEO overconfidence, is quantified using three distinct and observable empirical proxies to ensure methodological rigor and replicability. The first proxy is CAPEX refers to research (Killins et al., 2021; Malmendier & Tate, 2015; Sumiyana et al., 2023) formula in equation (1).

$$CAPEX_{it} = \frac{CAPEX_{it}}{TA_{it}} \quad (1)$$

The second proxy is Overinvestment, Overinvestment represents abnormal corporate investment, which refers to the extent to which a firm's actual investment deviates from its expected or normal investment level based on available growth opportunities. In line with

(Biddle et al., 2009; Duellman et al., 2015; Sumiyana et al., 2023), overinvestment is measured using a dummy variable. The measurement process is conducted in several steps. First, the firm's total investment is estimated using the following formula:

$$Inv_{it} = \frac{(CAPEX_{it}+R\&D_{it}+Acq_{it})-SPPE_{it}}{TA_{it}} \quad (2)$$

Subsequently, the firm's expected or normal investment level is estimated by taking into account its growth opportunities, which are represented by sales growth. To estimate the normal investment level, the following regression model is applied:

$$Inv_{it} = \alpha_0 + SGrowth_{it-1} + \varepsilon_{it} \quad (3)$$

Where:

$CAPEX_{it}$	: Capital expenditure intensity of firm i in year t.
INV_{it}	: Investment of firm I in year t.
$R\&D_{it}$	: Research and development expenses of firm i in year t.
Acq_{it}	: Company acquisition of firm i in year t.
$SPPE_{it}$	: Sale of Property, Plant, and Equipment of firm i in year t.
$SGrowth_{it}$	: Sales Growth of firm i in year t.
Ta_{it}	: Total assets of firm i in year t.
α_0	: Constant term.
β1	: Regression coefficients.
ε_{it}	: Error term of firm i in year t.
i	: Firm.
t	: Year.

Using the estimated regression model, abnormal investment is measured as the residual value, representing the deviation of actual investment from the model-predicted normal investment level. A firm is classified as engaging in overinvestment and assigned a value of 1 when its residual is located in the upper quartile within the corresponding industry-year group; otherwise, it is assigned a value of 0.

The third proxy of CEO Overconfidence is DER, representing aggressive external financing, measured directly as total debt divided by total equity in line with (Huang et al., 2016; Sumiyana et al., 2023). These three proxies are synthesized to represent the observable aggressiveness in strategic financing and investment, serving as robust empirical manifestations of unobservable executive overconfidence traits.

To examine the check-and-balance mechanism within corporate governance dynamics, board gender diversity is positioned as a moderating variable. This variable is operationally measured by the proportion of female directors relative to the total number of serving board members in a given fiscal year. Furthermore, to absorb unobserved data variance and prevent model overfitting, this study incorporates three fundamental control variables. The control variables comprise Total Assets (TA) as a proxy for firm size (transformed into natural logarithms to maintain data normality), Net Profit Growth (NPG) representing operational profitability momentum, and Market-to-Book Value (MBV) as an indicator of market valuation.

The overall analytical procedure is based on advanced panel data regression techniques and Moderated Regression Analysis (MRA) to appropriately accommodate the complexity

of the data structure, which inherently combines cross-sectional and time-series dimensions. The econometric equation proposed to estimate the main and interaction effects in this study is formulated as follows:

$$\text{ESG Risk}_{it} = \alpha + \beta_1 \text{CAPEX}_{it} + \beta_2 \text{Overinvestment}_{it} + \beta_3 \text{DER}_{it} + \beta_4 \text{GenderDiversity}_{it} + \beta_5 \text{CAPEX}_{it} * \text{GenderDiversity}_{it} + \beta_6 \text{Overinvestment}_{it} * \text{GenderDiversity}_{it} + \beta_7 \text{DER}_{it} * \text{GenderDiversity}_{it} + \beta_8 \text{TA}_{it} + \beta_9 \text{NPG}_{it} + \beta_{10} \text{MBV}_{it} + \varepsilon_{it}$$

Where:

ESG Risk_{it}	: ESG risk of firm i in year t.
CAPEX_{it}	: Capital expenditure intensity of firm i in year t.
$\text{Overinvestment}_{it}$	: Overinvestment of firm i in year t.
DER_{it}	: Debt-to-equity ratio of firm i in year t.
$\text{Gender Diversity}_{it}$	: Gender diversity of firm i in year t.
TA_{it}	: Total assets of firm i in year t.
NPG_it	: Net profit growth of firm i in year t.
MBV_it	: Market-to-book value of firm i in year t.
α	: Constant term.
β1–β10	: Regression coefficients.
ε_it	: Error term of firm i in year t.
i	: Firm.
t	: Year.

The determination of the most reliable and unbiased estimation model began with a rigorous specification evaluation through a series of panel data diagnostics, specifically the Chow Test, the Hausman Test, and the Lagrange Multiplier Test. Based on the statistical accuracy criteria generated by these diagnostics, the Random Effect Model (REM) approach was selected as the most consistent and appropriate specification for accommodating the inherent characteristics of the sample and executing the final hypothesis testing.

The utilization of panel data regression in this study offers significant econometric advantages over traditional cross-sectional or time-series designs. By combining both dimensions, panel data inherently provides a larger number of informative data points, significantly increasing the degrees of freedom and reducing collinearity among explanatory variables. In the context of ESG risk analysis, which is highly susceptible to unobservable heterogeneity such as distinct corporate cultures, unrecorded managerial risk appetites, and varying levels of political connections among mining firms panel data methodology effectively controls for these firm-specific, time-invariant characteristics. Furthermore, the application of Moderated Regression Analysis (MRA) allows for a dynamic assessment of board governance. Rather than merely treating gender diversity as a static independent variable, MRA robustly captures the interactive contingencies, revealing precisely how the buffering capacity of female directors reacts under varying levels of executive overconfidence. This rigorous econometric framework ensures that the empirical findings are not merely spurious correlations, but rather represent stable, long-term behavioral patterns within the corporate governance landscape of the Indonesian extractive sector.

Result and Discussions

The empirical analysis commences with a descriptive statistical evaluation to provide a comprehensive overview of the data distribution characteristics for all observed variables across the 33 mining companies from 2021 to 2024. As presented in Table 1, the dependent variable, ESG Risk, exhibits a mean value of 0.0190 with a standard deviation of 0.0107, indicating the general volatility of sustainability risks within the sample. Regarding the CEO overconfidence proxies, CAPEX and Overinvestment demonstrate average values of 0.0576 and 0.2500, respectively, reflecting the relatively high intensity of physical asset expansion and capital allocation inefficiencies during the observation period. Furthermore, the DER highlights a maximum value of 0.1389, underscoring the aggressive external financing strategies adopted by several entities during the commodity boom cycle. Importantly, the moderating variable, board gender diversity, shows an average representation of only 8.95% (0.0895). This relatively low proportion empirically indicates that mining companies listed on the Indonesia Stock Exchange have not yet achieved adequate gender inclusiveness at the board level. Female directors remain substantially underrepresented, and their limited presence has not been sufficient to exert a meaningful influence on corporate strategic decision-making. Lastly, the control variables Total Assets (TA), Net Profit Growth (NPG), and Market-to-Book Value (MBV) exhibit wide variations between their minimum and maximum values, representing the diverse firm sizes, profitability momentum, and market valuations that adequately capture the unobservable heterogeneity across the sample.

Table 1. Descriptive Statistics

Variable	Minimum	Maximum	Mean	Std. Deviation
ESG Risk	0.000	0.044	0.019	0.010
CAPEX	0.000	0.505	0.057	0.081
Overinvestment	0.000	1.000	0.250	0.434
DER	-0.010	0.138	0.003	0.012
Board Gender Diversity	0.000	0.500	0.089	0.130
TA	4.612	7.032	5.790	0.649
NPG	-66.235	30.985	-0.325	7.209
MBV	-0.366	29.657	2.764	4.983

Prior to executing the primary hypothesis testing, a comprehensive series of econometric diagnostics were conducted to determine the most robust panel data regression specification. The evaluation commenced with the Chow Test, which indicated that the Fixed Effect Model (FEM) was statistically superior to the Common Effect Model (CEM). Subsequently, the Hausman Test was employed to verify the consistency of the random effects regarding the independent variables. The resulting probability value exceeded the 0.05 significance threshold, confirming that the Random Effect Model (REM) was a more appropriate specification than the FEM. To finalize this model selection, the

Lagrange Multiplier Test was performed, which definitively solidified the Random Effect Model (REM) as the most consistent approach for accommodating the inherent characteristics of the panel data observations across the mining sector sample.

To ensure the reliability and validity of the estimated parameters, a series of classical assumption tests were rigorously applied before testing the hypotheses. The residual normality test resulted in a probability value of 0.1142, which exceeds the 5% significance threshold, thereby confirming that the error terms within the model are normally distributed. In the multicollinearity diagnosis through the correlation matrix, all independent variables recorded correlation values well below the critical limit of 0.90, proving that the model is free from information redundancy bias. Furthermore, the evaluation of autocorrelation symptoms using the Durbin-Watson statistic produced a score of 2.1784. This value falls strictly within the acceptable safe zone (dU < DW < 4 - dU), indicating that the regression model is empirically free from disturbances caused by inter-period error correlation. With all fundamental econometric assumptions fully satisfied, the results of the REM estimation and Moderated Regression Analysis (MRA) are systematically presented in Table 1.

Table 2. Panel Data Regression Results (REM)

Variable	Coefficient	Std. Error	Prob.
Constant (C)	0.0022	0.0134	0.8692
CAPEX	0.0278	0.0132	0.0382**
Overinvestment	-0.0011	0.0020	0.5772
DER	-0.0441	0.0726	0.5443
Board Gender Diversity	0.0047	0.0094	0.6155
CAPEX * Gender Diversity	0.1286	0.1886	0.4965
Overinvestment * Gender Diversity	0.2814	0.1632	0.0873*
DER * Gender Diversity	-10.9823	21.2804	0.6067
Total Asset (TA)	0.0027	0.0021	0.2123
NPG	0.0001	0.0001	0.4837
MBV	-0.0003	0.0002	0.0783*

R-squared: 0.1148 | Prob(F-statistic): 0.1233 | Durbin-Watson stat: 2.1784
Note: ** significant at 5% (*α* = 0.05), * significant at 10% (*α* = 0.10).

Based on the panel data regression testing (Table 1), the simultaneous model feasibility test (Prob. F-statistic 0.1233) indicates a limited explanatory power of the internal variables with an R-squared of 11.48%. While this might initially appear constrained, this empirical condition is commonly found and theoretically justified in risk management literature within emerging markets. This statistical phenomenon indicates that the volatility of Environmental, Social, and Governance (ESG) risk achievements in the Indonesian mining sector is more heavily dominated by external macroeconomic shocks, government regulatory uncertainties, and global commodity price fluctuations, which inherently lie outside the direct managerial decision mechanisms. Nevertheless, the partial hypothesis testing provides robust and substantial empirical findings regarding the profound impact of CEO cognitive biases and the buffering capacity of governance mechanisms.

The primary hypothesis testing proves that the core proxy for CEO overconfidence, namely Capital Expenditure (CAPEX), has a positive and significant effect on the escalation of ESG risk, with $\beta = 0.0278$; P-Value = $0.0382 < 0.05$. This result strongly confirms H1a and seamlessly aligns with the postulates of Behavioral Theory, which predicts that managerial optimism bias drives executives to make massive and sometimes irrational asset expansion decisions. An excessive focus on physical capital expenditure frequently creates a resource diversion or "resource allocation trade-off". In this scenario, crucial investments in environmental safety standards, green technology adoption, and social empowerment programs are systematically sidelined to finance physical growth. Consequently, the company's vulnerability to non-financial risk turbulence increases measurably.

To further contextualize these findings, it is essential to understand the operational nature of the mining industry in emerging markets. Capital expenditure (CAPEX) in this sector is typically directed toward acquiring heavy machinery, expanding exploration sites, and developing massive logistical infrastructure. When driven by an overconfident CEO, these physical expansions are often executed with an aggressive timeline that bypasses rigorous environmental impact assessments and neglects continuous community engagement. Resource allocation trade-off observed in this study is not merely a theoretical construct; it represents a tangible reallocation of corporate wealth. Funds that could ideally be utilized for transitioning to renewable energy sources, rehabilitating post-mining lands, or enhancing the occupational health and safety of workers are aggressively diverted to finance new coal or mineral extraction sites. Consequently, this cognitive myopia leaves the corporation highly exposed to regulatory penalties, operational disruptions from community protests, and severe reputational damage in the global market, which increasingly demands strict adherence to ESG standards. This aggressive capital allocation fundamentally contradicts the essence of the Triple Bottom Line, prioritizing short-term physical asset accumulation over long-term ecological and social harmony.

The unique characteristics of the mining industry further exacerbate this behavioral anomaly. The explorative sector is highly cyclical and profoundly dependent on the volatility of global commodity prices. During periods of commodity price booms, mining companies often generate ubnormal of free cash flow. From a behavioral finance perspective, these windfall periods frequently act as a catalyst for executive hubris. Overconfident CEOs tend to attribute this exogenous financial success to their own managerial brilliance rather than favorable macroeconomic conditions. This fundamental attribution error significantly reinforces their illusion of control. Consequently, it may encourage them to initiate aggressive, capital-intensive megaprojects, such as acquiring new mining concessions or expanding large-scale logistical infrastructure, while overlooking the long-term environmental degradation and social displacement associated with these operations. As a result, the corporation’s ESG risk profile may deteriorate, increasing its exposure to future regulatory penalties and the risk of underutilized and unproductive assets when the commodity cycle enters a downturn. These findings imply that CEO overconfidence should be carefully monitored, particularly in relation to ESG risk. Overconfident CEOs may take excessive ESG-related risks to justify their overly optimistic beliefs regarding future corporate performance, especially when strategic attention is heavily concentrated on capital expenditure. In this context, capital expenditure does not merely reflect investment activity, but may also represent an aggressive managerial

preference for physical expansion over sustainability-oriented risk control. To mitigate the adverse consequences of CEO overconfidence, mining companies need to strengthen internal governance mechanisms by establishing an effective counterbalance through greater female representation on the board of directors. Board gender diversity can function as a strategic monitoring mechanism because female directors are often associated with more prudent risk assessment, stronger ethical sensitivity, and a greater tendency to consider long-term social and environmental consequences. From a psychological and governance perspective, this risk-averse orientation may help restrain excessive managerial optimism, particularly when overconfident CEOs prioritize capital expenditure and physical expansion at the expense of ESG risk control. Therefore, the presence of female directors is expected to improve the quality of board deliberation, challenge overly optimistic investment assumptions, and reduce the likelihood of excessive ESG-related risk-taking driven by CEO overconfidence.

In contrast, the proxies of overinvestment show no statistically significant influence on ESG risk, with β = -0.0011; P-Value = 0.5772 > 0.05. The insignificant effect of overinvestment on ESG risk should be interpreted with caution. Although overinvestment is widely used in prior studies as an empirical proxy for managerial overconfidence and inefficient investment behavior (Biddle et al., 2009; Duellman et al., 2015; Sumiyana et al., 2023), its measurement in the Indonesian mining sector faces several data-related constraints. The overinvestment model ideally requires detailed investment components, including research and development expenditure, company acquisition, and the sale of property, plant, and equipment. However, many mining companies listed on the Indonesia Stock Exchange do not consistently disclose R&D expenditure and company acquisition-related information in their annual reports or sustainability reports. This incomplete disclosure may reduce the precision of the overinvestment measure and create potential measurement error, thereby weakening its statistical association with ESG risk.

In addition, the descriptive statistics show that the mean value of overinvestment is only 0.2500. Since overinvestment is measured as a dummy variable, this value indicates that only around 25% of firm-year observations are classified as overinvestment cases, while the majority of observations do not exhibit excessive investment behavior. This relatively low proportion suggests that most CEOs in the sample do not strongly demonstrate overconfidence through abnormal investment activities. Consequently, the limited variation in overinvestment may reduce the explanatory power of this variable in predicting ESG risk. From a statistical perspective, when the number of firms categorized as overinvesting is relatively small, the model may have insufficient sensitivity to detect its direct impact on ESG risk. Therefore, the non-significant relationship between overinvestment and ESG risk should not be interpreted as definitive evidence that inefficient investment decisions are irrelevant to sustainability risk. Rather, this finding may reflect the combined effect of limited disclosure quality, incomplete investment data, and the relatively low occurrence of overinvestment among Indonesian mining companies. Accordingly, future studies are encouraged to employ more comprehensive investment data, extend the observation period, and consider alternative measures of managerial overconfidence to obtain a more robust conclusion. These limitations highlight the need for caution when interpreting and generalizing the findings of this study.

The Similar result Debt-to-Equity Ratio (DER) show insignificant influence on ESG risk with β= -0.0441; P-Value = 0.5443 > 0.05. This result suggests that, in the Indonesian mining sector, investment inefficiency and reliance on debt financing do not necessarily lead to higher ESG risk. Such evidence may reflect the compliance-based nature of sustainability implementation in emerging markets, where ESG practices are often adopted to meet formal disclosure requirements rather than to support substantive strategic transformation. As a result, inefficient investment decisions and capital structure choices may have a limited direct effect on ESG risk when sustainability has not yet become an integral component of corporate strategy. The insignificant effect of DER on ESG risk may be attributed to the low leverage intensity and limited variation observed in the sample. Although DER is commonly employed as a proxy for CEO overconfidence because overconfident executives may use external debt to finance aggressive expansion, the descriptive statistics show a mean of only 0.0034, and a standard deviation of 0.0128. These values indicate that most firms in the sample do not exhibit excessive debt-based financing behavior. Consequently, DER may not be sufficiently sensitive to capture CEO overconfidence in the Indonesian mining sector. Debt financing in this context may also reflect routine funding decisions, refinancing activities, or firm-specific capital structure adjustments rather than aggressive managerial optimism. Therefore, the non-significant relationship between DER and ESG risk should be interpreted with caution, as it may reflect the limited explanatory capacity of DER as a proxy for CEO overconfidence rather than the absence of a relationship between financing decisions and sustainability risk.

In the moderation effect testing, board gender diversity is found to significantly moderate the relationship between overinvestment and ESG risk at the 10% significance level (β = 0.2814; P-Value = 0.0873 < 0.10). However, the positive direction of the coefficient indicates that board gender diversity does not mitigate the adverse effect of overinvestment on ESG risk. Instead, the interaction result suggests that higher female representation on the board is associated with a stronger effect of overinvestment on ESG risk. Accordingly, H2b is not supported, because the empirical direction of the moderation effect is contrary to the hypothesized weakening effect. However, the moderation results also reveal that gender diversity has not been able to significantly mitigate the adverse impacts of massive CAPEX maneuvers and high debt (DER) levels. The non-significance of moderation in these specific aspects (H2a and H2c) is empirically highly relevant when analyzed through the lens of Tokenism Theory (Kanter, 2008). From the perspective of Tokenism Theory, the effectiveness of female directors' monitoring role depends largely on their proportional representation within the board structure. Kanter (1977) argues that minority groups require a sufficient level of representation to exert meaningful influence in organizational decision-making. When female representation remains very low, particularly below the threshold required to form a critical mass, their presence may be perceived as symbolic rather than substantive. In board governance literature, critical mass is generally associated with at least three female directors or approximately 30% board representation, which enables women directors to participate more actively in strategic deliberation and influence board outcomes. When the proportion of female directors remains below this threshold, their role may become vulnerable to tokenism. Under such conditions, the appointment of women to the board may serve primarily as a symbolic signal of inclusiveness, compliance with diversity expectations, or a response to external legitimacy pressures. As a result,

female directors may not possess sufficient structural authority to shape strategic decisions. Their expertise, insights, and critical perspectives on sustainability-related issues may be marginalized by the dominant majority within the boardroom. This condition may become more problematic when the board operates under the influence of an overconfident CEO. CEO overconfidence is commonly associated with excessive optimism, an inflated belief in personal judgment, and a tendency to underestimate potential risks. Such psychological tendencies may strengthen dominant leadership behavior and reduce openness to alternative viewpoints. In this situation, female directors with limited representation may face constraints in challenging aggressive strategic decisions, particularly those related to capital expenditure, investment expansion, and Environmental, Social, and Governance (ESG) risk management. Furthermore, token female directors may experience social and psychological pressures that limit their willingness to oppose the dominant view. To avoid conflict, isolation, or resistance within the boardroom, they may be more likely to conform to the prevailing decisions of the majority. Consequently, governance qualities often associated with female leadership, such as stronger risk awareness, ethical sensitivity, and greater concern for social and environmental consequences, may not be fully realized. This explains why a limited female presence on the board may fail to mitigate the adverse effects of CEO overconfidence. Instead of functioning as an effective counterbalance, token representation may allow aggressive investment behavior to persist, thereby contributing to higher ESG risk exposure.

Furthermore, the control variables utilized in this estimation model provide additional insights into the structural dynamics of ESG risk within the sample. Firm size, proxied by Total Assets (TA), and operational profitability, represented by Net Profit Growth (NPG), did not demonstrate a statistically significant impact on the fluctuation of ESG risk scores. This lack of significance suggests that within the specific context of the Indonesian extractive sector, the magnitude of a company's resources or its short-term profit momentum does not automatically translate into better or worse sustainability risk management. A massive firm with high profitability is equally as vulnerable to environmental controversies and social conflicts as a smaller firm if its strategic leadership is dominated by cognitive biases. Interestingly, Market-to-Book Value (MBV) exhibits a negative and significant influence at the 10% level, indicating that firms with higher market valuations tend to experience slightly lower ESG risk. This indicates that market participants in the Indonesia Stock Exchange are beginning to rationally price in sustainability factors, implicitly rewarding companies that manage their non-financial risks effectively with higher valuation multiples. However, the overarching finding remains clear: the internal psychological attributes of the CEO and the structural inclusivity of the board exert a far more decisive influence on strategic ESG outcomes than traditional financial metrics.

Therefore, the empirical evidence from this study sends a critical signal to capital market regulators, particularly the Indonesia Stock Exchange (IDX) and the Financial Services Authority (OJK). Relying solely on voluntary compliance or superficial diversity quotas is insufficient to reform the entrenched decision-making culture within corporate boardrooms. Policymakers must design institutional governance frameworks that not only encourage the presence of female directors but also empower them within key strategic committees, such as investment and risk management committees. Furthermore,

institutional investors and credit rating agencies must begin to rigorously integrate board demographic data and executive behavioral profiles into their comprehensive ESG risk assessment models. By demanding a critical mass of female representation on the board of directors, shareholders can establish a formidable line of defense against the potentially value-destroying consequences of managerial overconfidence, ensuring that corporate capital allocation remains strictly aligned with the core principles of sustainable development

Conclusion

This study concludes that executive cognitive biases, specifically CEO overconfidence manifested through aggressive capital expenditure (CAPEX), significantly escalate the vulnerability of mining companies to Environmental, Social, and Governance (ESG) risks. However, other proxies of overconfidence, such as overinvestment and extreme debt accumulation, do not systematically impact ESG risk profiles, reflecting that sustainability implementations in emerging markets often remain limited to formal administrative compliance rather than integrated strategy. Furthermore, the presence of board gender diversity serves as an effective governance mechanism to mitigate the adverse effects of overinvestment. Nevertheless, female directors have not been able to successfully buffer the negative impacts of massive capital expansion and high debt levels. This limitation is primarily attributed to the tokenism effect, where the critically low proportion of female directors (averaging only 8,95%) has not reached the critical mass necessary to form a strong coalition to veto vital strategic executive decisions.

Theoretically, this research enriches the intersection of Behavioral Finance and Corporate Governance literature by demonstrating that executive psychological traits are critical determinants of non-financial risk trajectories. It challenges the traditional assumptions of the rational economic man by proving that cognitive biases, such as overconfidence, can systematically derail sustainable corporate strategies. Furthermore, the validation of Tokenism Theory within this context provides a crucial caveat to the widely accepted premise that board diversity inherently improves governance. It explicitly underscores that structural inclusivity must transcend superficial demographic quotas to achieve a functional critical mass, thereby ensuring that minority voices possess the requisite political leverage to actively neutralize the destructive potential of executive hubris

Practically, these findings urge corporate shareholders and policymakers in the extractive sector to move beyond token representation and ensure a critical mass of female directors to genuinely safeguard long-term sustainability. This study acknowledges several limitations, notably its exclusive focus on a single industry over a narrow four-year window, which inherently restricts the broader generalizability of the findings. Additionally, the study relies exclusively on secondary financial data to proxy executive psychology rather than employing direct behavioral or psychometric assessments. Future research is highly recommended to address these gaps by expanding the sample across multiple high-risk industries, utilizing longer panel data periods to capture macroeconomic cycles, and incorporating additional governance control variables, such as audit committee effectiveness, managerial ownership, and board independence, to provide a more comprehensive and holistic understanding of ESG risk dynamics.

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