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Does Biodiversity Disclosure Matter? Evidence on Investor Risk Perception, Firm Performance, and the Moderating Role of ISO 14001 Certification

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ABSTRACT

This research is conducted to analyze whether biodiversity disclosure (BDD) affects investor risk perception and firm performance. The role of ISO 14001 certification was also examined to assess whether it strengthens this relationship. This study employed a quantitative approach, involving panel data from companies engaging in the mining, energy, and agricultural sectors in Indonesia during 2019–2023, with firm performance measured through market and financial performance. The findings reveal that BDD is negatively associated with investor risk perception and positively associated with market performance, although no significant association is found with financial performance. Furthermore, ISO 14001 certification strengthens the relationship between BDD, investor risk perception, and firm performance. These results show that BDD plays an important role in corporate communication, particularly in influencing investor responses in capital markets. This study contributes to the literature by expanding empirical evidence on BDD, investor risk perception, and firm performance. It offers novel insights from Indonesia as a mega biodiverse emerging market, examining biodiversity sensitive sectors with ISO 14001 certification as a moderator between BDD and firm performance, with implications for investors, regulators, and policymakers to strengthen biodiversity transparency and environmental risk communication in capital markets.

1. INTRODUCTION

Biodiversity disclosure (BDD) has increasingly attracted global attention and affected multiple sectors, such as the economic, especially after the issuance of the global framework and declaration related to Nature-related Financial Disclosures and Sustainable Development Goals (SDGs) by the United Nations [1, 2]. It is considered crucial in the global economic production as over half of the global production moderately or substantially relies on biodiversity and environmental stability [2]. However, biodiversity continues to decline, including in megadiverse countries. As long known as the home of the biggest biodiversity in Asia, Indonesia, for example, has contributed to 58.2% of rainforest destruction, primarily due to massive mining activities [3]. Ironically, the commercial industry, including mining, is recognised as the biggest contributor to the declining biodiversity [4]. In fact, industry or companies will deal with a huge risk with this loss since it will affect their regulation, supply chain, reputation, and financial performance [5]. Thus, it is important to understand how companies disclose biodiversity-related risks in order to assess their environmental performance comprehensively. Despite its global importance, biodiversity-related information is still marginalised in corporate reporting practices when compared to other environmental issues.

Nevertheless, companies' attention to BDD is still far from satisfactory. It is still lower than the disclosures of climate change, carbon emission, circular economy, waste management, and resource use [6]. Studies on BDD are also insufficient, especially those investigating its impact on economic and financial performance [2]. Previous studies have heavily focused on climate change, carbon emission, circular economy, and waste management [7-12]. In fact, this topic is also crucial and even more complex due to its major contributions to global economic production [2]. This limited attention raises a fundamental question regarding the role and effectiveness of BDD in capital markets.

Limited practices and research on this topic reveal a fundamental issue: the role of BDD remains unclear. Ideally, it should serve as an indicator that investors can use to assess environmental risks and thus impact the company. However, in practice, some companies still see it as a mere symbolic report. Scholars argue that this issue comes from the low practice of BDD [13, 14], a non-uniform reporting standard, and minimal empirical evidence that associates this disclosure with a company's financial performance. This condition is even more crucial in developing and mega-biodiverse countries, like Indonesia. However, most of previous studies have focused on European countries and other developed areas, such as those conducted in Europe [15], United States [16], and Australia [17]. Therefore, empirical evidence from Asian countries is needed, one of which is Indonesia, which is

a mega biodiversity country in Asia. This country often faces high ecological pressure, yet it still has a relatively limited regulatory framework for BDD. This situation has the potential to make information disclosure less effective in reflecting the company's substantial environmental commitments. The effectiveness of BDD therefore depends not only on the quantity of information disclosed, but also on its credibility in the eyes of investors. In this context, ISO 14001 certification, an environmental management system standard issued by the International Organization for Standardization (ISO), plays a crucial role in enhancing the company's credibility. This certification reflects the company's commitment and capability in systematically managing the environmental impacts. Therefore, ISO 14001 certification is believed to enhance the influence of BDD on investor risk perception and company performance.

Despite this urgency, the current literature reveals several key limitations. For example, as argued earlier, many authors still focus on developed countries that do not completely represent developing countries. Second, previous studies often analyse the ecological effects from a macro perspective. Meanwhile, its impact on the company level is not sufficiently discussed. Third, many studies combine BDD with other environmental disclosures. In fact, this issue carries different and more complex risk characteristics. Therefore, to fill this gap, this study aims to examine whether BDD affects investor risk perception and company performance, and whether ISO 14001 certification strengthens this relationship by increasing the credibility of disclosure, particularly in Indonesia, a developing country with the highest biodiversity in Asia.

This study is significant due to three main reasons. First, this study extends the BDD literature to an underexplored institutional context, namely Indonesia, the most biodiverse country in Asia, where dedicated regulatory frameworks for biodiversity reporting remain limited, with existing requirements covering only minimal disclosure items embedded within broader sustainability reporting obligations. Unlike prior studies focused on European or developed country samples, this study provides empirical evidence from a mega biodiverse emerging market characterised by high ecological pressure and sector specific biodiversity dependency. Second, it offers practical implications for companies to treat BDD as a strategic decision, rather than a mere social obligation. It presents empirical evidence on how BDD impacts the company's risk and performance. Third, this study introduces ISO 14001 certification as a credibility enhancing moderator in the BDD performance nexus, a mechanism that has not been empirically examined in prior literature. This addresses a critical gap between symbolic disclosure and substantive environmental commitment. Furthermore, the findings provide empirical justification for regulators and policymakers to strengthen BDD requirements beyond current minimal obligations, particularly in high impact sectors such as mining, energy, and agriculture, and to consider ISO 14001 environmental management certification as a complementary mechanism in biodiversity reporting frameworks.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 Biodiversity disclosure and investor risk perception

According to the signalling theory, visible signals may reduce asymmetric information between companies and investors [18]. Visible signals can enhance effectiveness in communicating about brand, intention, action, and performance [19]. Typically, a reduction in asymmetry information can lead to lower uncertainty and enhanced capabilities in assessing risks [20]. Additionally, it makes the company's stocks more liquid, which eventually decreases the cost of equity (COE). Comprehensive information also decreases investors' expected returns [21, 22]. It indicates that good information transparency can minimise uncertain risks among investors. Therefore, a company must achieve high information transparency to balance between investment attractiveness and risk management.

One of the strategies to achieve information transparency is through non-financial disclosure (such as BDD), as stated in a company's sustainability report [19]. This disclosure is important to bridge the information gap between companies and stakeholders or investors [23]. In a sustainability report, BDD is considered a voluntary signal showing a company's commitment to managing environment-related risks.

Scholars argue that companies engaged in non-financial disclosure, including those related to the environment, can achieve better financial performance in the long term [24]. In addition, they are believed to be more resilient in dealing with crises [25]. Investors will view information transparency as a positive signal from the company, as it shows the company's long-term goals and reduces potential losses associated with environmental risks [21, 26]. Hence, scholars believe that BDD can lower the COE. Companies that engage in disclosure have lower cost equity, which eventually decreases investor risk perceptions [19, 27]. BDD negatively affects the COE which eventually decreases investor risk perceptions [28], particularly for sectors that depend on biodiversity (dependency sectors). Based on the above elaboration, this study formulates the first hypothesis:

H1: BDD is negatively associated with investor risk perception.

2.2 Biodiversity disclosure and firm performance

Recently, the relationship between a company's performance and environmental sustainability has gained increasing attention. Previous studies have found that biodiversity affects a company in multiple forms, such as their values [1, 28], stock prices [29-31], and future analysis [32]. From a signalling perspective, BDD provides information about a firm's environmental commitment and risk management, helping reduce information asymmetry between firms and investors.

Scholars believe that companies must maximise BDD to enhance their financial performance and market value [5]. To do so, they can promote regulations that protect and restore the ecosystem. Such a regulation is deemed effective in improving a company's resilience in facing external disruption [2]. This regulation can be successfully implemented, as demonstrated in research on the Fukushima nuclear accident in Japan, which found that Japanese companies that conducted BDD were more advantaged than those that did not [27]. These companies benefit from lower regulatory risks, improved operational efficiency, and an increasing reputation among investors and consumers [5, 33]. On the other hand, companies with poor biodiversity management practices faced sanctions, tighter regulations, and potential harm to their reputation [1, 34].

Other studies have also provided empirical evidence on how

BDD has affected the company's performance around the world. For instance, a study employed the Chinese A-firm model to assess this variable in relation to the company's performance, represented by Tobin's Q [2]. On the other hand, another study used the 100 Fortune Global Companies to analyse the impacts of this disclosure on financial performance, reflected by the return on assets (ROA) value [1]. Their study demonstrates positive results.

Based on findings of prior studies in various countries, this study reviewed its research objectives using two main indicators: market-based and accounting-based. According to prior study, market-based indicators were evaluated using Tobin's Q, while the accounting-based counterparts were measured using ROA [7]. Therefore, the hypotheses in this study were formulated as follows:

H2: BDD is positively associated with market performance.

H3: BDD is positively associated with financial performance.

2.3 Biodiversity disclosure, investor risk perception, and certification in the environmental management system

Signalling theory describes that companies engage in BDD to show their quality in managing risk, maintaining sustainable capacity, and promoting long-term prospects [1, 28, 29]. However, sustainability information is often regarded as signal that is difficult to verify. Investors need additional evidence to confirm that the disclosure accurately reflects the actual condition on the ground. This can be achieved through certification in the environmental management system because this certification is obtained through external audits, compliance-related expenditures, and the implementation of a well-structured environmental management system [35, 36]. When the disclosure is supported by an environmental certification, the company's credibility signals increase, and investors perceive the company as having lower environmental risks. In other words, the decline in perceived risk consequently reduces investors' perceptions of risk. Therefore, certification in the environmental management system is predicted to strengthen the negative effects of BDD on investor risk perceptions.

H4: Certification in the environmental management system strengthens the negative association between BDD and investor risk perception.

2.4 Biodiversity disclosure, firm performance, and certification in the environmental management system

According to the signalling theory, BDD shows a long term commitment in the environmental management [1, 2, 37]. However, the disclosure alone is not sufficient in the market. The certification in the environmental management system enhances investor trust that companies really implement accountable environmental practices, not greenwashing. This certification indicates that the company has fulfilled international standards, carried out well-documented processes, and passed independent audits [38-40]. This credibility enhances market's positive responses as reflected in the Tobin's Q. On the other hand, a structured environmental management system can lead to efficient operations, reduced waste, and improved process that contributes to improving a company's financial performance, as reflected in their ROA. In this way, this environmental certification is predicted to enhance the positive relationship between BDD and the two indicators in financial performance.

H5: Certification in the environmental management system strengthens the positive association between BDD and market performance.

H6: Certification in the environmental management system strengthens the positive association between BDD and financial performance.

3. METHODOLOGY

This study employed a quantitative approach. It involved secondary data, which consisted of panel data ranging from 2019 to 2023. The data were obtained from either the companies' annual report or sustainability report. The study focused on companies engaging in the mining, energy, and agricultural sectors, which are particularly prone to biodiversity damage, resulting in 458 firm-year observations from 116 firms. The panel is unbalanced, as data availability varies across firms and years, with each firm observed for between two and five years.

The independent variable in this study is BDD, measured using a disclosure index adopted from Ali et al. [41], which consists of nine items across three themes. The index was developed by integrating indicators from prior literature, Global Reporting Initiative (GRI) standards, UN and OECD frameworks, and the EFRAG Sustainability Reporting Standards, and is applied in this study as originally constructed. This index was selected as it represents the most comprehensive and systematically constructed BDD instrument in recent literature, integrating diverse international frameworks into a single coherent measure. Its framework-based design makes it appropriate for the Indonesian context, given that Indonesia has not established detailed and measurable standards for BDD and Indonesian companies predominantly refer to GRI and global guidance in sustainability reporting practice.

Following the structure of Ali et al. [41], the index organises the nine items into three themes, with details of each index item presented in appendix 1 (Table A1). The first theme covered specific business regulations on biodiversity, providing information that enables an understanding of a company's commitment, action plans, and major risks potentially arising from its activities involving biodiversity. The second theme involved the management of biodiversity, involving characteristics and impacts of activities, products or services, biodiversity values, as well as efforts and actions made to conserve, maintain, and restore biodiversity. The evaluation of ecosystem services within a value chain was covered in the third theme, which led to a comprehension of the management strategy for all operations. This covered methods for analysing suppliers, comments from other interested parties, and more general biodiversity considerations related to human rights, indigenous people, local communities and workers, and animal rights.

The reliability of the manual coding process was examined through a second coder who independently scored a randomly selected subsample of 91 firm-year observations, approximately 20 % of the full sample of 458 firm-year observations, without access to the original scores. This subsample size exceeds the minimum threshold recommended for formal intercoder reliability testing, which should not be less than 50 units or 10 % of the full sample [42]. As the BDD index is manually derived from corporate annual and

sustainability reports rather than extracted through an automated procedure, establishing this reliability is essential to demonstrate that the resulting scores are not dependent on a single coder's judgment. Because the index assigns ordinal scores to each item rather than a simple binary present or absent code, agreement between the two coders was assessed using Cohen's weighted kappa [43], which allows partial credit for scoring discrepancies rather than treating all disagreements as equal. Reliability was calculated separately for each scoring component of the index, since the nine items are not scored on a uniform scale and therefore cannot be combined into a single contingency table for the kappa calculation. Six items (Bio01, Bio02, Bio03, Bio07, Bio08, Bio09) are scored from 0 to 2, yielding 546 pairs of item scores from 91 firm year observations multiplied by six items, while three items (Bio04, Bio05, Bio06) are scored from 0 to 3, yielding 273 pairs of item scores from 91 observations multiplied by three items. As shown in Table 1, the weighted kappa was 0.71 for the six items scored from 0 to 2 and 0.79 for the three items scored from 0 to 3, and both values are within the substantial agreement range according to the benchmark of Landis and Koch [44]. Weighting these two figures by their respective number of item pairs produces a combined weighted kappa of 0.74 across the nine BDD index items, which is within the substantial range, supporting the reliability of the coding process.

Table 1. Inter-coder reliability of biodiversity disclosure (BDD) index

Scoring Component	Item Scale	Weighted Kappa	Interpretation
Six items	0 to 2	0.71	Substantial
Three items	0 to 3	0.79	Substantial

This study also involved three dependent variables, measured using data from earlier research, including Elsayed [1], Dakhli [24], Eriandani et al. [45], and Alodat et al. [46]. The first dependent variable is investor risk perception, proxied by the COE, which was estimated using the Capital Asset Pricing Model (CAPM), consistent with previous studies examining environmental disclosure and the COE in the Indonesian context [45]. The risk-free rate was proxied by the Bank Indonesia (BI) Rate for each year, obtained from Bank Indonesia's official statistical database, as it represents the standard domestic benchmark for risk-free returns in the Indonesian capital market. Firm-level beta was retrieved from Yahoo Finance using the 5 year monthly beta estimate, which reflects each firm's systematic risk based on 60 monthly return observations relative to the market index. This beta was treated as time-invariant across the 2019–2023 observation period. Market return was proxied by the annual return of the IHSG (Jakarta Composite Index), as it represents the broadest market benchmark encompassing all stocks listed on the Indonesia Stock Exchange. The COE was calculated at the firm-year level. The second dependent variable is financial performance, proxied by ROA, which was calculated as the ratio of net income to total assets, reflecting the firm's ability to generate profits from its asset base. The third dependent variable is market performance, proxied by Tobin's Q, which was calculated as the firm's total market value divided by the firm's total value of assets, reflecting investors' valuation of the firm relative to its underlying resources. Control variables like size, debt-to-asset ratio (DAR), and COVID-19 were also included in the study [47-49]. COVID-19 is incorporated as a dummy variable to capture the exogenous shock of the pandemic, taking a value of 1 for COVID-19 years and 0 otherwise. To ensure the robustness of the results, an alternative measure of BDD based on GRI 304 was also employed, operationalised as a dummy variable that takes a value of 1 if a company discloses at least one item under GRI 304 and 0 otherwise. In addition, subsample analyses were conducted based on firm size, using the median value as the cutoff point. Firms with total assets above the median were classified as large size firms, while those below the median were classified as small size firms. In data analysis, several equations were employed to test the hypotheses and empirically investigate the effects of BDD on investor risk perceptions and firm performance.

The following equation was used to estimate the effects of BDD on investor risk perceptions, which were moderated by environmental management system certification.

$$COE_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ Control_{i,t} + \varepsilon$$

$$COE_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ ISO_{i,t} + \beta 3\ Control_{i,t} + \varepsilon$$

$$COE_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ ISO_{i,t} + \beta 3\ BDD*ISO_{i,t} + \beta 4\ Control_{i,t} + \varepsilon$$

The effects of BDD on financial performance with environmental management system certification as a moderating variable were estimated using this equation.

$$ROA_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2 Control_{i,t} + \varepsilon$$

$$ROA_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ ISO_{i,t} + \beta 3\ Control_{i,t} + \varepsilon$$

$$ROA_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ ISO_{i,t} + \beta 3\ BDD*ISO_{i,t} + \beta 4\ Control_{i,t} + \varepsilon$$

Finally, the effects of BDD on market performance with environmental management system certification as a moderating variable were estimated using the following specific formula.

$$TOBINSQ_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2 Control_{i,t} + \varepsilon$$

$$TOBINSQ_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ ISO_{i,t} + \beta 3\ Control_{i,t} + \varepsilon$$

$$TOBINSQ_{i,t} = \alpha + \beta 1\ BDD_{i,t} + \beta 2\ ISO_{i,t} + \beta 3\ BDD*ISO_{i,t} + \beta 4\ Control_{i,t} + \varepsilon$$

Table 2 summarises the variable definitions and measurements.

Table 2. Variable measurement

No.	Variable	Acronym	Measurement
1	Biodiversity disclosure	BDD	Each item was rated 0 if no information was available, 1 if a general description was available, and 2 if the description enabled us to know the detailed effects, commitment, and initiatives of the companies on biodiversity. In addition, for items related to biodiversity management, a score of 3 was given to companies that disclosed accurate quantitative data about these effects

2	Biodiversity disclosure GRI	BDGRI	Dummy variable, 1 for companies that disclosed at least 1 item in GRI 304 and 0 for those that did not
3	Investor risk perceptions	COE	Capital Asset Pricing Model, the formula is: $E(Ri) = Rf + \beta i\ (Rm - Rf)$
4	Financial performance	ROA	Ratio of total net income to total assets
5	Market performance	TOBINSQ	The firm's total market value divided by the firm's total value of assets
6	Environmental management certification	ISO	Dummy variable, companies possessing ISO 14001 certification were rated 1, while 0 was given to those that did not
7	COVID	COV	Dummy variable, 1 for COVID years, 0 otherwise
8	Company size	SIZE	Natural logarithm of total assets
9	Debt-to-asset ratio	DAR	Total debt and total asset ratio

4. RESULTS AND DISCUSSION

4.1 Descriptive statistics

Descriptive statistics are first presented to summarise the characteristics of the data, followed by an examination of annual BDD trends. As shown in Table 3, the mean value of BDD was 3.755. The index comprises nine items scored across three components, namely information on biodiversity policy and business action plans with a maximum score of 6, information on biodiversity management covering projects and impacts with a maximum score of 9, and information on biodiversity management in the supply chain with a maximum score of 6, yielding a total maximum possible score of 21. The mean BDD score thus represents approximately 17.8% of the maximum attainable score, indicating that the biodiversity issue has not become a primary focus in the non-financial reports among Indonesian companies. The low level of this disclosure was also evident in the minimum score, which remained at one item, indicating that some companies disclose merely a symbolic report. Prior to regression analysis, BDD was standardised to a mean of 0 and standard deviation of 1 to facilitate interpretation of coefficient magnitudes, while raw scores are retained in the descriptive statistics for reporting purposes.

Meanwhile, other variables were found within a reasonable range for a developing country context. The mean score of investor risk perceptions was 0.0519, reflecting a moderate level. Similar findings were also reported for financial performance, with a mean of 5.048% and a minimum of 1.022%. Further, market performance was observed at a mean score of 1.03, reflecting a market value slightly above its book value. The ISO variable, with a mean of 0.711, indicates that approximately 71.1% of firm-year observations in the sample hold ISO 14001 certification, suggesting that environmental management system adoption is relatively prevalent among companies in biodiversity-sensitive sectors in Indonesia. Other variable controls, such as DAR, SIZE, and COV, showed adequate variations to support regression analysis.

Table 3. Descriptive statistics

	BDD	COE	ROA	TOBINSQ	ISO	DAR	SIZE	COV
Mean	3.755459	0.051914	5.04844	1.033979	0.711790	37.928253	22.22901	0.393013
Maximum	19.00000	0.136457	11.66148	1.969266	1.000000	59.549370	34.32423	1.000000
Minimum	1.000000	0.010162	1.02208	0.504973	0.000000	10.590624	17.13355	0.000000
Std. Dev.	2.797685	0.020150	2.67715	0.322324	0.453424	14.115881	2.056571	0.488954
Observations	458	458	458	458	458	458	458	458

Note: BDD = biodiversity disclosure; COE = cost of equity; ROA = return on assets; TOBINSQ = Tobin's Q; ISO = environmental management certification; DAR = debt-to-asset ratio; SIZE = company size; COV = COVID-19 dummy.

Table 4. Biodiversity disclosure (BDD) annually

	Year of BDD Observation				
	2019	2020	2021	2022	2023
Mean	3.45122	3.483516	3.865169	3.94444	3.971698
Max	13	15	17	17	19
Min	1	1	1	1	1

Table 4 shows a gradual increase in the annual BDD, from 3.45 items in 2019 to 3.97 items in 2023. Despite its small increase, this pattern suggests a growing attention to biodiversity issues, which aligns with the national regulatory drive, global sustainability demands, and Indonesian regional commitment. The annual trends reveal a gradual increase, with the most significant increase recorded in 2021. This jump may be associated with the implementation of sustainability report guidelines on SEOJK 16/2021, which was stipulated in 2021. This guideline encourages companies to extend the sustainability aspects that they must disclose, including biodiversity.

4.2 Multicollinearity test

Table 5. Variance inflation factor (VIF) test

Variable	VIF	1/VIF
BDD	1.8423	0.5427
ISO	2.1034	0.4754
BDD×ISO	3.1649	0.3160
DAR	1.2187	0.8206
SIZE	1.1849	0.8440
COV	1.0041	0.9959

Note: BDD = biodiversity disclosure; COE = cost of equity; ROA = return on assets; TOBINSQ = Tobin's Q; ISO = environmental management certification; DAR = debt-to-asset ratio; SIZE = company size; COV = COVID-19 dummy.

Having observed the characteristics of data in this study, it is necessary to examine the relationship between independent variables through a multicollinearity test by measuring the variance inflation factor (VIF) and tolerance. Table 5 shows that there is no multicollinearity problem among the

independent variables. All VIF scores were noted below 10, while the tolerance scores (1/VIF) were all above 0.1 [50].

After that, the correlation matrix confirmed no multicollinearity. As shown in Table 6, the correlation value among variables was below 0.9, as suggested by previous scholars [51].

Table 6. Multicollinearity test

	BDD	COE	ROA	TOBINSQ	ISO	DAR	SIZE	COV
BDD	1							
COE	0.035432	1						
ROA	0.149734	0.061723	1					
TOBINSQ	0.040592	0.060570	0.172670	1				
ISO	0.056237	0.017985	0.048240	0.004633	1			
DAR	0.011050	-0.013454	-0.331495	0.132664	-0.172043	1		
SIZE	0.275803	-0.007906	0.209217	-0.134192	0.051722	0.260216	1	
COV	-0.027276	-0.133121	-0.139234	-0.036032	-0.030816	0.021438	-0.039218	1

Note: BDD = biodiversity disclosure; COE = cost of equity; ROA = return on assets; TOBINSQ = Tobin's Q; ISO = environmental management certification; DAR = debt-to-asset ratio; SIZE = company size; COV = COVID-19 dummy.

4.3 Main regression results

There is no multicollinearity found among the variables in this study. The study then proceeds to select the appropriate estimation technique for the main regression analysis to test the proposed hypotheses. The regression analysis started with selecting the estimation technique using the Chow test, the Lagrange Multiplier (LM) test, and the Hausman test. The Hausman test was conducted separately for the cross-section and period dimensions. As reported in Table 7, the results of these tests consistently support the fixed effects model across all nine models.

Table 7. Model selection tests

Panel A. Chow and Lagrange Multiplier (LM) Tests			
Dependent Variable	**Chow Chi Square (Prob.)**	**LM (Both) (Prob.)**	**Selected**
COE (model 1)	0.0012***	0.0000***	FE
COE (model 2)	0.0000***	0.0000***	FE
COE (model 3)	0.0000***	0.0000***	FE
ROA (model 1)	0.0041***	0.0000***	FE
ROA (model 2)	0.0003***	0.0000***	FE
ROA (model 3)	0.0000***	0.0000***	FE
Tobin's Q (model 1)	0.0025***	0.0000***	FE
Tobin's Q (model 2)	0.0000***	0.0000***	FE
Tobin's Q (model 3)	0.0001***	0.0000***	FE
Panel B. Hausman Tests			
Dependent Variable	**Hausman Cross Section (Prob.)**	**Hausman Period (Prob.)**	**Selected**
COE (model 1)	0.0046***	0.0218**	FE
COE (model 2)	0.0187**	0.0079***	FE
COE (model 3)	0.0008***	0.0136**	FE
ROA (model 1)	0.0324**	0.0415**	FE
ROA (model 2)	0.0029***	0.0842*	FE
ROA (model 3)	0.0091***	0.0198**	FE
Tobin's Q (model 1)	0.0004***	0.0038***	FE
Tobin's Q (model 2)	0.0267**	0.0615*	FE
Tobin's Q (model 3)	0.0055***	0.0114**	FE

Note: p < 0.01***, p < 0.05**, p < 0.1*.

Heteroskedasticity and serial correlation in the residuals were also examined, as both can bias the standard errors in panel data estimation. Heteroskedasticity was assessed using the modified Wald test for groupwise heteroskedasticity in fixed effects models [52], while serial correlation was assessed using the Wooldridge test for autocorrelation in panel data [53], which examines whether the residuals of a firm in one year are correlated with its own residuals in the previous year. The results are presented in Table 8.

Table 8. Heteroskedasticity and serial correlation tests

Dependent Variable	Modified Wald Chi-square	Prob.	Wooldridge F	Prob.
COE (model 1)	418.72	0.000***	4.86	0.029**
COE (model 2)	366.91	0.000***	2.11	0.149
COE (model 3)	452.38	0.000***	7.54	0.007***
ROA (model 1)	311.46	0.000***	1.64	0.202
ROA (model 2)	487.29	0.000***	5.37	0.022**
ROA (model 3)	344.88	0.000***	3.02	0.085*
Tobin's Q (model 1)	271.54	0.000***	0.96	0.329
Tobin's Q (model 2)	359.11	0.000***	2.74	0.101
Tobin's Q (model 3)	298.43	0.000***	4.18	0.043**

Note: COE = cost of equity; ROA = return on assets.

The modified Wald test rejected the null hypothesis of homoskedasticity in all nine models ($p < 0.01$), indicating that heteroskedasticity is present across all specifications regardless of the dependent variable. The Wooldridge test rejected the null hypothesis of no serial correlation in five of the nine models, namely COE Model 1, COE Model 3, ROA Model 2, ROA Model 3, and Tobin's Q Model 3, while the remaining four models showed no significant evidence of serial correlation. Given the consistent presence of heteroskedasticity and the presence of serial correlation in several models, standard errors were clustered at the firm level in the main regression models, which corrects for both heteroskedasticity and within firm serial correlation simultaneously without requiring a different correction strategy for each model [54].

Table 9. Main regression results

Variable	COE		ROA		TOBINSQ	
	Coefficient	p-Value	Coefficient	p-Value	Coefficient	p-Value
Model 1						
BDD	-0.0013 (0.0003)	0.000***	0.1389 (0.3412)	0.685	0.0501 (0.0257)	0.052*
COV	-0.0004 (0.0003)	0.170	-2.6087 (0.8416)	0.002***	-0.0470 (0.0515)	0.363
DAR	0.0017 (0.0011)	0.123	-0.1864 (0.0460)	0.000***	0.1121 (0.0316)	0.000***
SIZE	0.0064 (0.0068)	0.349	1.4138 (0.3345)	0.000***	-0.0554 (0.0148)	0.000***
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.000		0.000	
Adj R^2	0.205		0.133		0.044	
Model 2						
BDD	-0.0112 (0.0033)	0.001***	0.1160 (0.3529)	0.743	0.0510 (0.0245)	0.038**
ISO	-0.0002 (0.0003)	0.544	-0.6189 (0.9247)	0.504	0.0473 (0.0561)	0.401
COV	-0.0035 (0.0016)	0.041**	-2.5707 (0.8285)	0.002***	-0.0471 (0.0508)	0.355
DAR	0.0002 (0.0001)	0.216	-0.1729 (0.0645)	0.008***	0.0217 (0.0064)	0.001***
SIZE	0.0301 (0.0474)	0.530	1.5133 (0.3608)	0.000***	-0.0578 (0.0145)	0.000***
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.000		0.000	
Adj R^2	0.282		0.170		0.048	
Model 3						
BDD	-0.0140 (0.0039)	0.000***	0.3029 (0.3645)	0.406	0.1305 (0.0428)	0.003***
ISO	-0.0001 (0.0002)	0.718	0.5874 (0.9522)	0.537	0.0322 (0.0553)	0.561
BDD*ISO	-0.0008 (0.0004)	0.064*	0.7787 (0.4538)	0.087*	0.1154 (0.0541)	0.034**
COV	-0.0035 (0.0016)	0.031**	-2.5549 (0.8297)	0.002***	-0.0454 (0.0506)	0.370
DAR	0.0004 (0.0002)	0.083*	-0.1437 (0.0698)	0.041**	0.1047 (0.0311)	0.001***
SIZE	0.0396 (0.0478)	0.408	1.4315 (0.3410)	0.000***	-0.0539 (0.0157)	0.000***
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.000		0.000	
Adj R^2	0.288		0.171		0.050	

Note: p < 0.01***, p < 0.05**, p < 0.1*. BDD = biodiversity disclosure; COE = cost of equity; ROA = return on assets; TOBINSQ = Tobin's Q; ISO = environmental management certification; DAR = debt-to-asset ratio; SIZE = company size; COV = COVID-19 dummy.

Table 9 indicates that BDD is negatively associated with investor risk perceptions. This finding confirms that BDD is associated with a lower investor risk perception (COE). Thus, hypothesis 1 is supported. Scholars argue that companies performing non-financial disclosure show a commitment to the future [27, 55]. This is a visible signal that can increase communication effectiveness in conveying the company's brand, intention, actions, and performance [19]. Once the communication becomes clearer, the information asymmetry between companies and investors is also low. This decreases the investor's uncertainty and increases the ability to assess risks [20]. High environmental reporting can provide information about policies made by the company [56] which can be a good signal for investors. In this way, the COE can decrease [57-59]. Additionally, some investors have certain social preferences [27]. These investors tend to invest in companies that have good concerns with the environment. They are willing to bear a lower COE as long as the company fulfils social and environmental goals [60], which means that investors' risk perception also decreases.

Furthermore, the influence of BDD on a company's performance was proxied with the financial (ROA) and market performance (Tobin's Q). Table 9 reveals that BDD is positively associated with Tobin's Q. This finding indicates that BDD is positively associated with market performance, thus supporting hypothesis 2 in this study. BDD is a strategic signal delivered to the market because it reflects a company's commitment toward sustainability and thus enhances investor's trust. Besides, it improves a company's management by balancing between short-term financial pressure and long-term financial benefits [2]. When a company can maximise this biodiversity as a source of differentiation, it can improve the company's performance from the market-based indicators [5].

Interestingly, BDD was reported to have no significant association with ROA. In other words, BDD is not significantly associated with financial performance; thus, hypothesis 3 is rejected. This finding conforms to previous studies [61], stating the disclosure's long-term orientation. Meanwhile, companies performing BDD should bear the conservation, surveillance, and reporting costs. Therefore, their profitability appears smaller in the short term because the financial benefits are only seen in the long term. Thus, it is more judicious to consider BDD with its sustainability value, rather than perceiving it as an instant leap in profitability. In fact, financial performance is more strongly affected by direct financial factors, such as sales, operating costs, and asset efficiency. Thus, the influence of BDD on financial performance is less visible.

Then, to ensure that the company accurately manages environmental issues, such as biodiversity, this study utilised ISO 14001 as a proxy for environmental management in the moderation analysis. ISO 14001 is an international certification that provides a systematic framework to help companies control environmental impacts [62]. Although this standard does not achieve certain goals, it defines methods that can be used to manage the environment. These methods are expected to improve a company's accuracy in monitoring and mitigating the negative impacts of the company on the environment [63, 64].

Adding ISO 14001 as a certification proxy for environmental management is hoped to strengthen the impacts of BDD on investor risk perceptions and company performance. A dummy interaction variable with BDD was used in this study to identify companies that had ISO 14001 certification and those that did not. Table 9 shows that the interaction involving ISO 14001 certification as the environmental management system is evidently effective in strengthening the relationship between independent and dependent variables. The interaction effect can be seen from the variable of investor risk perception, showing a significantly negative effect. It means that ISO 14001 certification in a company sends investors a strong signal that the company takes their biodiversity seriously. Thus, the risk perception tends to be lower. On the other hand, the interaction effects can also be observed from the company performance variable. The interaction effect is significantly positive for both financial and market performance. The positive and marginally significant interaction effect suggests that ISO 14001 certification strengthens the relationship between BDD and ROA. This indicates that the presence of certification plays a role in whether BDD is associated with improved accounting performance. However, when supported by a certified environmental management system, it is associated with improved financial performance, as it enhances operational efficiency and profitability. Additionally, the market perceives the interaction between BDD and the ISO 14001 certification as a company's commitment to long-term sustainability [62] that is directly implemented. This will increase market optimism and drive market value reflected in Tobin's Q.

4.4 Subsample regression analysis

Table 10. Subsample regression analysis

Variable	COE		ROA		TOBINSQ	
	Coefficient	p-Value	Coefficient	p-Value	Coefficient	p-Value
Large Companies						
BDD	-0.0024 (0.0004)	0.000***	0.1794 (0.0937)	0.057*	0.1376 (0.0748)	0.068*
ISO	0.0005 (0.0007)	0.487	-0.3018 (0.1186)	0.012**	-0.1814 (0.0936)	0.054*
BDD*ISO	-0.0069 (0.0034)	0.044**	0.2647 (0.1095)	0.017**	0.0054 (0.0019)	0.005***
COV	0.0018 (0.0021)	0.401	-0.0912 (0.7816)	0.907	-0.0087 (0.2846)	0.976
DAR	-0.0004 (0.0003)	0.286	-0.1589 (0.0716)	0.028**	0.0063 (0.0028)	0.027**
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.039		0.000	
Adj R^2	0.247		0.031		0.046	
Small Companies						
BDD	-0.0037 (0.0040)	0.365	-0.1418 (0.1816)	0.436	0.1784 (0.0897)	0.046**
ISO	0.0094 (0.0248)	0.705	-0.7924 (0.9147)	0.388	-0.0715 (0.0917)	0.436
BDD*ISO	-0.0058 (0.0113)	0.609	-0.0186 (0.2673)	0.945	0.0638 (0.0416)	0.126
COV	-0.0078 (0.0141)	0.581	-0.4721 (0.2148)	0.029**	-0.1186 (0.0514)	0.022**
DAR	0.0031 (0.0062)	0.618	-0.1587 (0.0826)	0.056*	0.0973 (0.0543)	0.073*
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.0045		0.000		0.000	
Adj R^2	0.172		0.428		0.474	

Note: p < 0.01***, p < 0.05**, p < 0.1*. BDD = biodiversity disclosure; COE = cost of equity; ROA = return on assets; TOBINSQ = Tobin's Q; ISO = environmental management certification; DAR = debt-to-asset ratio; SIZE = company size; COV = COVID-19 dummy.

The results of the subsample regression analysis show that there is a clear difference in how the market and investors in large and small companies appreciate BDD. As shown in Table 10, BDD provides a positive influence on market (Tobin's Q) and financial (ROA) performance in large companies and decreases investor risk perception. One potential reason is that such companies have sufficient capacity to manage the environment, so their disclosure is deemed more credible and substantive. The market assumes that large companies that disclose their biodiversity management practices have stronger environmental management, more controllable operating risks, and more stable prospects in the long run. This condition drives market values and increases operating efficiency, reflected in the financial performance (ROA) [1]. At the same time, investors view a lower environmental risk, so they demand lower risk premiums and decreased risk investor perceptions.

A certification in the environmental management system strengthens this relationship because it serves as formal evidence that the environmental practices have been implemented in accordance with the regulated standards. With the ISO 14001 certification, BDD is not only viewed as a symbolic report but also a strong signal that the company is capable of implementing consistent environmental practices [62]. This factor emphasises that the interaction between BDD and ISO enhances the positive perceptions of the market and investors.

In small companies, BDD is only associated with market performance as measured by Tobin's Q. Tobin's Q reflects forward-looking market valuations, so investors may respond to disclosures directly even though their impact is not yet reflected in historical accounting figures such as ROA. Financial performance as measured by ROA is not significantly associated. Investor risk perception is also not significantly associated. Environmental management system certification also does not strengthen the relationship between BDD and company performance in this group. These findings suggest that in small companies, BDD is more associated with how the market responds in general, rather than financial performance or investor risk perception.

4.5 Robustness test (Global Reporting Initiative index specification)

To examine the robustness of the main findings, this study conducts a robustness test using an alternative specification of BDD based on the GRI index. The results are presented in Table 11. The robustness test was conducted using an alternative specification model to ensure that the results are stable. The study employed the GRI index to investigate the BDD [14]. Although the approach and model were different from the main analysis, the relationship pattern of the variables was consistent. The robustness test continues to show that BDD consistently has a negative correlation with investor risk perceptions, highlighting that the decrease in investor risk perceptions due to environmental disclosure is not a sensitive phenomenon to the model variation. Findings in the market and financial performance also demonstrate that BDD consistently improves market value, but does not have a significant effect on financial performance. Companies that transparently report environmental information are seen as more trustworthy and long-term oriented [65].

Besides, the moderating effects of certification in the environmental management system are still significant in the robustness test. The interaction between BDD and certification in environmental management continues to generate a negative effect on investor risk perception and a positive effect on firm performance. This consistency shows that the role of this certification is stable in nature, not affected by either estimation technique changes or alternative variable definition. Therefore, this test enriches our understanding that the findings in this study are not caused by any specific models. Instead, they reflect a stable relationship within the data.

Table 11. Robustness regression results (GRI index specification)

Variable	COE		ROA		TOBINSQ	
	Coefficient	p-Value	Coefficient	p-Value	Coefficient	p-Value
Model 1						
BDDGRI	-0.0113 (0.0039)	0.004***	0.1197 (0.0968)	0.217	0.0738 (0.0369)	0.046**
COV	-0.0080 (0.0032)	0.014**	-0.4973 (0.2367)	0.037**	-0.0584 (0.0392)	0.138
DAR	-0.0023 (0.0015)	0.129	-0.1862 (0.0629)	0.004***	0.1465 (0.0356)	0.000***
SIZE	-0.00036 (0.0002)	0.047**	0.4386 (0.1214)	0.001***	-0.0392 (0.0094)	0.000***
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.000		0.000	
Adj R^2	0.2715		0.0489		0.0316	
Model 2						
BDDGRI	-0.0238 (0.0072)	0.001***	0.1369 (0.1018)	0.179	0.1497 (0.0678)	0.027**
ISO	-0.1478 (0.9865)	0.881	0.0418 (0.1036)	0.687	0.0825 (0.0947)	0.383
COV	-0.0079 (0.0031)	0.013**	-0.5981 (0.1986)	0.003***	-0.0398 (0.0322)	0.217
DAR	-0.0038 (0.0020)	0.061*	-0.1764 (0.0669)	0.009***	0.1418 (0.0348)	0.000***
SIZE	-0.0017 (0.0008)	0.031**	0.1412 (0.0362)	0.001***	-0.0617 (0.0187)	0.001***
Firm Effect	Yes		Yes		Yes	

Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.000		0.000	
Adj R^2	0.2989		0.1317		0.0378	
Model 3						
BDDGRI	-0.0176 (0.0064)	0.006***	0.1238 (0.0948)	0.193	0.2764 (0.0915)	0.003***
ISO	0.0116 (0.0028)	0.000***	0.0876 (0.0967)	0.366	0.2718 (0.0894)	0.002***
BDDGRI*ISO	-0.0032 (0.0008)	0.000***	0.1827 (0.0956)	0.056*	0.3621 (0.1087)	0.001***
COV	-0.0040 (0.0015)	0.009***	-0.4216 (0.1268)	0.001***	-0.0468 (0.0463)	0.314
DAR	-0.0021 (0.0009)	0.029**	-0.1719 (0.0704)	0.016**	0.1016 (0.0314)	0.001***
SIZE	-0.0003 (0.0002)	0.302	0.1128 (0.0283)	0.000***	-0.0458 (0.0117)	0.000***
Firm Effect	Yes		Yes		Yes	
Year Effect	Yes		Yes		Yes	
Prob F stat	0.000		0.000		0.000	
Adj R^2	0.3884		0.1846		0.0538	

Note: p < 0.01***, p < 0.05**, p < 0.1*. BDD = biodiversity disclosure; COE = cost of equity; ROA = return on assets; TOBINSQ = Tobin's Q; ISO = environmental management certification; DAR = debt-to-asset ratio; SIZE = company size; COV = COVID-19 dummy.

5. CONCLUSIONS

This study shows that BDD provides economic benefits to companies in Indonesia's mining, energy, and agricultural sectors. Companies in these sectors that disclose biodiversity issues transparently are associated with a lower COE, reflecting reduced investor risk perception. BDD is also positively associated with market performance (Tobin's Q) among the sampled firms, although its direct association with financial performance (ROA) is not statistically significant. These findings are reinforced when the sampled companies hold ISO 14001 certification, as the moderating effect of certification is significant for investor risk perception and market performance, while its effect on financial performance is only marginally significant. The certification makes BDD more credible because it shows that companies seriously implement environmental management practices, providing a stronger signal to investors and the market, particularly with respect to risk perception and market valuation.

Additional analysis dividing small-scale and large-scale companies also demonstrates significant results, particularly among large companies in the sample. A potential reason is that large companies have an established and transparent reporting system, and public attention is also high. With these characteristics, information regarding biodiversity issues is easier to read and has a higher possibility of influencing the market. Meanwhile, in small scale companies, limited resources and a simple reporting system make biodiversity information overlooked by investors, so the tested relationship does not show a statistically significant effect. Thus, the difference observed in this study reflects variations in reporting visibility and practices rather than a difference in key findings. The robustness test supports the main findings of this study. Models remain consistent when tested using alternative measurements and specifications, indicating that the observed pattern, including the significant associations with investor risk perception and market performance, as well as the non-significant association with financial performance, is stable and does not rely on any specific approach.

Overall, this study emphasises that attention to biodiversity is not only ecologically important but also provides added value to companies in Indonesia's biodiversity-sensitive sectors. Biodiversity transparency and environmental management practices, particularly through ISO 14001 certification, represent two strategies that can increase a company's credibility and attract investor trust, particularly in shaping market perceptions and reducing perceived investment risk. These findings are specific to Indonesian mining, energy, and agricultural firms over the 2019–2023 period, and generalisation to other sectors, countries, or regulatory contexts should be made with caution. One limitation of this study is the use of a time invariant beta in estimating the COE, which does not capture potential year to year variation in systematic risk across the 2019–2023 period. Future research could estimate firm specific historical year over year betas using rolling regressions of monthly stock returns relative to market returns, provided that sufficient historical stock price data is available, in order to better capture temporal variations in systematic risk. Future studies are encouraged to develop a BDD index specifically tailored to the Indonesian regulatory and institutional context, given that existing instruments such as the one adopted in this study were originally constructed based on global frameworks and large multinational samples. A context-specific index would better capture the nuances of biodiversity reporting practices in Indonesia, particularly in high-impact sectors such as mining, energy, and agriculture where biodiversity dependency is highest.

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APPENDIX

Table A1. Biodiversity disclosure index from Ali et al. [41]

Items	Points
	Information on biodiversity policy and business action plans
Bio01. The company reports on specific biodiversity policies.	0 – There is no information available 1 – Very general description 2 – The description allows to know the specific commitment of the company
Bio02. The company identifies the main risks that its activities may have on biodiversity	0 – There is no information available 1 – Very general description 2 – The description allows to know the specific operational, legal, financial risks of the company
Bio03. The company reports on action plans on biodiversity	0 – There is no information available 1 – Very general description 2 – The description allows to know the quantifiable objectives of the action plans
	Information on biodiversity management: Projects and impacts
Bio04. The company reports on its operations within protected natural areas and/or areas of high biodiversity value	0 – There is no information available 1 – Very general description 2 – The description provides information on (i) the different operational centers in terms of location, position, size, type of operation, etc.; and (ii) the species included in the IUCN red list and in national conservation lists whose habitats are located in areas affected by the organization's operations, by level of threat of extinction 3 – Additionally, the value of protected areas or biodiversity can be identified
Bio05. The company reports on the nature of significant direct and indirect impacts on biodiversity	0 – There is no information available 1 – Very general description 2 – The description makes it possible to know: (i) the nature of the impacts resulting from the activity and products or services, i.e., construction or use of land, mines or infrastructure, use of substances, introduction of invasive species, etc.; and (ii) from other drivers of biodiversity loss, i.e., climate change, overexploitation of resources, etc. 3 – In addition, the company reports on the impacts resulting from its activities, products or services, i.e., duration, extent, degree of reversibility, species affected, etc.
Bio06. The company reports on activities to reduce its impacts on biodiversity	0 – There is no information available 1 – Very general description 2 – The description provides information on the projects and activities promoted or sponsored to conserve, restore or enhance ecosystems or biodiversity in protected and sensitive areas. The external organizations involved must be identified 3 – In addition, it provides quantitative information that allows to know the location, extension, status, certifications, other standards and methodologies used regarding protected or restored habitats
	Information on biodiversity management in the supply chain
Bio07. The company reports on biodiversity management in the value chain.	0 – There is no information available 1 – Very general description 2 – The description makes it possible to know the projects, impacts, valuation of ecosystem services, etc. of the different actors in the value chain (e.g., management plans with suppliers, information on the reactions of other stakeholders)
Bio08. The company considers additional human rights related to	0 – There is no information available 1 – Very general description

biodiversity	2 – The description allows to know the requirements, initiatives, impacts, etc. on human rights related to indigenous peoples, local communities and workers 0 – There is no information available 1 – Very general description
Bio09. The company considers additional animal rights criteria related to biodiversity	2 – The description provides information on: (i) initiatives to ensure the use of handling methods appropriate to the biological characteristics of the animals and environment, as well as the traceability and identification of the animal welfare record at all stages of production; and (ii) initiatives to ensure animal welfare associated with ensuring that animals are free from hunger, thirst and malnutrition, fear and distress, physical and thermal discomfort, etc.