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Expanding horizons, shrinking habitats: Firm scope and biodiversity risk

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ABSTRACT

Biodiversity risk represents a pressing global challenge with far-reaching consequences for ecosystems, economic stability, and corporate sustainability. This study explores the link between firm scope—the breadth of related product markets a firm engages in—and biodiversity risk, leveraging a comprehensive dataset of U.S. publicly listed firms. Our findings reveal a significant positive relationship between firm scope and biodiversity risk, indicating that firms operating across broader product markets face greater ecological vulnerabilities. However, this relationship weakens in firms with strong corporate culture and high operational efficiency, while it intensifies in environmentally sensitive industries and those with greater analyst coverage. These findings enrich the literature by highlighting how corporate diversification strategies can exacerbate ecological risks. The study provides practical implications for managers and policymakers, underscoring the urgency of embedding environmental considerations into strategic planning to mitigate biodiversity risks.

1. Introduction

Biodiversity risk is a global challenge with profound implications for ecosystems, economic stability, and human well-being. Estimates suggest that biodiversity loss cost the global economy between $4 trillion and $20 trillion annually (Kapnick, 2022), posing substantial threats to business sustainability and economic frameworks worldwide. Current species extinction rates are tens to hundreds of times higher than historical averages over the past 10 million years (Dasgupta, 2021). According to the World Economic Forum (2023), approximately 50 % of global GDP depends on nature, underscoring that biodiversity loss jeopardizes ecological balance and the long-term viability of businesses reliant on natural ecosystems. In this context, this paper examines the relationship between firm scope and biodiversity risk, exploring how corporate strategies impact environmental conservation and sustainable economic practices.

Firm scope, the range of related product markets a firm operates in, is central to corporate strategy and organizational design. Literature highlights that diversification enhances firm performance, optimizes resource allocation, and strengthens competitive advantage (Hill and Hoskisson, 1987; Penrose,1959; Teece,1980). Firms with broader scopes benefit from cross-market synergies, improved risk management, and enhanced adaptability in dynamic environments (Matvos et al., 2018; Montgomery, 1994). Recent

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studies show that firm scope enhances valuation, drives growth, and correlates with increased acquisitions, fewer divestitures, increased R&D, greater outsourcing, and more vertical integration (Hoberg and Phillips, 2025).

This study is motivated by the increasing need to align corporate strategies with environmental sustainability. Hoberg and Phillips (2025) report a 60 % rise in average firm scope, predominantly with related industries, with notable implications for performance and valuation. Despite extensive research on corporate actions and environmental risks, the link between biodiversity risk and firm scope remains underexplored. Understanding this relationship is vital, as a broader firm scope may bolster resilience through resource diversification or amplify vulnerability due to complex ecosystem dependencies. This study aims to inform strategic business decisions and promote sustainable practices to mitigate ecological harm.

Drawing on the resource-based view and organizational complexity perspectives, we propose competing hypotheses on the relationship between firm scope and biodiversity risk. On one hand, firms with broader product market portfolios may exhibit better capacity to manage biodiversity risks due to superior resource capabilities. These capabilities facilitate comprehensive environmental risk identification and mitigation strategies. The complexity of their operations fosters cross-functional learning and integrated biodiversity conservation strategies (Hoberg and Phillips, 2025). Additionally, such firms often face greater stakeholder scrutiny, driving stronger institutional pressures for proactive environmental management (Delmas and Toffel, 2008).[1]

Conversely, a broader firm scope potentially escalates biodiversity risk through increased ecosystem interactions and complex supply chains. Resource dependency theory suggests that diversified external inputs heighten environmental uncertainties (Pfeffer and Salancik, 1978). Expansion into related industries may intensify habitat fragmentation and resource depletion, while complex supply chains can obscure environmental impacts, complicating biodiversity risk management (Zhu and Sarkis, 2016).

Analyzing a large sample of US publicly listed firms, we find a robust positive relationship between firm scope and biodiversity risk, indicating that broader market operations heighten exposure to such risks. This relationship remains consistent after addressing endogeneity concerns. This effect is attenuated in firms with superior corporate culture and higher operational efficiency. Conversely, it is more pronounced in environmentally sensitive industries and firms with extensive analyst coverage.

This study makes several key contributions. First, it extends firm scope literature by linking broader operational reach across product markets to increased biodiversity risk, introducing an environmental dimension to prior findings on scope's influence on valuation and strategy (e.g., Berger et al., 1995; Hoberg and Phillips, 2025). While Hoberg and Phillips (2025) show that scope expansions enhance market coverage without increasing reported segments, and Denis et al. (1997) highlight diversification's agency costs, we uniquely connect firm scope to biodiversity risk, an underexplored consequence. Second, we demonstrate that operational breadth intensifies biodiversity risks, enriching traditional environmental research beyond pollution (Cheng et al., 2024) and carbon emissions (Matsumura et al., 2014). Our findings reveal that this relationship weakens in firms with strong corporate culture and operational efficiency but exacerbated in environmentally sensitive industries and under higher analyst coverage. These insights emphasize the strategic factors that influence environmental outcomes, offering guidance for sustainable practices (Hasan and Chen, 2025; Hasan et al., 2025). Finally, our study provides practical insights for managers and policymakers by illustrating how firm scope decisions shape environmental risk profiles.

2. Research method

2.1. Sample and data

Our sample is constructed by combining firm scope data from Hoberg & Phillips (2025) with biodiversity risk data from 10-K filings for U.S. public firms. Financial data is sourced from Compustat, analyst forecasts from IBES, and institutional holdings from 13F filings. We exclude financial firms (SIC codes 6000–6999) and remove observations with missing key variables, resulting in a final sample of 109,207 firm-year observations covering the period 1994 - 2021. Continuous variables are winsorized at the 1 % level to reduce the impact of outliers.

Online appendix OA.1 presents an industry breakdowns based on the Fama-French 12 classification. The Business Equipment sector has the highest frequency (22.6 5%) but a low mean biodiversity risk (0.022), whereas the Energy sector, despite comprising of only 5.1 7% of the sample, demonstrates the highest mean biodiversity risk (0.535).

2.2. Measurement of firm scope

We employ the firm scope measure by Hoberg and Phillips (2025), which employs a text-based analysis of 10-K business descriptions to capture firm-year product market scope. This method applies a doc2vec embedding model to extract semantic relationships from 10-K filings, decomposing business descriptions into subdialects representing distinct product markets.

The process involves clustering single-segment firm vectors using k-means to identify 450 initial candidate industries, which are subsequently refined to 300 unique "D2V industries" by removing redundant categories. The doc2vec model improves industry-specific scoring of 10-K texts, eliminates boilerplate content, and intuitively labels industries. Firm scope is measured by the

[1] Biodiversity risk comprises physical and transition risks (Giglio et al., 2023). Physical risk arises from firms' dependence on ecosystem services and biodiversity degradation, while transition risk stems from regulatory, market, and societal shifts toward biodiversity protection. We contend that firms operating across multiple markets face heightened transition risks through diverse compliance requirements and changing consumer preferences for biodiversity-friendly products.

number of doc2vec segments a firm spans annually, providing a granular view of product market diversity.

2.3. Biodiversity risk

We measure firm-level biodiversity risk exposure using the 10K-biodiversity-count score, derived from textual analysis of firms' 10-K filings. This approach utilizes a biodiversity dictionary, refined with specific terms, to identify biodiversity-related sentences (Giglio et al., 2023). We conduct this analysis using the Seekinf platform (https://www.seekinf.com/), which applies regular expression searches to locate sentences referencing biodiversity risk. Additional filters are applied to exclude irrelevant mentions. Appendix OA.2 details the biodiversity vocabulary and specific terms used in the analysis. This measure quantifies firms' biodiversity awareness and reporting, serving as a proxy for biodiversity risk exposure.

2.4. Regression model

To test our hypothesis, we estimate the following regression model:

$$Biodiversity = a_0 + \beta_1 Scope + \phi controls + fixedeffects + \varepsilon$$

where *Biodiversity* indicates biodiversity risk extracted from 10 K files, *Scope* is our key variable of interest capturing firm scope, controls indicate firm level controls and ε indicates error term. We control for the natural logarithm of total assets, financial leverage, growth, profitability, tangible assets, capital expenditure, cash holdings, analyst following, institutional ownership, and cashflow volatility. We incorporate year and firm fixed effects. Variables are defined in Table 1.

3. Results

3.1. Summary statistics and correlations

Table 1 presents descriptive statistics for variables. The biodiversity measure has a mean of 0.093 with most observations clustering at zero, while firm scope averages 7.781 with a standard deviation of 5.974.[2] Firms in our sample are moderately large, with the natural logarithm of total assets averaging 5.15, and display low to moderate levels of debts and growth opportunities. On average, profitability is negative, with moderate cash reserves (21.8 % of assets) and tangible asset intensity (25.7 %).

Online appendix OA.3 reveals a statistically significant positive correlation between Biodiversity risk and scope ($\rho = 0.175$; $p < 0.01$). Moreover, the variance inflation factor (VIF) value remains below thresholds, thus mitigating potential multicollinearity concerns.

3.2. Main regression results

Table 2 presents main regression results, revealing a robust and statistically significant positive relationship between firm scope and biodiversity risk across all models (columns 1–5). The coefficient of scope remains positive and highly significant at the 1 % level in every specification, suggesting that as firms expand their scope (engaging in a broader range of related markets), biodiversity risk increases. This relationship persists after controlling for various factors, including firm, year and industry fixed effects, and alternative regression model (logit model in column 5), demonstrating the robustness and consistency of the results. Our findings are also economically meaningful. For instance, the coefficient in column (2) suggests that a one standard deviation increase in scope is associated with a 6.87 % rise in biodiversity risk, relative to its standard deviation (calculated as (5.974 * 0.004)/0.348).

Among the control variables, total assets and tangible assets consistently show a positive and significant relationship with biodiversity, indicating that larger firms and those with more tangible assets are more exposed to biodiversity risk. Conversely, profitability exhibits a negative and significant association, implying that profitable firms engage in practices that mitigate biodiversity risk, potentially reflecting greater resources or incentives to enhance environmental stewardship.

3.3. Endogeneity tests

We adopt four strategies to address potential endogeneity concerns arising from omitted variables, measurement error, or simultaneity.

3.3.1. Two-stage least-squares (2SLS) regression

To address endogeneity concerns, we employ a 2SLS regression using Lewbel's (2012) instrumental variable approach. Unlike traditional instrumental variable methods, Lewbel's approach uses heteroscedasticity in the error term as an internal instrument, making it particularly valuable in settings where valid external instruments are difficult to identify. The method works by leveraging

[2] Giglio et al. (2023) find that 3.8% of 10-K filings from 2015-2020 mention biodiversity. Differences in measurement approach and sample period may explain the differences in our results.

Table 1
Summary statistics.

	Mean	SD	p25	Median	p75
Biodiversity (ln)	0.093	0.348	0.000	0.000	0.000
Scope	7.781	5.974	3.000	6.000	11.000
Total Assets (ln)	5.153	2.658	3.457	5.257	7.018
Financial Leverage	0.373	0.874	0.024	0.204	0.396
MTB	1.170	0.683	0.765	0.961	1.325
Profitability	−0.218	1.295	−0.068	0.084	0.148
Tangible Asset	0.257	0.244	0.066	0.170	0.382
Cash	0.218	0.253	0.029	0.111	0.322
Capex	0.052	0.064	0.013	0.031	0.064
Analyst Coverage	1.054	1.145	0.000	0.693	2.079
Institutional Ownership	0.345	0.356	0.000	0.228	0.683
δCashflow	0.272	0.909	0.032	0.062	0.140

This table presents the summary statistics of the variables used in the analysis. Biodiversity (ln) is the natural logarithm of biodiversity risk. Scope is the firm scope measure defined by Hoberg and Phillips (2025). Total Assets (ln) represents the natural logarithm of total assets. Financial Leverage is calculated as total debt scaled by total assets. MBT denotes the market-to-book ratio. Profitability is measured as return on assets. Tangible Asset refers to property, plant, and equipment scaled by total assets. Cash represents cash holdings as a proportion of total assets. Capex is capital expenditure divided by total assets. Analyst Coverage is the natural logarithm of the number of analysts following a firm in a given year. Institutional Ownership is the proportion of shares held by institutional investors. δCashflow is the rolling standard deviation of cash flow scaled by total assets over the previous five years.

Table 2
Main regression.

VARIABLES	(1) Biodiversity (ln)	(2) Biodiversity (ln)	(3) Biodiversity (ln)	(4) Biodiversity (ln)	(5) Bio_D
Scope	**0.010*** **	**0.004*** **	**0.007*** **	**0.005*** **	**0.033*** **
	[0.001]	**[0.001]**	**[0.001]**	**[0.000]**	**[0.003]**
Total Assets (ln)		0.012***	0.006***	0.008***	0.054***
		[0.003]	[0.002]	[0.002]	[0.010]
Financial Leverage		0.002	0.004*	0.002	0.039*
		[0.002]	[0.002]	[0.002]	[0.021]
MTB		−0.000	−0.015***	0.004	−0.056*
		[0.003]	[0.004]	[0.003]	[0.031]
Profitability		−0.004***	−0.005***	−0.002*	−0.036**
		[0.001]	[0.002]	[0.001]	[0.015]
Tangible Asset		0.081***	0.187***	0.014	0.724***
		[0.019]	[0.021]	[0.017]	[0.093]
Cash		0.020***	−0.011	0.001	−0.168**
		[0.006]	[0.008]	[0.006]	[0.084]
Capex		−0.015	0.065	0.039	0.435**
		[0.031]	[0.049]	[0.028]	[0.183]
Analyst Coverage		0.009**	−0.002	0.003	−0.048**
		[0.003]	[0.004]	[0.003]	[0.022]
Institutional Ownership		−0.028***	−0.020	−0.016*	0.003
		[0.009]	[0.013]	[0.009]	[0.070]
δCashflow		0.000	−0.003	−0.001	−0.038**
		[0.001]	[0.002]	[0.002]	[0.017]
Constant	0.013***	−0.027	−0.018*	0.006	−1.630***
	[0.004]	[0.017]	[0.010]	[0.015]	[0.233]
Year FE	No	Yes	Yes	No	Yes
Firm FE	No	Yes	No	Yes	No
Industry FE	No	No	Yes	No	Yes
Industry x Year FE	No	No	No	Yes	No
Observations	109,207	109,207	109,207	109,207	107,725
Adj. R-squared	0.031	0.714	0.261	0.740	0.288

This table reports the results of regressions examining the relationship between firm scope and biodiversity risk. Standard errors clustered at the firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Variable definitions are provided in Table 1.

the variability in the error term to generate instruments that are uncorrelated with the endogenous regressors but correlated with the outcome variable.

We present the results of the 2SLS estimation using Lewbel (2012) methodology in column (1) of Table 3. The instrumented firm scope remains positive and significant ($p < 0.01$), reinforcing the reliability of our initial findings. Diagnostic tests, including the Hansen J-test for overidentifying restrictions and the Kleibergen-Paap test for weak identification, validate the instrumental approach

Table 3
Endogeneity tests.

VARIABLES	(1) 2SLS	(2) EBE	(3) Change regression
Second stage			
Scope	**0.005****	**0.005*****	**0.002*****
	[0.002]	**[0.001]**	**[0.000]**
Total Assets (ln)	0.012***	0.011***	0.006***
	[0.003]	[0.003]	[0.002]
Financial Leverage	0.002	0.003	0.001
	[0.002]	[0.003]	[0.001]
MTB	−0.000	−0.002	−0.001
	[0.003]	[0.004]	[0.002]
Profitability	−0.004***	−0.005***	−0.001
	[0.001]	[0.002]	[0.001]
Tangible Asset	0.081***	0.091***	0.008
	[0.019]	[0.024]	[0.012]
Cash	0.020***	0.034***	0.003
	[0.007]	[0.008]	[0.004]
Capex	−0.015	−0.016	0.009
	[0.031]	[0.038]	[0.017]
Analyst Coverage	0.009**	0.010***	0.002
	[0.003]	[0.004]	[0.002]
Institutional Ownership	−0.028***	−0.029***	−0.010
	[0.009]	[0.009]	[0.007]
δCashflow	0.000	−0.001	0.000
	[0.001]	[0.002]	[0.001]
Constant		−0.035	0.004***
		[0.022]	[0.000]
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Observations	109,207	109,207	94,574
R-squared	0.029	0.748	0.048
Kleibergen-Paap rk LM statistic	262.35***		
Cragg-Donald Wald F statistic	104.116		
Stock-Yogo critical value	98.11		
Hansen J statistic (*p*-value)	32.988		
	(0.517)		

This table reports the results of endogeneity tests. Columns (1) presents the 2SLS regression results using a heteroskedasticity-based identification strategy (Lewbel, 2012), column (2) displays the entropy-balanced regression results, and column (3) provides the change regression results. Standard errors clustered at the firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Variable definitions are provided in Table 1.

and mitigate concerns about potential endogeneity bias.

3.3.2. Entropy balancing estimates

Next, we apply entropy balancing estimates (EBE) to ensure covariate balance between treated and control groups by reweighting observations, thereby addressing potential confounding effects. Firms with a scope above the median are categorized as the treated group, while those below the median form the control group. As shown in Table OA. 4, EBE effectively achieves covariate balance across key characteristics between the two groups. The results in Column (2) of Table 3 indicate that the coefficient for firm scope remains positive and significant ($p < 0.01$), reinforcing our main findings.

3.3.3. Change regression

We also conduct a change regression to control for time-invariant firm-specific factors by regressing the change in biodiversity risk on the change in firm scope and control variables. The coefficient for the change in firm scope remains positive and significant ($p < 0.01$), supporting the evidence that broader firm scope is associated with increased biodiversity risk (Column 3).

3.3.4. Impact threshold for a confounding variable (ITCV) analysis

The ITCV analysis quantifies the required correlation of an omitted variable to explain the observed relationship. In OA.5, the ITCV exceeds the control variables' impacts, reinforcing the robustness of our findings against unobserved confounding factors.

3.4. Cross-sectional analyses

3.4.1. The role of corporate culture

We explore the moderating role of corporate culture in the relationship between firm scope and biodiversity risk. Corporate culture is a critical driver of environmental responsibility, as shared values and norms foster sustainable practices and accountability (Hasan

et al., 2024). Building on this foundation, we posit that firms with strong corporate cultures are better equipped to integrate environmental stewardship into their expanded operations, mitigating the biodiversity risks associated with broader scope.

To test this conjecture, we use the machine learning-based corporate culture score from Li et al. (2021) and interact this score with firm scope. As shown in column (1) of Table 4, the interaction term is negative and significant at the 1 % level, suggesting that a strong corporate culture mitigates the biodiversity risks typically linked to broader firm scope.

3.4.2. The role of firm efficiency

We further examine whether the positive relationship between firm scope and biodiversity risk is moderated by firm efficiency. Operational efficiency enables firms to allocate resources more effectively, streamline processes, and adopt innovative practices that mitigate adverse environmental impacts. This underscores the critical role of efficiency in reducing biodiversity risks associated with broader scopes. Accordingly, we hypothesize that the positive link between firm scope and biodiversity risk weakens in firms with higher operational efficiency.

To test this conjecture, we employ the widely used efficiency measure of Demerjian et al. (2012) and interact it with firm scope. The results, presented in column (2) of Table 4, confirm that operational efficiency significantly mitigates the biodiversity risks typically associated with broader firm scope.

3.4.3. The role of analyst coverage

We investigate the role of analyst coverage on the relationship between firm scope and biodiversity risk. Drawing on institutional theory, we argue that analysts' dual role—promoting transparency while pressuring firms for short-term financial performance—creates systemic pressures that may undermine long-term ecological sustainability (Healy and Palepu, 2001; Ioannou and Serafeim, 2015). As firms expand their operational boundaries, heightened analyst coverage intensifies the tendency to prioritize immediate financial metrics over environmental considerations, potentially increasing biodiversity risk.

To test this hypothesis, we interact analyst coverage with firm scope. The results in Table 4 column (3) reveal a positive and significant interaction term ($p < 0.05$), indicating that increased analyst coverage amplifies the biodiversity risks associated with broader firm scopes.

3.4.4. The role of environmental sensitivity

Finally, we investigate how environmental sensitivity moderates the relationship between firm scope and biodiversity risk. Environmental sensitivity reflects the extent to which a firm's operations depend on or impact natural ecosystems. Firms with broader scopes often operate across diverse geographies and ecosystems, increasing their potential to influence biodiversity through resource extraction, pollution, and habitat disruption.

Table 4
Cross-sectional analysis.

VARIABLES	(1) Biodiversity (ln)	(2) Biodiversity (ln)	(3) Biodiversity (ln)	(4) Biodiversity (ln)
Scope	0.005***	0.006***	0.003***	0.002***
	[0.001]	[0.001]	[0.001]	[0.000]
Culture	0.014***			
	[0.004]			
Scope × Culture	**−0.002*** **			
	[0.000]			
Firm Efficiency		0.019**		
		[0.008]		
Scope × Firm Efficiency		**−0.002** **		
		[0.001]		
Analyst Coverage			0.001	
			[0.004]	
Scope × Analyst Coverage			**0.001** **	
			[0.000]	
Env Sen				–
Scope × Env Sen				**0.012*** **
				[0.002]
Constant	−0.005	−0.051**	−0.020	−0.026
	[0.047]	[0.020]	[0.017]	[0.017]
Other controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	44,036	93,568	109,207	109,207
Adj. R-squared	0.776	0.712	0.714	0.716

This table presents cross-sectional regression results. We test the moderating impact of corporate culture (Column 1), firm efficiency (Column 2), analyst coverage (Column 3), and environmental sensitivity (Column 4). Standard errors clustered at the firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Variable definitions are provided in Table 1.

Using environmentally sensitive industries (Env Sen), defined by 2-digit SIC codes (10, 12, 13, 26, 28, 29, 33, and 49) as per Hasan and Chen (2025), we interact Env Sen with firm scope. The results in Table 4 column (4) show a positive and highly significant interaction term ($p < 0.01$), indicating the positive relationship between firm scope and biodiversity risk is amplified for firms in environmentally sensitive industries.

3.5. Robustness test

In our main analyses, we measure firm scope as the number of D2V-300 segments that exhibit similarity to each firm's 10-K product descriptions (Hoberg and Phillips, 2025). To test the robustness of our findings, we employ two alternative measures: standardized values and the natural logarithm of firm scope. As reported in Table OA.6, these alternative specifications produce qualitatively similar results, reinforcing the validity of our conclusions. We further test the robustness of our results using a binary measure of biodiversity risk, as proposed by Giglio et al. (2023), and obtain qualitatively similar results (see column 3 of Table OA.6).

3.6. Additional test: industry-level regression

We perform an industry-specific analysis using regressions for the Fama-French 12 industry groups to examine the relationship between firm scope and biodiversity risk. As shown in Table OA.7, the positive relationship holds consistently across most industries, except for the telecommunication and utilities sectors. These findings suggest that while the overall relationship is robust, industry characteristics, such as the nature of operations and regulatory environments, play a role in shaping the relationship between firm scope and biodiversity risk.

4. Conclusion

This study investigates the relationship between firm scope and biodiversity risk, providing new insights into the environmental implications of corporate diversification. Using a sample of U.S. publicly listed firms, we document a significant positive relationship between firm scope and biodiversity risk. This relationship is more pronounced in environmentally sensitive industries but is weaker in firms with strong corporate culture and operational efficiency.

Our findings contribute to the literature by linking firm scope—a critical dimension of corporate strategy—to biodiversity risk, expanding the discussion on the environmental consequences of firm diversification. These insights provide valuable guidance for managers and policymakers. Since broader firm scope is linked to higher biodiversity risk, managers should incorporate environmental risk assessments into their strategic decisions to minimize ecological vulnerabilities. This can be achieved thorough comprehensive environmental due diligence during expansion initiatives, improved supply chain transparency, and the adoption of biodiversity-conscious practices. For policymakers, our results highlight the need for regulations that promote biodiversity-conscious strategies, such as enhanced environmental disclosure requirements and incentives for sustainable business practices. However, our study is limited by its focus on U.S. firms, which may constrain the generalizability of the findings to other institutional contexts. Future research could explore cross-country variations to enrich understanding of these dynamics.

CRediT authorship contribution statement

Mostafa Monzur Hasan: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ashrafee T. Hossain:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Lien Duong:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that there is no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.frl.2025.107271.

Data availability

Databases are subscription based and has legal limit to share

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