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Biodiversity risk and seasoned equity offerings

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ABSTRACT

This study explores the relationship between a firm's exposure to biodiversity risk and its decision to undertake seasoned equity offerings (SEOs). Our results show that firms facing significant biodiversity risks are more likely to engage in SEOs, especially those with greater external financial needs. Additionally, firms with stronger managerial capabilities are better equipped to manage biodiversity risks by obtaining additional funding through SEOs. Our research adds to the corporate finance literature by emphasizing the influence of biodiversity risk on a firm's external financing decisions.

1. Introduction

Biodiversity, defined as the variety of genes, species, and ecosystems, is a critical concern. The extinction of wild mammals, plants, marine environments, and the potential loss of millions of other species pose significant economic risks (Karolyi and Tobin-de la Puente, 2023). Recent estimates suggest that the degradation of biodiversity services could cause annual damages ranging from $4 trillion to $20 trillion, highlighting its substantial economic impact (Ahmad and Karpuz, 2024). Addressing biodiversity risks could therefore have profound economic benefits.

Karolyi and Tobin-de la Puente (2023) emphasize the urgent need to address biodiversity loss, which is emerging as a significant challenge for sustainable finance, potentially even more pressing than climate change. They highlight a gap in finance research regarding the risks of biodiversity loss, its pricing, and the mobilization of private investment. Financial institutions, asset managers, and corporate financial officers urgently need to understand and manage the biodiversity risks associated with their investments.

Building on Ahmad and Karpuz (2024), who found that firms increase cash reserves in response to biodiversity risks, indicating a higher precautionary demand for cash, our study explores how firms might increase their cash holdings. Firms may use internal, debt or equity financing. Debt is ruled out due to higher yield spreads and the additional risks and covenants associated with debt financing (Soylemezgil and Uzmanoglu, 2024). Instead, equity financing is preferred for its flexibility during uncertain times, allowing firms to hold additional precautionary cash or manage litigation costs without immediate financial burdens (Carpenter and Petersen, 2002). Further, risk averse managers tend to prefer equity over debt due to the volatility costs of debt (Lewellen, 2006). Since rights offerings are typically used by distressed firms in the U.S. (Ursel, 2006), we argue that firms with high biodiversity risks are incentivized to choose seasoned equity offerings (SEOs) over rights offerings to avoid signaling financial distress to investors.

The study utilizes a measure of biodiversity risk exposure developed by Giglio et al. (2023) through textual analysis of U.S. firms' 10-K statements. The findings indicate that firms exposed to biodiversity risks are more likely to undertake SEOs compared to those without such exposure. This is primarily driven by the need for external capital to manage or mitigate these risks. Consistent with DeAngelo et al. (2010), who found that meeting near-term cash needs is a primary motive for SEOs, the study argues that firms with greater external capital requirements are more inclined to use SEOs to fund precautionary cash reserves aimed at managing biodiversity risks. Additionally, the cross-sectional analysis shows that these results are more pronounced in

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Table 1
Descriptive Statistics
This Table provides the descriptive statistics for variables in the baseline model over the sample period from 2005 to 2018. All variables are defined in the Appendix.

Variable	N	Mean	Median	S.D.	0.25	0.75
SEO	22,304	0.026	0.000	0.159	0.000	0.000
BIORISK_COUNT	22,304	0.030	0.000	0.171	0.000	0.000
BIORISK_REG	22,304	0.020	0.000	0.140	0.000	0.000
MTB	22,304	4.057	0.707	14.471	0.022	1.608
FIRMSIZE	22,304	1.411	1.978	1.047	0.000	2.251
LEVERAGE	22,304	0.760	0.398	1.938	0.024	0.970
PRERET	22,304	0.070	0.006	0.390	−0.159	0.217
FURET	22,304	0.024	−0.014	0.379	−0.193	0.189
IPO	22,304	0.163	0.000	0.369	0.000	0.000
VOLATILITY	22,304	2.401	2.379	0.855	1.807	2.960
RD	22,304	0.023	0.000	0.075	0.000	0.002

firms with stronger managerial capabilities.

The study contributes to the literature on biodiversity risk by examining the relationship between a firm's exposure to biodiversity risk and its corporate financing decisions. It addresses a significant gap by investigating how biodiversity risk influences the decision to issue SEOs. The paper highlights the role of biodiversity risks in driving SEOs, adding to the extensive literature on equity issuances. While theories on equity issuances are well-documented, the impact of corporate ecological risks on these issuances is less explored, especially when such risks create substantial short-term financing needs. The study complements previous research by showing that SEOs can help firms facing biodiversity risks raise capital to meet a higher precautionary demand for cash and investments.

2. Data and methodology

We use data on firms' exposure to biodiversity risk provided by Giglio et al. (2023). Further, we collect annual financial statement data from Compustat, return data from the CRSP database, and SEO data from the SDC Global New Issues database Following previous research, firms in the financial and regulated sectors are excluded. The final sample includes 22,304 firm-year observations from 2005 to 2018. Our sample includes firms listed on NYSE, AMEX, or NASDAQ, with at least one year of prior stock return data and no missing values for variables needed in the baseline regression analysis.

To investigate the effect of firm's biodiversity risk exposure on SEO decisions, we estimate the following logit regression:

$$\begin{aligned}\mathrm{SEO}_{i,t+1} = {} & \beta_0 + \beta_1\mathrm{BIORISK}_{i,t} + \beta_2\mathrm{MTB}_{i,t} + \beta_3\mathrm{FIRMSIZE}_{i,t} + \beta_4\mathrm{LEVERAGE}_{i,t} + \beta_5\mathrm{PRERET}_{i,t} \\ & + \beta_6\mathrm{FURET}_{i,t} + \beta_7\mathrm{IPO}_{i,t} + \beta_8\mathrm{VOLATILITY}_{i,t} + \beta_9\mathrm{RD}_{i,t} + \mathrm{Industry\,fixed\,effect} + \mathrm{Year\,fixed\,effect}\end{aligned} \quad (1)$$

The study examines the likelihood of firms initiating SEOs based on their exposure to biodiversity risks. The dependent variable, $\mathrm{SEO}_{i,t+1}$, is a binary indicator set to 1 if a firm initiates at least one SEO in the following year, and 0 otherwise. The primary variable of interest, $\mathrm{BIORISK}_{i,t}$, measures a firm's exposure to biodiversity risks using two specific metrics:

BIORISK_COUNT: Assigned a value of 1 if a firm's 10-K statement includes at least two sentences mentioning biodiversity, and 0 if there is no mention.

BIORISK_REG: Assigned a value of 1 if the 10-K statement includes at least two sentences referencing biodiversity, with at least one addressing regulatory aspects, and 0 if these conditions are not met.

The study also includes common firm-level determinants of SEOs,

Table 2
Biodiversity Risk and SEO
This table displays Logit regression results analyzing the impact of biodiversity risk on SEO. Control variables, detailed in the Appendix, are incorporated in all regressions, along with industry and year fixed effects. Significance levels are denoted as *** (1 %), ** (5 %), and * (10 %). Z-statistics are in parentheses.

	SEO	SEO
BIORISK_COUNT	**0.606****	
	(2.35)	
BIORISK_REG		**0.535***
		(1.74)
MTB	0.003	0.003
	(1.33)	(1.30)
FIRMSIZE	−0.122*	−0.124**
	(−1.95)	(−1.98)
LEVERAGE	0.034	0.034
	(1.46)	(1.47)
PRERET	0.320***	0.318***
	(3.22)	(3.20)
FURET	0.483***	0.478***
	(4.97)	(4.92)
IPO	1.528***	1.531***
	(12.53)	(12.57)
VOLATILITY	0.059	0.058
	(0.87)	(0.86)
RD	2.425***	2.434***
	(6.03)	(6.07)
Constant	−6.305***	−6.289***
	(−10.07)	(−10.05)
N	22,304	22,304
Pseudo R-squared	0.188	0.188
Year FE	Yes	Yes
Industry FE	Yes	Yes
Cluster Firm	Yes	Yes

Table 3
Channel Analyses
This table presents the channel analyses of the effect of biodiversity risk on SEO. *EFN* is indicator variable which is equal to 1 if the firm's external finance need exceeds the sample median, and 0 otherwise. All other control variables are defined in Appendix A. All regressions include year and industry fixed effects. ***, **, * indicate significance at the 1 %, 5 %, and 10 % level respectively. Z-statistics is in parentheses.

	SEO	SEO
BIORISK_COUNT	−0.315	
	(−0.56)	
BIORISK_REG		−0.485
		(−0.71)
BIORISK_COUNT*EFN	**1.192****	
	(2.20)	
BIO_RISK_REG*EFN		**1.272****
		(2.06)
EFN	−0.535***	−0.520***
	(−3.89)	(−3.81)
Constant	−5.838***	−5.824***
	(−9.13)	(−9.11)
N	22,304	22,304
Pseudo R-squared	0.192	0.191
Controls	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Cluster Firm	Yes	Yes

Table 4
Additional Analyses
This table presents the results of additional analyses. Panel A presents the cross-sectional analysis of the effect of biodiversity risk on SEO. We categorize firms into high (MA_SCORE_H) and low (MA_SCORE_L) managerial ability groups using the top and bottom 25 % of our sample. These variables are then interacted with BIORISK_COUNT and BIORISK_REG in our baseline model. Panel B presents a subsample analysis exploring the impact of biodiversity risk on SEO, focusing on industries most directly affected by biodiversity risks. In Columns (1) and (2), high-sensitivity industries are defined as sectors significantly impacted by biodiversity challenges, specifically agriculture (SIC 2-digit = 01–09), energy (SIC 2-digit = 49), and mining (SIC 2-digit = 10–17). In Columns (3) and (4), following Giglio et al. (2023), high-sensitivity industries include energy (GICS = 1010), utilities (GICS = 5510), and real estate (GICS = 6010). All other control variables are defined in Appendix A. All regressions include year and industry fixed effects. ***, **, * indicate significance at the 1 %, 5 %, and 10 % level respectively. Z-statistics is in parentheses.

Panel A Cross-sectional analysis				
	(1) SEO	(2) SEO	(3) SEO	(4) SEO
BIORISK_COUNT	0.303	0.673**		
	(1.02)	(2.49)		
BIORISK_REG			0.081	0.665**
			(0.21)	(2.13)
BIORISK_COUNT*MA_SCORE_H	**1.249*** **			
	(3.12)			
BIORISK_COUNT*MA_SCORE_L		**−0.293**		
		(−0.61)		
BIORISK_REG*MA_SCORE_H			**1.513*** **	
			(3.27)	
BIORISK_REG*MA_SCORE_L				**−0.566**
				(−1.00)
MA_SCORE_H	−0.846***		−0.848***	
	(−5.44)		(−5.51)	
MA_SCORE_L		0.427***		0.438***
		(3.30)		(3.42)
Constant	−6.281***	−6.432***	−6.278***	−6.417***
	(−10.12)	(−10.34)	(−10.12)	(−10.33)
Observations	22,304	22,304	22,304	22,304
Pseudo R-squared	0.196	0.191	0.196	0.191
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Cluster Firm	Yes	Yes	Yes	Yes
Panel B Subsample analysis				
	(1)	(2)	(3)	(4)
	High-sensitivity industries: agriculture, mining, & energy		High-exposure industries: energy, utilities, & real estate	
BIORISK_COUNT	**1.196*** **		**1.206*** **	
	(3.84)		**(3.69)**	
BIORISK_REG		**1.095*** **		**1.143*** **
		(3.10)		**(3.21)**
Constant	−4.935***	−4.865***	−5.732***	−5.678***
	(−5.93)	(−5.85)	(−6.48)	(−6.51)
Observations	3208	3208	4165	4165
Pseudo R-squared	0.131	0.123	0.145	0.140
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	No	No	No	No
Cluster Firm	Yes	Yes	Yes	Yes

such as market-to-book ratio, firm size, leverage, lagged stock return, future stock return, volatility, IPO dummy, and R&D expenditures. Year and industry fixed effects are included to control for time-variant trends and industry-specific effects. Continuous variables are winsorized at the 1st and 99th percentiles to mitigate the impact of outliers. Summary statistics are provided in Table 1.

3. Results

3.1. Baseline results

Table 2 displays the baseline regression estimates. In column (1), the coefficient for BIORISK_COUNT is positive and significant at the 5 percent level (coef. = 0.606, z-stat = 2.35), suggesting that firms' exposure to biodiversity risks significantly influences their SEO activities. The marginal effects indicate that a firm's exposure to biodiversity risk increases its likelihood of undertaking SEOs by 1.4 percentage points. Given that the unconditional average probability of conducting an SEO is 2.6 %, this increase is economically significant. Column (2) confirms the robustness of this result, showing consistent findings when using BIORISK_REG as an alternative measure for biodiversity risk.[1]

3.2. Channel analysis

We also examine the mechanisms through which biodiversity risk positively impacts a firm's SEO decision, with a particular focus on external finance need. According to DeAngelo et al. (2010), firms primarily conduct SEOs to meet near-term liquidity needs. Thus, external financing need emerges as a potential channel through which biodiversity risks affects a firm's issuance choice. We use an indicator

[1] In terms of marginal effect, a firm's exposure to regulation related biodiversity risk increases its likelihood of undertaking SEOs by 1.2 percentage points, which is also economically significant.

Table 5
Entropy balance
This table reports results of the entropy balance regression. All control variables are included for entropy balancing. All variables are defined in Appendix A. All regressions include year and firm fixed effects. ***, **, * indicate significance at the 1 %, 5 %, and 10 % level respectively. Z- statistics is in parentheses.

	SEO	SEO
BIORISK_COUNT	**0.563*** **(1.81)**	
BIORISK_REG		**0.544*** **(1.69)**
Constant	−7.030*** (−13.10)	−7.7268*** (−13.11)
Observations	22,304	22,304
Pseudo R-squared	0.271	0.320
Controls	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Cluster Firm	Yes	Yes

variable, EFN, which equals 1 if a firm's external finance need[2] exceeds the sample median, and 0 otherwise. Table 3 shows that the coefficients on the interaction term BIORISK × EFN are positive and significant at the 5 percent level, indicating that biodiversity risk has a greater positive impact on firms issuance of SEOs for firms with higher dependence on external financing. Table 4

3.3. Additional analyses

Prior research indicates that firms with highly capable managers prefer equity financing over debt due to their ability to effectively communicate the firm's value to investors, reducing information asymmetry. This is particularly crucial in the context of biodiversity risk, where information opacity is high. To examine the influence of managerial ability on the relationship between biodiversity risk and SEOs, the study conducts a cross-sectional analysis using the managerial ability score (MA_SCORE) from Demerjian et al. (2012). Firms are classified into high and low managerial ability groups based on the top and bottom 25 % of the sample. The results show that firms with higher managerial ability are more likely to engage in SEOs when facing higher biodiversity risk, while those with lower managerial ability are less likely to do so. This suggests that firms with higher managerial ability are better equipped to manage biodiversity risk by raising funds through SEOs.

Additionally, the study explores how industries particularly susceptible to biodiversity risk respond to these challenges through subsample analyses.[3] The results indicate a significantly positive relationship between biodiversity risk and SEOs in these sectors, suggesting that firms in highly sensitive and highly exposed industries tend to manage risks through SEOs. Further, the coefficients of biodiversity risks are higher compared to the overall sample. This highlights an industry-specific effect regarding how firms tailor their financing strategies to address environmental challenges.

3.4. Robustness tests

3.4.1. Entropy balancing

In this section, we conduct additional robustness tests. Our sample comprises 670 observations with biodiversity risk exposure (BIORISK_COUNT =1) and 22,634 without (BIORISK_COUNT =0), indicating potential covariate imbalance. To systematically address sample selection bias, we apply entropy balancing (Hainmueller et al., 2012; Armstrong et al., 2010) to match firms across baseline control variables, generating continuous weights to equalize group means. We then re-estimate the baseline equation on this adjusted sample. The results, presented in Table 5, show that the coefficients on BIORISK_COUNT and BIORISK_REG remain significantly positive, reinforcing the robustness of our findings after accounting for selection bias.

Table 6
Difference in difference
This table shows the results of the difference-in-difference analysis. Panel A summarizes the difference-in-differences analysis, with the control group as firms unexposed to biodiversity risk and the treated group as those exposed. P-values for differences in means between two groups are based on the Standard *t*-tests. Panel B reports the results of the difference-in-differences analysis, estimated using an OLS model to improve robustness. *TREATED* is equal to 1 if a firm has ever been exposed to biodiversity risk, and 0 otherwise. *POST* is equal to 1 if 1 if fiscal year equal 2008, and 0 otherwise. All variables are defined in Appendix A. All regressions include year and firm fixed effects. ***, **, * indicate significance at the 1 %, 5 %, and 10 % level respectively. T- statistics is in parentheses.

Panel A Summary Statistics in Difference-in-difference				
Variable	Control group	Treated group	Difference	p value
SEO	0.029	0.043	−0.014***	0.002
BIORISK_COUNT	0.000	0.512	−0.512***	0.000
BIORISK_REG	0.000	0.343	−0.343***	0.000
MTB	4.209	4.101	0.108	0.780
FIRMSIZE	1.022	1.493	−0.471***	0.000
LEVERAGE	0.802	0.975	−0.172***	0.003
PRERET	−0.003	0.044	−0.047***	0.000
FURET	−0.012	0.004	−0.017***	0.131
IPO	0.182	0.165	0.017**	0.096
VOLATILITY	1.842	2.455	−0.613***	0.000
RD	0.027	0.004	0.023***	0.000
Panel B Difference-in-difference				
			SEO	SEO
BIOCOUNT_POST_TREATED			**0.038*** **(2.78)**	
BIOREG_POST_TREATED				**0.045**** **(2.01)**
BIORISK_COUNT			−0.013 (−0.91)	
BIORISK_REG				−0.025 (−1.17)
TREATED			−0.008 (−0.93)	−0.009 (−1.06)
Constant			0.043 (1.24)	0.047 (1.36)
Observations			19,693	19,693
Adjusted R-squared			0.363	0.363
Controls			Yes	Yes
Year FE			Yes	Yes
Firm FE			Yes	Yes
Cluster Firm			Yes	Yes

Table 7
Parallel Trend
This table reports the results from a *t*-test analyzing the mean differences in firm efficiency between control and treated groups over the years 2007 and 2008. Treated group include firms have ever been exposed to biodiversity risk, and control group include firms never been exposed to biodiversity risk. All variables are defined in Appendix A. ***, **, * indicate significance at the 1 %, 5 %, and 10 % level respectively.

T-test (Year 2007 & Year 2008)				
variable	Mean (Control)	Mean (Treated)	Mean-difference	t-stat
SEO_DELTA	0.1453	0	0.145	0.82

[2] We follow Demirgüç-Kunt and MakSimovic (2002) and Durnev and Kim (2005), both of which defined external financing needs as the difference between a firm's actual growth rate and its sustainable growth rate. Higher the difference greater the dependence on external finance.

[3] We thank the anonymous reviewer for this suggestion.

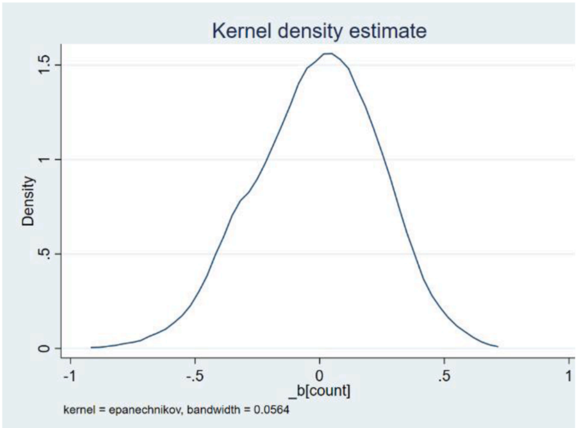

Fig. 1. Distribution of the estimated coefficients with placebo BIORISK_COUNT and SEO.

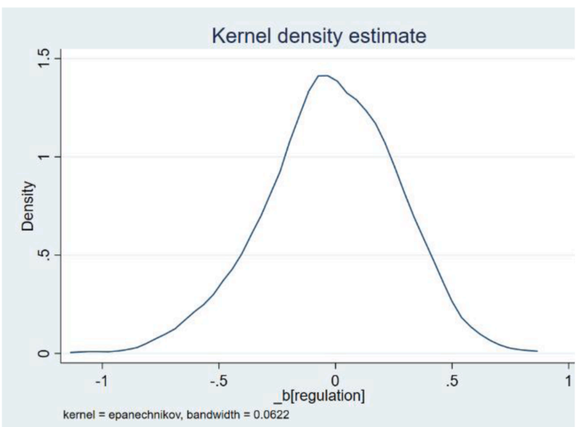

Fig. 2. Distribution of the estimated coefficients with placebo BIORISK_REG and SEO.

3.4.2. Difference in differences

To address potential endogeneity concerns, we conduct a difference-in-differences analysis. Prior research has established a link between biodiversity risk and related events since 2007. For instance, Ma et al. (2024) reports a spike in biodiversity risk following the 2008 World Food Security Conference, and Kalhoro and Kyaw (2024) find abnormal stock market returns for firms exposed to such risks. Building on these insights, we hypothesize that firms facing biodiversity risk (treatment group) are more likely to engage in SEOs in 2009 compared to those never exposed (control group). We define TREATED as 1 for firms encountering biodiversity risk during the sample period and 0 otherwise,[4] and POST as 1 for the fiscal year 2009 and 0 otherwise. To test this, we interact BIORISK_COUNT and BIORISK_REG with TREATED and POST. The results in Table 6 Panel B show a significant positive effect of BIORISK $\times$ TREATED $\times$ POST, confirming that treated firms have a higher likelihood of engaging in SEOs, supporting our baseline results.

To validate the parallel trend assumption in our difference-in-differences model, we compared the mean yearly changes in SEO between the control and treated groups before 2009. A *t*-test on SEOs changes from 2007 to 2008, presented in Table 7, shows no significant differences between the groups, confirming the parallel trends assumption and supporting our hypothesis that any observed differences are likely due to random effects.

3.4.3. Falsification tests

We perform a falsification test to verify whether BIORISK_COUNT and BIORISK_REG genuinely increase the likelihood of SEOs. In Fig. 1, the distribution of 1,000 placebo regressions for BIORISK_COUNT on SEOs centers around zero, indicating no significant relationship. This suggests that the positive association in our baseline regression is unlikely due to omitted variable bias. Similar results for BIORISK_REG are shown in Fig. 2, further supporting that firms exposed to biodiversity risks are more likely to engage in SEOs.

4. Conclusion

We present new and compelling evidence that a firm's exposure to biodiversity risk significantly increases the likelihood of undertaking SEOs. This effect is particularly strong in firms that are heavily reliant on external financing and those with stronger managerial capabilities. Overall, these findings indicate that SEOs are a crucial financing choice for firms facing biodiversity risks to raise additional capital.

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Appendix

Variables	Definitions
BIORISK_COUNT	An indicator which is equal to 1 if a firm's 10-K statement includes at least two sentences that mention biodiversity; it is equal to 0 if there is no mention of biodiversity-related terms.
BIORISK_REG	An indicator which takes a value of 1 if a company's 10-K file includes at least two sentences referencing biodiversity, with at least one of these sentences specifically addressing regulatory aspects related to biodiversity; it is 0 if these conditions are not met.
EFN	the difference between a firm's actual growth rate and its sustainable growth rate.
FIRMSIZE	The natural logarithm of total assets, adjusted to 2005 dollars.
FURET	The market-adjusted stock return over the 12 months in year $t + 1$. The CRSP value-weighted index return serves as the proxy for the market return.
IPO	An indicator that takes the value of 1 if the firm has been public for less than two years, and 0 otherwise.
LEVERAGE	The ratio of the sum of debt in current liabilities and long-term debt to total assets.
MA_SCORE_H	An indicator which is equal to 1 if the managerial ability score is in the top 25 % of our sample, and 0 otherwise.
MA_SCORE_L	An indicator which is equal to 1 if the managerial ability score is in the bottom 25 % of our sample, and 0 otherwise.

(*continued on next page*)

[4] We have included descriptive statistics for the treated and control groups in Panel A of Table 6. The results show that the treated group exhibits a significantly higher mean for the dependent variable, SEO, with a t-test confirming significance at the 1% level.

(*continued*)

Variables	Definitions
MTB	The market value of equity divided by the book value of equity. The standardized market-to-book ratio is derived by subtracting the mean M/B from raw M/B and dividing the result by the standard deviation of M/B for all sample firms.
POST	An indicator which is equal to 1 if the fiscal year equal 2008, and 0 otherwise.
PRERET	The market-adjusted stock return over the 12 months ending immediately before the end of year t. The CRSP value-weighted index return serves as the proxy for the market return.
RD	Research and development expenditures divided by total assets.
SEO	An indicator that takes the value of 1 if a firm undertakes at least one SEO within the next year after a given year t, and 0 otherwise.
TREATED	An indicator which is equal to 1 if a firm has ever been exposed to biodiversity risk, and 0 otherwise.
VOLATILITY	Annualized standard deviation of daily stock returns measured over one year.

Data availability

Data will be made available on request.

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