Received: 29 March 2023 | Revised: 6 December 2023 | Accepted: 7 February 2024

DOI: 10.1002/bse.3725

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Biodiversity management and stock price crash risk

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Abstract

This study explores the link between corporate biodiversity management and the risk of sudden declines in future stock prices, an area largely overlooked in empirical research despite the societal significance of biodiversity loss. We posit that robust corporate biodiversity efforts mitigate the suppression of negative information, consequently reducing the risk of abrupt stock price declines. Leveraging a global dataset and innovative biodiversity management metrics from Moody's ESG Solutions (former Vigero Eiris), our multivariate regression analysis demonstrates that companies with stronger biodiversity structures and actions exhibit lower stock price crash risk. In an additional analysis, we focus on environmental inspections as a possible conduit for releasing negative information on biodiversity management. Using a subsample of North American firms that were inspected by the U.S. Environmental Protection Agency (EPA), we find that firms which experience an inspection record an increase in their stock price crash risk.

KEYWORDS

biodiversity loss, biodiversity management, nature-related risks, stock price crash risk

1 | INTRODUCTION

Biodiversity loss and its consequences are currently recognized as one of the most urgent risks the world is facing (WEF, 2022). Therefore, the objective of this study is to investigate whether financial markets are aware of the biodiversity risks that companies face. In contrast to climate change, which receives significant attention from both investors and the financial research community (Krueger et al., 2020; Stroebel & Wurgler, 2021), biodiversity issues are not an area of importance for corporate reporting (Adler et al., 2018, 2017), firms' financial decisions (Nedopil, 2022), or firms' overall sustainability practices (Schaltegger et al., 2022). This is despite the fact that an estimated 20% of the largest publicly traded companies face material risks associated with biodiversity loss and its impacts (de Carvalho et al., 2022).

The surveys by Krueger et al. (2020) and Stroebel and Wurgler (2021) show that most institutional investors consider climate risks a material risk factor. For instance, climate risks significantly increase a company's credit default swap or bond spreads, both measures of an increased corporate risk profile (Kölbel et al., 2020; Seltzer et al., 2022). However, unlike climate change risks, biodiversity risks are harder to grasp due to their high complexity and lack of unified indicators (Schaltegger et al., 2022). Thus, with respect to biodiversity, and in particular the impacts and interdependencies associated with it, there are higher levels of uncertainty and asymmetric information. For instance, companies that cause significant negative impacts on biodiversity adopt reporting techniques to dilute said impacts (Boiral, 2016). Withholding such information could lead to stockpiling

Abbreviations: CSRD, Corporate Sustainability Reporting Directive; EPA, Environmental Protection Agency; ESRS, European Sustainability Reporting Standards; GDP, gross domestic product; SPCR, stock price crash risk; TNFD, taskforce on nature-related financial disclosures.

negative information, resulting in sudden declines in stock prices once the information is revealed to the market (Benmelech et al., 2010; Hutton et al., 2009; Kothari et al., 2009). Strong engagement in sustainability suggests more ethical behavior on the part of management that results in lower information asymmetries and thus reduces the risk of future stock price crashes (El Ghoul et al., 2018; Y. Kim et al., 2014). Yet sustainability engagement and performance thereon may not fully encompass all subtopics, and different elements may exert varying effects (Edmans, 2023).

There has been a substantial increase in large publicly traded companies emphasizing their commitment to biodiversity conservation (29% of the largest publicly traded companies in 2018), in particular among companies that are more dependent on or have a greater impact on ecosystem services (de Carvalho et al., 2022). In analogy to existing research, we argue that strong biodiversity management reduces negative news hoarding associated with biodiversity impacts and dependencies. We hypothesize that, due to the distinct features of biodiversity risks, strong biodiversity management is negatively associated with the risk of a future stock price crash. To our knowledge, this paper is the first to empirically analyze the relationship between a company's actions on reducing its biodiversity impacts and dependencies (i.e., biodiversity management) and a company's financial risk profile.

We capture the risk of a drop in stock prices by stock price crash risk (SPCR), a measure frequently applied to assess the risk of substantial negative stock returns (Habib et al., 2018). In a multivariate analysis, we study whether strong biodiversity management is acknowledged as value-preserving by financial markets and whether it can help reduce a company's risk profile. To measure biodiversity management, we use data from Vigeo Eiris, a data provider that was fully integrated into Moody's ESG Solutions in 2020. Vigeo Eiris is one of the few data providers to collect yearly data on corporate biodiversity management. Drawing on a global dataset spanning 45 countries and 1402 listed firms, our results indicate that companies with stronger biodiversity management are at lower risk of significant stock price declines. We use a global dataset because the loss of biodiversity affects companies worldwide. Our results show that the management of biodiversity impacts and dependencies thereon have an influence on the risk of a future sudden decline in stock prices, besides overall sustainability performance. A one standard deviation increase in overall biodiversity management is associated with a decrease of 4.2393% and 5.0388%, respectively, for our two measures of stock price crash risk. Moreover, we find that stakeholder feedback on firms' biodiversity management is of special importance for firms in need of legitimacy, that is, those with low overall sustainability performance or low profitability.

In an additional analysis, we consider environmental inspections by the US Environmental Protection Agency (EPA) as an exogenous shock to the information environment around the state of a firm's biodiversity management. In a difference-in-differences design, we find that firms that undergo an EPA inspection see a significant increase in their SPCR in the year following the inspection. This underlines that a firm's impact on the state of biodiversity around its operating facilities is a potential financial risk factor. We argue that environmental inspections are one channel through which negative information on companies' biodiversity stewardship is revealed to the public.

The scientific contribution of our study is twofold. First, it enhances our understanding of the importance of environmental risk factors for financial markets besides climate change. While climate change and its consequences are currently gaining major attention (Giglio et al., 2021; H. Hong et al., 2020), this study underlines that specific environmental risks should not be limited to this one topic. Prior research so far examines how companies value biodiversity itself (Anthony & Morrison-Saunders, 2022), the extent to which they report on biodiversity (Hassan et al., 2022), their commitment to biodiversity (Silva et al., 2019), and the factors that motivate companies to publish disclosures on biodiversity (Hassan et al., 2020). Moreover, de Carvalho et al. (2022) finds that companies exposed to biodiversity-related risks implement biodiversity policies. Thus, our findings extend these studies on the importance of biodiversity management in financial decision making. By examining the financial consequences of biodiversity management, we open up a new strand in the biodiversity disclosure and management literature, which has mainly focused on the importance and motives of biodiversity disclosure (Boiral & Heras-Saizarbitoria, 2017a, 2017b).

Second, this study adds to the literature on how non-financial factors influence stock price crash risk. While Kim et al. (2014) establish a positive relationship between overall non-financial performance and SPCR, others have called for dismantling overall non-financial performance scores and measures (Edmans, 2023). Distinct factors may show a different relationship; for example, Wang, Liu, and Wu (2021) find a positive effect between social engagement and SPCR of financial institutions. In addition, most studies limit their sample on a subset of industries such as banking or renewable energy (Fiordelisi et al., 2023; Yildiz & Karan, 2020). By contrast, our sample includes a wide range of different industries across multiple countries, all of which have varying relationships with and dependencies on biodiversity. Therefore, through our results regarding the relationship between biodiversity management and SPCR we add to the disaggregation of broad non-financial indicators, attempting to provide a more granular perspective on individual non-financial factors and their relationship with SPCR.

Finally, our study has practical implications for companies, investors, and policy makers. For companies and their management, our results suggest that actively managing biodiversity reduces the risk of sudden declines in stock prices in the future, thus highlighting the importance of integrating biodiversity into corporate strategies, policies, and actions. Moreover, an awareness of this relationship may also be important for investors, either as a factor when screening investments or as a parameter to be included in engagement strategies. Lastly, holistic information on biodiversity management is crucial for assessing corporate biodiversity management, which is why our research underscores the importance of the global shift in non-financial reporting. For example, the EU's Corporate Sustainability Reporting Directive (CSRD) requires companies to report according to the recently adopted European Sustainability Reporting Standards (ESRS), of which one is dedicated to biodiversity and ecosystems (ESRS E4). The majority of these reporting requirements are of a (semi) qualitative nature and relate in particular to strategies, policies, and actions (EFRAG, 2023). Similarly, three of the four disclosure pillars recommended by the recently published final framework of the Task Force on Nature-related Financial Disclosures (TNFD) include mainly qualitative information on governance, strategy, and risk and impact management of biodiversity-related dependencies and impacts (TNFD, 2023).

The remainder of the paper is structured as follows. The next section reviews prior literature and develops our hypotheses. Section 3 presents our methodology and the sample selection procedure. We provide and discuss the results in Section 4. Section 5 displays additional results and robustness checks. Section 6 concludes.

2 | HYPOTHESES DEVELOPMENT

2.1 | The risk of biodiversity loss

Intact biodiversity and ecosystems are responsible for up to half of global gross domestic product (GDP) (WEF, 2020). The accelerating loss of species and biodiversity is therefore considered one of the most serious risks by scientific, social, and business experts (WEF, 2021, 2022). Nature-related financial risks to businesses stem from the loss of biodiversity and its consequences for nature and society. These risks are assigned to one of three categories (*physical* risks, *transition* risks, and *litigation* risks) that affect business operations and have financial implications in their own specific ways (Dasgupta, 2021).

Businesses in certain sectors depend on different types of ecosystem services (Winn & Pogutz, 2013).[1] Chemical or energy industries may require functioning rivers to cool their operations, while agricultural firms rely on pollination. Disruption in these areas can result in business interruption or crop failure (*physical* risks) (Dasgupta, 2021; TNFD, 2023). However, through their business activities, companies contribute to all of the major direct drivers of biodiversity loss that have a negative impact on the state of nature (Díaz et al., 2019). Mining companies contribute to land use change to extract resources, negatively affecting species and ecosystems. Consequently, companies may face pressure from civil society or regulators either through litigation (*litigation* risk) or emerging regulation (*transition* risk), (TNFD, 2023). Such pressure negatively impacts a company's reputation, exposes the company to the risk of having to pay for damages caused, or could even jeopardize the current business model through legislation (Miller et al., 2020; Wang, Xu, & Liang, 2021).

Nature-related risks stemming from biodiversity loss substantially differ from the non-financial risk factors analyzed in previous literature (e.g., such as climate change). In particular, nature-related risks constitute prominent and large-scale issues. Yet empirical financial research has not yet examined financial consequences of biodiversity (loss) for capital markets.

2.2 | Biological diversity and related business activities

There is great variation in terms of how companies report on biodiversity-related issues (Adler et al., 2018, 2017; Anthony & Morrison-Saunders, 2022), suggesting that companies' attitude toward biodiversity is heterogeneous. Companies mostly engage in preservation and restoration and report on those biodiversity related activities for reputational reasons and to gain and maintain legitimacy (Hassan et al., 2020; Wagner, 2022). For instance, companies adopt biodiversity policies when faced with risks related to their impacts on biodiversity but underestimate the risks resulting from their dependency on biodiversity (de Carvalho et al., 2022).

Contrary to climate risks, biodiversity-related impacts, dependencies, and actions are harder to grasp and evaluate in corporate reporting due to their high complexity (Schaltegger et al., 2022). There is no unifying indicator, such as carbon emissions, to measure and manage biodiversity-related risks (Kennedy et al., 2022); neither are there clear thresholds for intactness (Addison et al., 2020). Consequently, compared to established topics and indicators such as carbon related risks and performance that feature consistent metrics, there may be greater information asymmetries and uncertainties regarding a company's impacts and dependencies on biodiversity.

2.3 | Stock price crash risk and biodiversity management

Asymmetric information distribution exacerbates the conflict between investors and inside managers to engage in sub-optimal decision making in an attempt to extract private rents (Jensen & Meckling, 1976) positively related to SPCR. Specifically, owing to these agency conflicts and the asymmetric distribution of information, inside managers are incentivized to protect their position by hiding information on these rent-seeking activities (Benmelech et al., 2010; Kothari et al., 2009). The result is an overvaluation of a firm's stock price. Thus, the moment information on managers' opportunistic behavior is revealed, a price correction occurs and the firm's stock price suddenly falls (Hutton et al., 2009).

Previous studies on SPCR show in particular that it is positively associated with firm-internal rent seeking activities, such as chief executive officer (CEO) power (Andreou et al., 2017), earnings smoothing (Hutton et al., 2009), and tax avoidance (J.-B. Kim et al., 2011). In addition, studies consider factors that affect the asymmetric distribution of information between managers and external stakeholders, such as the readability of financial reports (C. Kim et al., 2019). However, the asymmetric distribution of information is influenced by external as well as internal factors. These include

[1]IBPES (2022) defines ecosystem services as "the benefits people obtain from ecosystems."

outside supervision by foreign investors (J.-B. Kim et al., 2020), overall country culture (Yildiz & Karan, 2020), or religiousness of a region (Callen & Fang, 2015).

Kim et al. (2014) suggest that sustainability engagement is negatively related to SPCR, based on the assumption that sustainability engagement signals higher ethical standards among managers, which in turn is negatively related to rent-seeking activities. However, overall sustainability engagement (or performance) may not be able to capture all subtopics. Different elements may have different effects on SPCR (Edmans, 2023). For instance, Wang, Liu, and Wu (2021) find that financial institutions' social engagement is positively related to SPCR, while Liu et al. (2022) confirm a negative relationship between environmental engagement on emissions and SPCR. As highlighted in the first section of this chapter, the management of nature-related risks is potentially of importance to financial markets. Thus, we argue that another important and distinct factor to consider is corporate actions around safeguarding biodiversity. In analogy to Y. Kim et al. (2014), we posit that companies that proactively manage their biodiversity risks and implement appropriate mitigation measures are less inclined to stockpile negative biodiversity-related information. In addition, high levels of biodiversity management signal that these companies are actively managing the pressures their operations place on biodiversity and reducing their dependence on well-functioning ecosystems. As a result, these companies are less exposed to or better prepared for biodiversity-related risks. In consequence, these companies may be less vulnerable to future stock price crashes.

Yet this proposed relationship may not manifest, as companies may be driven to actively engage in biodiversity management in order to obscure negative impacts or unmanaged dependencies on biodiversity (Kim et al., 2014). Previous literature shows that companies frequently remain vague in their biodiversity disclosures, tending to exaggerate positive aspects or downplay negative impacts on biodiversity and ecosystems (Boiral, 2016; Smith et al., 2019). Therefore, from the viewpoint of the information obfuscation hypothesis in the context of the sustainability commitment debate (McWilliams et al., 2006), one would expect a positive relationship between biodiversity management and the risk of a stock price crash. Given the above countervailing considerations, which we believe indicate a rather negative relationship, we formulate our first hypothesis as follows:

> **Hypothesis 1.** (H1). Strong biodiversity management is negatively associated with a firm's stock price crash risk.

2.4 | Stakeholder feedback and biodiversity management

Chiu and Sharfman (2011) indicate that the visibility of corporate actions to stakeholders is a channel through which corporate legitimacy is influenced. Thus, firms adopt broader sustainability programs to gain and maintain their legitimacy (Chiu & Sharfman, 2011; Kölbel et al., 2020), resulting in lower SPCR (Y. Kim et al., 2014). Positive feedback from stakeholders on broad sustainability practices and policies reflects trust in actions and policies, resulting in reduced risk exposure due to leveraged legitimacy. Similarly, positive stakeholder feedback on biodiversity-related practices indicates confidence in biodiversity-related actions and policies, thereby increasing legitimacy and reducing risk exposure. However, we argue that on the one hand, intact biodiversity is particularly important for society as a whole and thus for a company's external stakeholders. On the other hand, biodiversity-related actions are only gradually gaining attention (Adler et al., 2018). Thus, given that companies maintain high levels of credibility with broader sustainability programs, information from stakeholder feedback on biodiversity-related actions and measures may not differ from information from feedback on overall performance in case of a positive performance.

However, prior literature reveals that some relationships between SPCRs are particularly evident when channels that usually mitigate SPCRs, such as governance structures, are weak (Hasan et al., 2021; Y. Kim et al., 2014). By analogy, we posit that a positive stakeholder feedback on biodiversity-related actions and measures signals credibility and mitigates asymmetric information in situations in which companies fall short on overall (sustainability) performance. In such cases, positive stakeholder feedback on biodiversity management and actions may provide a fallback option. Thus, our second research hypothesis is as follows:

> **Hypothesis 2.** (H2). Stakeholder feedback on biodiversity management is negatively associated with stock price crash risk in the event companies need legitimacy.

3 | METHODOLOGY

3.1 | Measuring stock price crash risk

To calculate measures of stock price crash risk, we follow J.-B. Kim et al. (2021) and start by estimating the following regression to estimate firm specific weekly stock returns:

$$r_{i,\tau} = \alpha_i + \beta_1 r_{m,\tau-2} + \beta_2 r_{m,\tau-1} + \beta_3 r_{m,\tau} + \beta_4 r_{m,\tau+1} + \beta_5 r_{m,\tau+2} + \epsilon_{i,\tau} \quad (1)$$

where $r_{i,\tau}$ depicts the return for firm i during week τ. $r_{m,\tau}$ depicts the market return for week τ. Moreover, we include the market returns two weeks around each week to control for nonsynchronous trading (Dimson, 1979; J.-B. Kim et al., 2021), using the country specific MSCI index return as a proxy for local market returns. We then define a firm's weekly stock return $W_{i,\tau}$, calculated as the natural logarithm of one plus the residual from Equation (1). Following the comprehensive literature on stock price crash risk (Hasan et al., 2021; H. A. Hong et al., 2017; J.-B. Kim et al., 2021), we use two measures of SPCR. The first, *NCSKEW*, is negative conditional return skewness, whereas the second, *DUVOL*, captures down-to-up volatility. *NCSKEW*, first introduced by Joseph Chen et al. (2001), is calculated using the negative third moment of a firm's weekly returns during a year and dividing that by the standard deviation of weekly returns, raised to the third power. We define *NCSKEW* in Equation (2). *DUVOL* states asymmetric volatilities by dividing the sum of a firm's squared weekly stock return $W_{i,\tau}$ in down weeks by the sum of all squared weekly returns in up weeks, as defined in Equation (3). Following Joseph Chen et al. (2001), we define up (down) weeks as those in which the return is greater (smaller) than a firm's average weekly return in the corresponding year. n_u and n_d, respectively, depict the number of up and down weeks within a firm-year. For both variables, higher values indicate a higher risk of a stock price crash.

$$NCSKEW_{i,t} = -\frac{n(n-1)^{3/2}\sum W_{i,t}^3}{(n-1)(n-2)\left(\sum W_{i,t}^2\right)^{3/2}} \quad (2)$$

$$DUVOL_{i,t} = \ln\left[\frac{(n_u-1)\sum_{DOWN} W_{i,t}^2}{(n_d-1)\sum_{UP} W_{i,t}^2}\right] \quad (3)$$

3.2 | Empirical model

We deploy the following regression to test our first hypothesis on the relationship between stock price crash risk and a firm's biodiversity management:

$$CRASH_{i,t} = \alpha + \beta_1 BIODIV_{i,t-1} + \sum_{k=2}^{K}\beta_k CONTROLS_{k,i,t-1} + \sum_{c=1}^{C}\tau_c Country_{c,i} + \sum_{j=1}^{J}\tau_j Industry_{j,i} + \sum_{t=1}^{T}\psi_t Year_t + \epsilon_{i,t}, \quad (4)$$

where $CRASH_{i,t}$ depicts one of the two measures of stock price crash risk, $NCSKEW_{j,t}$ or $DUVOL_{j,t}$. $Biodiversity_{i,t-1}$ depicts our main variable of interest, indicating a firm's overall biodiversity management in the previous year. The overall biodiversity management variable is calculated by averaging all three biodiversity subscores provided by Vigeo Eiris. We use the subscores as further variables of interest. First, *Biodiv. Leadership* proxies a firm's overall commitment toward preserving biodiversity, indicating, for example, the existence of clear policies related to the topic and the public visibility thereof. Second, *Biodiv. Implementation* indicates the state of overall implementation of said commitment. The pillar assesses the means allocated to achieving the commitment and the scope of implementation in both geographical and operating segments. Finally, *Biodiv. Results* evaluates the results of a firm's ambitions, looking at stakeholder feedback or biodiversity measures. Each of the three biodiversity scores ranges between 0 and 100, with higher values indicating stronger performance. See the studies by Bilbao-Terol et al. (2019) and Cavaco et al. (2020) for a more detailed description of the three-pillar structure established by Vigeo Eiris.

Additionally, we follow J.-B. Kim et al. (2021) and include several control variables that the prior literature identifies as determinants of stock price crash risk. We include the lagged negative skewness of stock returns (*LAGNCSKEW*), detrended trading volume (*DTURNOVER*), average weekly returns *(RET)*, and the standard deviation of weekly returns (*SIGMA*). Furthermore, we include several control variables based on company fundamentals. These are firm size (*SIZE*), market to book ratio (*MB*), leverage (*LEV*), and return on assets (*ROA*). We follow the approach by H. A. Hong et al. (2017) to control for opaqueness (*OPAQUE*). We retrieve all data for stock prices as well as control variables from Refinitiv Datastream. As our sample consists of a global sample of companies from different countries, we convert all currency amounts into USD. As a final control variable, we include a firm's sustainability performance (*ESG*) using Refinitiv ESG data to ensure that the biodiversity variable is not merely a proxy for a firm's overall sustainability performance, which Y. Kim et al. (2014) find to be another determinant of stock price crash risk. We winsorize all control variables at the top and bottom 1% level to reduce the possible impact of outliers.[2] Further, we include country and industry fixed effects to control for time invariant specific factors. We include year fixed effects to account for temporal events. See Table 1 for a detailed overview of the variables included in our analysis.

3.3 | Sample selection and descriptive statistics

Our sample starts with all companies covered by the Vigeo Eiris biodiversity score worldwide. Vigeo Eiris is one of the few providers of firm-level biodiversity information.[3] Due to a strong uptake in firms with available data on biodiversity management, we start our sample period in 2009. Our sample covers a period of 13 years, ending in 2021. We begin with a total of 12,483 observations from 2230 unique companies. After excluding companies with missing stock price data, missing controls, and sustainability variables, the sample includes 7161 observations from 1402 companies across 45 countries. Table 2 provides detailed steps of the sample selection procedure.

Table 3 gives an overview of the distribution of companies across industries (Panel A) and countries (Panel B) included in our sample. Around 18% (257 firms) of the companies included in our sample are headquartered in the US, followed by Australia and the United Kingdom with both around 8% (115 and 114 firms, respectively). Other countries with a large number of companies are Canada (108 firms), Japan (81 firms), and Hong Kong (64 firms).

Tables 4 and 5, respectively, display the summary statistics and pairwise correlation coefficients of the variables used in the baseline analysis. The control variables are generally of similar size and

[2]In untabulated analysis, we find that the results are qualitatively similar if we do not winsorize our control variables.

[3]Vigeo Eiris has been providing sustainability research, data, and ratings since the 1990s. In 2019, Moody's acquired a majority stake in this company, which officially became part of Moody's ESG Solutions in 2020.

TABLE 1 Variable description.

Variables	Definition
$Biodiversity_{i,t}$	Overall biodiversity management score, measured by the Vigeo Eiris ENV1.4 score.
$Biodiv.Leadership_{i,t}$	Score on biodiversity leadership, measured by the corresponding Vigeo Eiris ENV1.4 subscore.
$Biodiv.Implementation_{i,t}$	Performance regarding the implementation of measures aimed at the protection of biodiversity, measured by the corresponding Vigeo Eiris ENV1.4 subscore.
$Biodiv.Results_{i,t}$	Performance regarding stakeholder feedback related to biodiversity management, measured by the corresponding Vigeo Eiris ENV1.4 subscore.
$DUOVOL_{i,t}$	Negative conditional firm specific weekly return skewness, defined as in Equation (3).
$NCSKEW_{i,t}$	Down-to-up volatility of firm specific weekly returns, defined as in Equation (2).
$LAGNCSKEW_{i,t}$	Lagged value of NCSKEW.
$SIGMA_{i,t}$	Weekly return volatility, calculated as the standard deviation of weekly returns over the year.
$RET_{i,t}$	Weekly return, measured as the yearly mean of firm specific weekly returns.
$DTUNROVER_{i,t}$	Change in monthly turnover, defined as the difference of average monthly share turnover between the current year and the previous year. Monthly share turnover is defined as the monthly trading volume divided by the total number of shares outstanding.
$SIZE_{i,t}$	Natural logarithm of market value of equity for firm *i* in year *t*.
$MB_{i,t}$	Market to book ratio, measured as the market value of equity divided by the book value of equity.
$LEV_{i,t}$	Leverage, defined as the total long-term debts divided by total assets.
$ROA_{i,t}$	Return on assets, defined as the income before extraordinary items divided by lagged total assets.
$OPAQE_{i,t}$	Firm opaqueness, measured as the prior 3 years' moving sum of the absolute value of discretionary accruals estimated by the model from Hutton et al. (2009).
$ESG_{i,t}$	The total Thomson Reuters ESG Refinitiv score for firm *i* in year *t*.

Note: This table reports descriptions of the variables used in my analysis. The control variables are defined following J.-B. Kim et al. (2021). The subscripts *i* and *t* indicate firm and year specific variables.

standard deviation compared to other studies on stock price crash risk (J.-B. Kim et al., 2021; Y. Kim et al., 2014). Our size variable is larger than in other studies analyzing factors influencing stock price crash risk, with a mean market capitalization of USD 6.7 billion. We attribute this to our measure for biodiversity management only being available for large companies. This is in line with other studies employing sustainability related data (Yildiz & Karan, 2020), as providers of sustainability data frequently focus their attention on companies with large market capitalization. The average firm shows a market-to-book ratio of 1.82 and a return on assets of 4.16%. The correlation coefficients between our different (sub)scores of biodiversity management are, except for the variable measuring the stakeholder response to biodiversity actions (*Biodiversity Results*), highly correlated with correlation coefficients ranging between 0.64 and 0.88 and statistically significant at the 5% level.

4 | RESULTS

4.1 | Biodiversity management and stock price crash risk

Tables 6 and 7 depict the regression results of Equation (4) for the two measurements of stock price crash risk (i.e., *DUVOL* and *NCSKEW*). For all our regressions, we report clustered standard errors by firm-level in parentheses below each coefficient. Column 1 in Table 6 (Table 7) indicates that overall strong biodiversity management is related to a lower stock price crash risk with a coefficient of −0.0017 for *DUVOL* (−0.0027 for *NCSKEW*), statistically significant at the 1% level. Both effects are statistically and economically significant. On average, a one standard deviation increase in overall biodiversity management is associated with a decrease of 4.2393% in *DUVOL* in the following year.[4] The effect size for *NCSKEW* is of similar magnitude (−5.0388%). These results suggest an economically significant negative relationship between biodiversity management and stock price crash risk, supporting our Hypothesis 1. The coefficients of our control variables are in line with other studies in terms of sign and magnitude (Jun Chen et al., 2017; Kim et al., 2021; Kim et al., 2014). Firms that show higher past returns, are larger, and exhibit a higher return on assets are subject to higher stock price crash risk.

Columns 2 to 4 in Table 6 (Table 7) show the results for each of the three subscores of biodiversity management separately. The coefficients on the two subscores indicating *Biodiv. Leadership* and *Biodiv. Implementation* are of the same sign and similar magnitude as the overall biodiversity management variable and are statistically significant at the at least 5% level. Interestingly, the coefficient for the *Biodiv. Results* variable, which captures the response of stakeholders, shows no statistical significance at frequently used levels. This pro-

[4] For *Biodiversity*, we obtain the effect size as follows: $\frac{\beta_{Biodiversity} * SD_{Biodiversity}}{SD_{DUVOL}}$, hence, $\frac{-0.0017 * 19.3809}{0.7772} =$ −4.2393 percent.

TABLE 2 Sample selection.

		Number of	
		Observations	Firms
	Biodiversity data	12,483	2230
-	Missing stock price data	142	14
-	Missing control data	4754	696
-	Missing sustainability data	426	118
=	Sample for baseline analysis	7161	1402
-	Firms outside North America	5740	1037
=	Sample for difference-in-differences analysis	1691	365

Note: This table reports our sample selection procedure. We start with the whole universe for which Vigeo Eiris provides data on biodiversity management. Our sample period spans the period from 2009 to 2021.

vides initial evidence for our Hypothesis 2, indicating that positive stakeholder feedback does not result in a general reduction in stock price crash risk.

4.2 | Stakeholder response to biodiversity management and legitimacy

To test the conditioned relationship between *Biodiv. Results* and stock price crash risk, we turn to an analysis using interaction terms. We calculate interaction terms between the *Biodiv. Results* variable and a set of variables capturing a company's requirement to establish legitimacy. We consider three different dimensions that may have an impact on the need for organizations to establish or maintain legitimacy. First, if they have weak biodiversity management and implementation; second, if they have overall weak sustainability performance; third, if they exhibit poor financial performance. Hence, we first include the two other subscores for biodiversity as moderators, as good performance regarding *Biodiv. Results* (i.e., positive stakeholder feedback) may only be of importance for a subgroup of firms (i.e., those with low implementation of their actions toward biodiversity). To capture overall sustainability performance, we include the overall ESG score. In the case of weak overall sustainability performance, stakeholder feedback for certain topics (e.g., biodiversity) may gain importance. The same applies to financial performance, which we capture with a proxy for profitability, namely return on assets.

For the analysis, we calculate the interactions between *Biodiv. Results* and a set of dummy variables. The dummy variable (i.e., *Low Biodiv. Leadership*) is equal to one if the value for the variable (i.e., *Biodiv. Leadership*) is smaller than the corresponding sample median, zero otherwise.[5] We use this approach for all interaction terms.

Table 8, Columns 1 to 4 regress our two measures of stock price crash risk on interaction terms between *Biodiv. Results* and dummy variables derived from the two other subscores of biodiversity management. None of the four interaction terms is statistically significant at the 10% level or lower, indicating that stakeholder feedback is not more important for firms with low biodiversity management (implementation). Columns 5 and 6 (7 and 8) show that the interaction terms between *Biodiv. Results* and *ROA* (*ESG*) are negative and statistically significant at the 10% (5%) level. This indicates that strong performance regarding *Biodiv. Results* (i.e., positive stakeholder feedback) is of special importance to the financial risk position of firms with low financial (sustainability) performance. Firms with low sustainability performance may derive a high marginal utility from good biodiversity management as they do not benefit from the risk-reducing effects of strong sustainability performance (Godfrey et al., 2009; Kim et al., 2014). Similarly, firms with low financial performance (i.e., low return on assets) may focus on strong management of biodiversity to gain or maintain their legitimacy. Overall, the results provide support for our Hypothesis 2.

5 | ADDITIONAL ANALYSIS

5.1 | Environmental inspections and stock price crash risk

Building on the above results, which indicate that biodiversity management reduces the risk of sudden stock price declines, in this section we attempt to establish a causal relationship. Following agency theory (Jensen & Meckling, 1976), the majority of studies on stock price crash risk attribute the occurrence of a sudden drop in share price primarily to bad news hoarding as a consequence of failure of corporate governance mechanisms (Hutton et al., 2009). Such a failure leads to an asymmetric information environment between management and outside stakeholders. In such a case, managers may withhold negative information through reduced transparency for personal benefits, such as empire building or higher compensation (Ball, 2009; Graham et al., 2005). Negative information is stockpiled and eventually released all at once when management is no longer able to withhold it (Kim et al., 2021). This revelation of bad news triggers a sudden share price decline, causing a stock price crash.

[5]Again, note that the results remain qualitatively unchanged if we form the two groups based on yearly median values (untabulated).

TABLE 3 Sector and country distribution of companies included in the analysis.

PANEL A: Sector distribution					
Generic Sector	**No.**	**%**	**Generic Sector**	**No.**	**%**
Electric and gas utilities	189	13.48%	Building Materials	49	3.50%
Mining and metals	147	10.49%	Financial Services - Real Estate	49	3.50%
Food	134	9.56%	Forest Products & Paper	37	2.64%
Pharmaceuticals and biotechnology	134	9.56%	Industrial Goods & Services	35	2.50%
Energy	124	8.84%	Luxury Goods & Cosmetics	34	2.43%
Specialized retail	112	7.99%	Chemicals	25	1.78%
Hotel, leisure goods, and services	70	4.99%	Waste & Water Utilities	17	1.21%
Supermarkets	57	4.07%	Tobacco	15	1.07%
Beverage	54	3.85%	Health Care Equipment & Services	11	0.78%
Heavy construction	54	3.85%	Travel & Tourism	1	0.07%
Oil equipment and services	54	3.85%	Total	1402	100.00%
PANEL B: Country distribution					
Country	**No.**	**%**	**Country**	**No.**	**%**
United States of America	257	18.33%	Malaysia	19	1.36%
Australia	115	8.20%	Sweden	19	1.36%
United Kingdom	114	8.13%	Mexico	18	1.28%
Canada	108	7.70%	New Zealand	16	1.14%
Japan	81	5.78%	Chile	15	1.07%
Hong Kong	64	4.56%	Indonesia	15	1.07%
China	48	3.42%	Norway	15	1.07%
South Korea	48	3.42%	Russia	15	1.07%
France	45	3.21%	Belgium	14	1.00%
India	38	2.71%	Denmark	13	0.93%
Italy	32	2.28%	Finland	13	0.93%
Brazil	31	2.21%	Peru	13	0.93%
Germany	31	2.21%	Poland	13	0.93%
Spain	27	1.93%	Portugal	10	0.71%
South Africa	24	1.71%	Singapore	10	0.71%
Taiwan	21	1.50%	Thailand	10	0.71%
Netherlands	20	1.43%	Other	50	3.57%
Switzerland	20	1.43%	Total	1402	100.00%

Note: This table gives an overview of our sample used for the baseline analysis. Panel A gives an overview of the industry. Distribution of the companies included in the baseline analysis using the Vigeo Eiris sector classification. Panel B gives an overview of the global distribution of the companies included in the baseline analysis by country of a company's headquarters. Both panels are sorted by frequency. For brevity, we display all countries with fewer than 10 companies as single group (Other). Other includes Austria, Colombia, the Czech Republic, Greece, Hungary, Ireland, Israel, the Philippines, Qatar, Turkey, and the United Arab Emirates. For our empirical analyses, we use country fixed effects for all countries, including those with fewer than 10 companies.

Emerging areas of importance for companies, such as sustainability, are particularly vulnerable to high information asymmetry, as there are often no established and standardized disclosure practices (Schiemann & Sakhel, 2019). One of these emerging areas is corporate reporting on biodiversity. Several studies analyze firms' disclosures and find that even the world's largest companies, or those operating in industries with high impacts or dependencies on biodiversity, such as mining, provide only limited information on biodiversity risks (Adler et al., 2018; Boiral, 2016; Hassan et al., 2020; Rimmel & Jonäll, 2013). Due to a pronounced information asymmetry between managers and outside stakeholders, this opaque environment is well suited for hoarding negative information related to biodiversity and ecosystem services.

Besides transparency toward these issues through, for example, strong biodiversity management, one possible factor attenuating information asymmetry is the existence of functioning internal and

TABLE 4 Descriptive analysis.

Variables	N	Median	Mean	Std. Dev.	P25	P75
Biodiversity	7161	28.0000	31.7713	19.3809	14.0000	43.0000
Biodiv. Leadership	7161	30.0000	31.5353	29.7860	0.0000	52.0000
Biodiv. Implementation	7161	20.0000	27.3586	28.4442	0.0000	44.0000
Biodiv. Results	7161	35.0000	36.2955	15.0913	28.0000	35.0000
DUVOL	7161	0.1137	0.1151	0.7772	−0.3642	0.5923
NCSKEW	7161	0.1116	0.1256	1.0385	−0.4545	0.6751
LAGNCSKEW	7161	0.1200	0.1555	0.9485	−0.4356	0.6779
SIGMA	7161	0.0419	0.0477	0.0237	0.0311	0.0577
RET	7161	0.1398	0.1361	0.6347	−0.2309	0.5043
DTURNOVER	7161	0.0000	0.0010	0.0338	−0.0094	0.0098
SIZE	7161	8.8110	8.8537	1.3873	7.9293	9.7411
MB	7161	1.8200	2.8646	3.8380	1.1100	3.2100
LEV	7161	0.2198	0.2313	0.1519	0.1229	0.3235
ROA	7161	0.0416	0.0512	0.0771	0.0165	0.0810
OPAQUE	7161	0.7897	0.6464	0.4146	0.5609	0.9064
ESG	7161	58.9600	56.8385	19.4279	43.6700	72.1100

Note: This table reports the summary statistics of the variables deployed in the baseline analysis. We winsorize all control variables at the 1% and 99% levels.

external control mechanisms. Prior studies show that internal and external controls have distinct influence on the information environment and subsequent stock price crash risk (Jun Chen et al., 2017; Kim et al., 2020; Kim et al., 2011). Especially inspections carried out by governmental agencies could detect the existence of bad information within a company (Zhang et al., 2021), leading to a subsequent release of this news and a corresponding reaction from shareholders.

In consequence, we analyze whether environmental inspections of corporate facilities are one of the channels through which stockpiled bad news is uncovered and subsequently made public. For the analysis, we focus on firms within the U.S. as we require data from the EPA. The EPA is a federal agency whose responsibilities include monitoring the compliance of potentially polluting facilities across the United States. It publishes extensive data on these polluting facilities and whether it conducted an inspection.[6] Additionally, we keep Canadian firms, as many of them operate facilities in the neighboring U.S. Overall, the EPA lists 62,048 facilities with a valid identifier of which the majority (41,426) were subject to an inspection at least once. The EPA only publishes the date of the most recent inspection for each facility,[7] so it is not possible to identify whether a facility was subject to a prior inspection. To mitigate this shortcoming, we aggregate the data on a firm level and use the earliest year any facility of one of the sample companies underwent an EPA inspection as treatment for the release of negative information on biodiversity management to the stock market. Moreover, the potential for missing an inspection prior to the most recent inspections published by the EPA rather reduces our chance of detecting significant effects, as negative biodiversity information may have been revealed by the earlier inspection, reducing the effect of the latter. As the EPA only inspects a small subset of facilities each year, inspections come as a surprise for investors. Thus, we use the event of an environmental inspection as a quasi-natural experiment where some of our sample companies receive a treatment. Overall, the sample for the difference-in-differences analysis includes 1701 observations and 365 unique firms which underwent a total of 704 inspections between 2010 and 2021. While our dataset for the baseline analysis starts in 2009, we only consider inspections starting in 2010 as we require one prior year without any inspection for propensity score matching. As only a minority of firms underwent an inspection (we identify a total of 57 companies as treated firms), we use a propensity score matching approach to create a balanced sample of treatment and control firms. We match treatment and control firms using a logit model with a binary variable equal to one for treated firms and equal to zero for control firms as the dependent variable and a firm's leverage and past stock returns as an independent variable to find the closest match in terms of financial health. We use data 1 year prior to the first inspection year for the matching approach (Caliendo & Kopeinig, 2008). After matching each treated firm to a corresponding control firm, we use a three-year period around each treatment (i.e., first time inspection) to analyze the effect of EPA inspections on stock price crash risk. Due to data restrictions for both treated and control firms, the difference-in-differences sample includes 301 observations (instead of the expected 342).

Table 9 depicts the sample means for the difference-in-differences sample split across the assignment to treatment or

[6]See the study by Kim (2015) which uses EPA inspections for a detailed description of EPA processes.

[7]For more information on the EPA's inspection guidelines and procedures, see https://www.epa.gov/enforcement/federal-facilities-inspections-guide-epas-access-and-inspection-authorities.

TABLE 5 Correlation analysis.

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	Biodiversity	1.00															
(2)	Biodiv. leadership	0.88*	1.00														
(3)	Biodiv. implementation	0.88*	0.64*	1.00													
(4)	Biodiv. results	0.47*	0.20*	0.22*	1.00												
(5)	DUVOL	−0.02	−0.02*	−0.01	−0.02	1.00											
(6)	NCSKEW	−0.02	−0.02	−0.01	−0.02	0.92*	1.00										
(7)	LAGNCSKEW	−0.05*	−0.04*	−0.03*	−0.03*	−0.01	0.00	1.00									
(8)	SIGMA	−0.02	−0.04*	−0.03*	0.06*	−0.09*	−0.09*	−0.08*	1.00								
(9)	RET	0.03*	0.03*	0.03*	0.00	0.08*	0.06*	−0.49*	0.03*	1.00							
(10)	DTURNOVER	−0.02*	−0.02	−0.02*	0.00	−0.03*	−0.03*	0.04*	0.29*	−0.07*	1.00						
(11)	SIZE	0.28*	0.29*	0.31*	−0.06*	0.08*	0.07*	0.03*	−0.39*	−0.01	−0.05*	1.00					
(12)	MB	0.03*	0.04*	0.03*	−0.01	−0.02	−0.01	−0.01	0.07*	−0.01	0.00	−0.04*	1.00				
(13)	LEV	0.04*	0.05*	0.03*	0.02	0.00	0.00	0.02*	−0.01	−0.04*	0.05*	0.04*	−0.05*	1.00			
(14)	ROA	0.03*	0.03*	0.03*	−0.01	−0.02	−0.02	−0.09*	−0.14*	0.21*	−0.05*	0.20*	−0.03*	−0.17*	1.00		
(15)	OPAQUE	−0.04*	−0.04*	−0.04*	−0.01	0.01	0.02	0.01	−0.12*	0.00	−0.02	0.01	0.01	0.04*	0.04*	1.00	
(16)	ESG	0.51*	0.50*	0.48*	0.08*	−0.01	0.01	0.01	−0.12*	0.02	−0.01	0.43*	0.02	0.05*	0.07*	−0.03*	1.00

Note: This table reports the pairwise correlation coefficients of the variables deployed in the baseline analysis.
*Significance at the 5% level.

TABLE 6 DUVOL regression analysis.

	(1)	(2)	(3)	(4)
Variables	DUVOL	DUVOL	DUVOL	DUVOL
Biodiversity	−0.0017***			
	(0.0006)			
Biodiv. Leadership		−0.0010**		
		(0.0004)		
Biodiv. Implementation			−0.0011***	
			(0.0004)	
Biodiv. Results				−0.0001
				(0.0006)
LAGNCSKEW	0.0229*	0.0233*	0.0232*	0.0242*
	(0.0128)	(0.0128)	(0.0128)	(0.0129)
SIGMA	−2.2474***	−2.2501***	−2.2515***	−2.2632***
	(0.6766)	(0.6767)	(0.6771)	(0.6772)
RET	0.1379***	0.1384***	0.1382***	0.1390***
	(0.0200)	(0.0200)	(0.0200)	(0.0200)
DTURNOVER	−0.0624	−0.0692	−0.0571	−0.0618
	(0.3386)	(0.3387)	(0.3388)	(0.3389)
SIZE	0.0332***	0.0323***	0.0342***	0.0284***
	(0.0101)	(0.0101)	(0.0101)	(0.0100)
MB	0.0036	0.0036	0.0035	0.0036
	(0.0027)	(0.0027)	(0.0027)	(0.0027)
LEV	−0.0778	−0.0788	−0.0821	−0.0825
	(0.0695)	(0.0695)	(0.0694)	(0.0691)
ROA	0.5470***	0.5445***	0.5443***	0.5580***
	(0.1637)	(0.1636)	(0.1636)	(0.1632)
OPAQUE	0.0021	0.0017	0.0025	0.0025
	(0.0224)	(0.0223)	(0.0224)	(0.0224)
ESG	−0.0007	−0.0007	−0.0008	−0.0013**
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Constant	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	7161	7161	7161	7161
Adjusted R-squared	0.0361	0.036	0.036	0.0352

Note: This table reports the results of an OLS estimation of Equation (4), regressing the Biodiversity score on DUVOL as one of two different measures of stock price crash risk. Standard errors clustered at the firm level in parentheses below each coefficient. We winsorize all control variables at the 1% and 99% level.
***Significance at the 1% level.
**Significance at the 5%.
*Significance at the 10% level.

control group 1 year prior to each treatment. As indicated by the results of a t-test in the far-right column, the majority of means of the control variables do not differ across the two groups, which indicates a good fit for our matching approach.

The variable of interest in a difference-in-differences regression is the interaction term *Treat***Post*, which is equal to one for treated firms in the years subsequent to the treatment (in this case, the first EPA inspection) and zero for all other observations. Table 10 contains the

TABLE 7 NCSKEW regression analysis.

	(1)	(2)	(3)	(4)
Variables	NCSKEW	NCSKEW	NCSKEW	NCSKEW
Biodiversity	−0.0027***			
	(0.0008)			
Biodiv. Leadership		−0.0015***		
		(0.0005)		
Biodiv. Implementation			−0.0016***	
			(0.0005)	
Biodiv. Results				−0.0005
				(0.0008)
LAGNCSKEW	0.0314*	0.0319*	0.0320*	0.0333*
	(0.0183)	(0.0182)	(0.0183)	(0.0183)
SIGMA	−3.0135***	−3.0173***	−3.0214***	−3.0371***
	(0.9215)	(0.9229)	(0.9216)	(0.9236)
RET	0.1644***	0.1653***	0.1651***	0.1660***
	(0.0273)	(0.0272)	(0.0273)	(0.0273)
DTURNOVER	−0.1147	−0.1254	−0.1071	−0.1129
	(0.4359)	(0.4363)	(0.4364)	(0.4363)
SIZE	0.0343**	0.0330**	0.0352***	0.0267**
	(0.0133)	(0.0134)	(0.0133)	(0.0133)
MB	0.0021	0.0021	0.002	0.0022
	(0.0039)	(0.0039)	(0.0039)	(0.0039)
LEV	−0.0227	−0.0243	−0.0296	−0.029
	(0.0937)	(0.0936)	(0.0935)	(0.0933)
ROA	0.5786**	0.5744**	0.5761**	0.5973***
	(0.2298)	(0.2301)	(0.2300)	(0.2301)
OPAQUE	0.0059	0.0053	0.0066	0.0065
	(0.0286)	(0.0285)	(0.0287)	(0.0287)
ESG	0.0002	0.0001	0.0000	−0.0006
	(0.0009)	(0.0009)	(0.0009)	(0.0008)
Constant	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	7161	7161	7161	7161
Adjusted R-squared	0.0286	0.0285	0.0283	0.0273

Note: This table reports the results of an OLS estimation of Equation (4), regressing the Biodiversity score on NCSKEW as one of two different measures of stock price crash risk. Standard errors clustered at the firm level in parentheses below each coefficient. We winsorize all control variables at the 1% and 99% level.
***Significance at the 1% level.
**Significance at the 5%.
*Significance at the 10% level.

results of the difference-in-differences regression on the two measurements of stock price crash risk. We include all control variables used in our main analysis.[8] As expected, the interaction term is positive and statistically significant, indicating that EPA inspections increase a firm's stock price crash risk, likely through the revelation of negative information on a firm's biodiversity activities.

5.2 | Industry-level risk

The fallout of biodiversity loss and lapse of ecosystem services is not evenly distributed across industries. Primary industries, that is, those

[8]Note that we do not include country fixed effects because the sample for the difference-in-differences design only includes companies from two countries. The results remain unchanged if we include country fixed effects for the analysis.

TABLE 8 Interaction analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW
Biodiv. results (X)	0.0002	0.0000	0.0005	0.0003	0.0004	0.0001	0.0004	0.0004
	(0.0007)	(0.0009)	(0.0006)	(0.0009)	(0.0006)	(0.0009)	(0.0007)	(0.0009)
Biodiv. leadership	−0.0012**	−0.0016**						
	(0.0005)	(0.0007)						
Biodiv. implementation			−0.0016***	−0.0022***				
			(0.0005)	(0.0007)				
Interaction term (below median)								
X * Low Biodiv. leadership	−0.0004	−0.0002						
	(0.0007)	(0.0010)						
X * Low Biodiv. implementation			−0.0009	−0.001				
			(0.0008)	(0.0010)				
X * Low ROA					−0.0013**	−0.0014*		
					(0.0006)	(0.0008)		
X * Low ESG							−0.0017**	−0.0025**
							(0.0008)	(0.0011)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7161	7161	7161	7161	7161	7161	7161	7161
Adjusted R-squared	0.0358	0.0282	0.036	0.0282	0.0356	0.0276	0.0357	0.0281

Note: This table reports the results of an OLS estimation, regressing the score capturing stakeholder feedback on biodiversity management on DUVOL and NCSKEW as our two different measures of stock price crash risk. We add interaction terms between the Biodiversity Results score and several dummy variables. We assign the dummy variable (i.e., Low Biodiv. Leadership) a value of one if the value of a firm-year observation (i.e., in terms of Biodiv. Leadership) is smaller than the median value of this variable in our whole sample, and zero otherwise. We include all control variables used in the main regression (Table 6 and Table 7). Standard errors clustered at the firm level in parentheses below each coefficient. We winsorize all control variables at the 1% and 99% level.

***Significance at the 1% level.

**Significance at the 5%.

*Significance at the 10% level.

which directly rely on natural resources as input for their production processes, are much more at risk than secondary industries with a less direct overlap with nature (de Carvalho et al., 2022; Wagner, 2022). We thus turn to an analysis where we differentiate firms by their exposure to biodiversity risks by following the approach of Rimmel and Jonäll (2013) and Adler et al. (2018). Both studies rely on the classification approach by F&C Asset Management (2004) into industries with red (high), amber (medium), and green (low) risks regarding biodiversity. We assign a dummy variable a value of one if a company is considered active in a red industry.[9] Overall, around 62% (4446) companies operate in industries with high biodiversity risks. Table 11 presents the results. The interaction terms on the overall measure of biodiversity management are only statistically significant for the *DUVOL* measure. Thus, the results only show weak indication of biodiversity management being of greater importance for the financial risk of companies in high risk industries. Only the interaction term derived from *Biodiv. Implementation* and the dummy variable indicating high risk industries seem to positively influence a firm's stock price crash risk across our two measures of stock price crash risk. This indicates that the risk-reducing effect of strong *Biodiv. Implementation* is less pronounced for firms in high risk industries.

5.3 | Robustness tests

In this section, we perform a battery of robustness tests (untabulated; tables available on request) to provide further support to our results. Table 5 shows high correlation coefficients between our control

[9] Note that F&C Asset Management (2004) uses the FTSE industry classification, whereas we use the industry classification provided by Vigeo Eiris, see Panel B of Table 3. Specifically, we set the dummy variable for a company equal to one if it is active in one of the following industries: Heavy Construction, Electric & Gas Utilities, Food, Forest Products & Paper, Hotel, Leisure Goods & Services, Mining & Metals, Oil Equipment & Services, Waste & Water Utilities, Energy.

TABLE 9 Environmental inspection subsample descriptive analysis.

	Treatment group		Control group		
VARIABLES	No.	Mean	No.	Mean	Diff
DUVOL	57	0.3671	57	0.4103	−0.0432
NCSKEW	57	0.4355	57	0.4448	−0.0092
LAGNCSKEW	57	0.4773	57	0.2604	0.2169
SIGMA	57	0.0310	57	0.0388	−0.0077***
RET	57	0.0782	57	0.0985	−0.0203
DTURNOVER	57	−0.0056	57	0.0006	−0.0062
SIZE	57	10.0193	57	9.3377	0.6816***
MB	57	3.7768	57	3.3574	0.4195
LEV	57	0.3037	57	0.3035	0.0002
ROA	57	0.0791	57	0.0661	0.0130
OPAQUE	57	0.5852	57	0.7467	−0.1615**
ESG	57	61.9253	57	47.013	14.9123***

Note: This table provides a summary of the variables used in the difference-indifferences regression for both treatment and control firms 1 year prior to the respective merger. Firms are assigned to the treatment group if their facilities were subject to an inspection by the US Environmental Protection Agency (EPA). The potential control group consists of all firms that had no inspection during the entire sample period.
***Significance at the 1% level.
**Significance at the 5%.
*Significance at the 10% level.

TABLE 10 Environmental inspection subsample difference-in-differences analysis.

	(1)	(2)
VARIABLES	NCSKEW	DUVOL
Post	−0.4779**	−0.3681**
	(0.2241)	(0.1506)
Treat*Post	0.4481*	0.3352*
	(0.2682)	(0.1810)
Treat	−0.0629	−0.0717
	(0.2011)	(0.1413)
Constant	Yes	Yes
Controls	Yes	Yes
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	301	301
Adjusted R-squared	0.0742	0.1199

Note: This table reports the results of a difference-in-differences estimation using a propensity score matched sample. Robust standard errors are reported in parentheses below each coefficient. We winsorize all control variables at the 1% and 99% level.
***Significance at the 1% level.
**Significance at the 5%.
*Significance at the 10% level.

variable capturing overall sustainability performance and our measures for biodiversity management. Correlation ranges between 0.51 for the overall measure of biodiversity management and 0.50 (0.48) for the variable indicating biodiversity leadership (implementation). To rule out that this correlation influences our findings, we rerun our regressions without controlling for overall sustainability performance. Our results show that the coefficients for our variables of interest remain unchanged in terms of magnitude and statistical significance, giving further support to Hypothesis 1.[10]

Second, we tackle the concern that overall biodiversity management may simply be a proxy for (i.e., highly correlated to) a company's overall disclosure quality or its awareness of emerging sustainability issues. As the issue of biodiversity loss is currently not of importance for many companies, firms with strong biodiversity management could simply be those that show high awareness of overall sustainability issues and potentially drive our results. To alleviate this concern, we add a further control variable for companies' awareness of sustainability issues. Using data from Refinitiv, we retrieve information on whether companies have policies in place to address sustainability issues. Overall, we collect information on 17 different sustainability topics.[11] From this data, we construct a variable depicting the share of 17 potential sustainability policies a firm has in place (i.e., if a company has policies for all 17 topics the variable is equal to 1, if the company has no policies in place the variable is equal to 0). We lose 293 observations compared to the baseline sample for which Refinitiv does not provide information on sustainability policies. We add the variable as an additional control to our baseline regression and find that our results remain unchanged. This further strengthens our results as it provides evidence that our variable on biodiversity management does not merely measure a company's overall awareness of emerging sustainability issues.

Next, alternative risk measures exist that capture the risk of a stock. We also test the relationship between biodiversity management and the standard deviation of returns in the respective year in order to obtain more robust results. Similar to our first hypothesis, we expect a negative relationship. The coefficient on biodiversity management does not appear to be significant. However, we further examine stocks that underperformed in the previous year,[12] as crash risk captures the risk of a sudden decline. For these stocks, we find a significant and negative relationship between biodiversity management and SPCR, which further supports our findings.

[10]The only two data items related to biodiversity that are included in the calculation of the Refinitiv ESG score are the items ENERDP019 and ENPIO10V. Both are yes/no questions and only contribute to the overall ESG score to a very limited extent.

[11]Following the classification of sustainability topics by Christensen (2016), we collect the following variables (Refinitiv codes in brackets): Society (SOCODP0067, SOCODP0066, SOCODP0069), product responsibility (SOPRDP0121, SOPRDP0124, SOPRDP0126, SOPRDP0128), labor (SODODP0081, SOHSD01V, SOTDD01V), human rights (SOHRD01V), environment (ENERDP0051, ENRRD01V, ENRRDP0121, ENRRDP0122, ENRRDP0124, ENRRDP0125).

[12]We define underperforming stocks as stocks with a mean (median) return lower than the annual industry mean (median).

TABLE 11 High risk industries analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW
High risk	0.0736	0.1161	0.0939	0.129	0.0991	0.1348	0.0798	0.1301
	(0.1003)	(0.1254)	(0.0972)	(0.1213)	(0.0954)	(0.1187)	(0.1066)	(0.1329)
Biodiversity	−0.0027***	−0.0036***						
	(0.0008)	(0.0011)						
Biodiv. leadership			−0.0015***	−0.0020**				
			(0.0006)	(0.0008)				
Biodiv. implementation					−0.0020***	−0.0025***		
					(0.0005)	(0.0008)		
Biodiv. results							−0.0007	−0.0008
							(0.0009)	(0.0013)
Interaction term (high risk industry)								
High Risk * Biodiversity	0.0018*	0.0017						
	(0.0010)	(0.0014)						
High Risk * Biodiv. leadership			0.0008	0.0008				
			(0.0007)	(0.0009)				
High Risk * Biodiv. implementation					0.0016**	0.0017*		
					(0.0007)	(0.0010)		
High Risk * Biodiv. results							0.001	0.0006
							(0.0013)	(0.0017)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7161	7161	7161	7161	7161	7161	7161	7161
Adjusted *R*-squared	0.0364	0.0287	0.0361	0.0284	0.0365	0.0286	0.0351	0.0272

Note: This table reports the results of an OLS estimation, regressing our measures of biodiversity management on our two different measures of stock price crash risk, DUVOL and NCSKEW. We add interaction terms between the biodiversity management (sub)scores and a dummy variable indicating sectors at high risk regarding biodiversity loss. We assign the dummy variable a value of one if the company is active in a red zone sector, defined by F&C Asset Management (2004), and zero otherwise. We include all control variables used in the main regression (Tables 6 and 7). Standard errors clustered at the firm level in parentheses below each coefficient. We winsorize all control variables at the 1% and 99% level.
***Significance at the 1% level.
**Significance at the 5%.
*Significance at the 10% level.

Finally, we recognize that while we control for country fixed effects in our fixed effects structure, this may not capture factors that influence a country's policy choice. Thus, we first include additional fixed effects to capture the legal origin of a country (La Porta et al., 2008, 1998), and second, we include country-year fixed effects to control for country specific macroeconomics and independent changes in regulation and enforcement (de Simone & Olbert, 2022). Our coefficients of interest remain of similar magnitude and show similar levels of significance for both tests, further strengthening our results.

6 | CONCLUSION

The economic value of ecosystem services provided by an intact biodiversity is undisputed on a societal level (Dasgupta, 2021). Capturing perceived financial risk by stock price crash risk, this paper looks at the importance of biodiversity management on a firm level. We construct a global sample of listed companies and find that strong biodiversity management decreases the risk of a stock price crash. In our analysis, we control for a multitude of different variables which prior literature finds to be determinants of crash risk and deploy several robustness checks to strengthen our findings. Thereafter, we use interaction analysis to test for which set of companies stakeholder feedback toward biodiversity management and actions is of importance. We find that those firms that need to build and maintain legitimacy, that is, those with low overall sustainability performance and low profitability, undergo a decrease in their stock price crash risk thanks to better stakeholder feedback on their biodiversity management and activities.

Going one step further, we use environmental inspections by the EPA as quasi-natural experiments which, we hypothesize, serve as a channel for revealing negative information on biodiversity management practices. A difference-in-differences regression on a propensity score matched sample shows that firms which are subject to an EPA inspection see an increase in their stock price crash risk. The results suggest a causal effect of biodiversity management on stock price crash risk, further supporting our main results.

Our paper contributes to our understanding of how non-financial risk factors influence companies' financial risks, adding to studies by Kim et al. (2014) and Zhang et al. (2021). Moreover, our results guide corporate management by showing the importance of allocating sufficient resources toward biodiversity-preserving actions to reduce a firm's financial risk profile. Companies should proactively approach emerging issues to avoid any negative financial consequences of abstaining from action.

This paper has several limitations. Most importantly, we are not able to apply firm fixed effects due to a low variation of our variables of interest within firms. Incorporating firm fixed effects would capture time invariant firm characteristics and provide further support to our results. The median (mean) standard deviation of our *Biodiversity* variable within firms is equal to 5.8189 (6.4733), which is substantially lower than the standard deviation across our whole sample. The low standard deviation indicates that biodiversity management is rather consistent across time on a firm level. However, we use a high number of control variables in addition to industry and year fixed effects to alleviate this concern as much as possible.

In addition, one may argue that other measures that capture the risk of a company exist, especially risk measures related to company fundamentals instead of market evaluations. We argue that we focus in particular on the risk of a stock price crash and hence a measure that is market based, as we attempt to capture the negative information on biodiversity impacts and dependencies that companies withhold.

One further caveat is that we rely on third-party data to measure biodiversity management. The factors influencing biodiversity degradation and how companies put pressure on local and global biodiversity are inherently complex and difficult to measure (Schaltegger et al., 2022). High complexity is put up as one reason why companies' responses to biodiversity loss have thus far been considered heterogeneous and often merely symbolic. With no good indicator to measure a company's impact on biodiversity (unlike emissions in the case of climate change), all existing variables are proxies at best. Future studies could use other indicators for corporate biodiversity management and the outcome thereof, or develop new measurements themselves.

ACKNOWLEDGMENTS

This paper has benefited from helpful comments from participants at workshops with the Hamburg University, University of Augsburg, University of Kassel. Open Access funding enabled and organized by Projekt DEAL.

DATA AVAILABILITY STATEMENT

Data are available from the sources cited in the text.

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How to cite this article: Bassen, A., Buchholz, D., Lopatta, K., & Rudolf, A. R. (2024). Biodiversity management and stock price crash risk. *Business Strategy and the Environment*, *33*(5), 4788–4805. https://doi.org/10.1002/bse.3725