Does Biodiversity Risk Matter to Capital Markets?

New Evidence from China

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Comments welcome

Abstract: This paper presents macro-, meso-, and firm-level measures of biodiversity risk specific to the Chinese capital market, and investigates how biodiversity risk relates to individual stock returns. Our measures indicate that biodiversity risk in China varies over time and across industries, and that aggregate attention to biodiversity issues has risen sharply over the past two decades. We then provide new evidence that corporate biodiversity risk exposure negatively relates to stock returns in the cross-section, significantly more so when aggregate attention to biodiversity issues rises and industry-level biodiversity risk increases. Furthermore, we obtain some evidence that weekly returns on a portfolio long (short) on stocks with low (high) biodiversity risk positively covary with contemporaneous shocks to aggregate biodiversity attention, although negatively with lagged shocks to attention. In addition, institutional ownership is lower when firms appear more vulnerable to biodiversity risk, even more so in years of rising attention to biodiversity.

Keywords: Biodiversity risk, stock returns, official news, investor perception, internal governance, external monitoring

JEL codes: G10, G11, G12, Q5, Q53, Q57

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1. Introduction

Global climate change has intensified faster and more rapidly than anticipated, resulting in widespread concern among governments. There has been a notable increase in the frequency of extreme natural disasters worldwide such as extensive wildfires in Australia and Siberia, the 2008 extensive cold snap in China, and the 2021 hefty rainfall in Henan, China. Furthermore, such climate-related risks can have significant negative effects on the real economy and the stability of financial markets. Over the past four decades, European countries have experienced economic losses between €450 billion and €520 billion due to extreme climatic events (EEA, 2022).[2] In 2023, all types of natural disasters caused economic losses of ¥345.45 billion to China[3].

Among the various climate-related issues, biodiversity is crucial in maintaining the stability of ecosystems and human well-being. Biodiversity, an umbrella term for the variability of life on Earth and the ecosystems on which different life forms depend, includes ecosystem diversity, species diversity, and genetic resource diversity. Kurth et al. (2021) argue that biodiversity, as the foundation for sustainable economic and social development, creates economic value through food supply, carbon sequestration, and water and air filtration of more than $150 trillion annually, roughly twice the global GDP. According to China's Ministry of Ecology and Environment 2021, more than 3 billion people worldwide depend on marine and coastal biodiversity for their livelihoods, more than 1.6 billion people depend on forests and non-timber forest products for their livelihoods, and more than 50% of the world's medicinal ingredients come from natural plants and animals. Pollination services for crops alone contribute more than 75% of global crop diversity and 35% of crop yields (Silva et al., 2021).

Given the importance of biodiversity for society and the economy, the question how firms and financial markets are affected by biodiversity-related risks has recently attracted considerable attention among investors, academics and policy makers; see, e.g. Karolyi and Tobin-de la Puente (2023). However, research in finance to date has mainly evaluated the

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[2] EEA (2022), "Economic losses from weather and climate-related extremes in Europe reached around half a trillion euros over past 40 years", https://www.eea.europa.eu

[3] Data from the National Basic Situation of Natural Disasters in 2023, published by the Ministry of Emergency Management of the People's Republic of China. https://www.mem.gov.cn/xw/yjglbgzdt/202401/t20240120_475697.shtml.

economic consequences of climate risk (Krueger et al., 2020; Battiston et al., 2021; Roncoroni et al., 2021; Ginglinger and Moreau, 2023; Pankratz et al., 2023; Ilhan et al., 2023; Sautner et al., 2023), but has paid less attention to the influence of biodiversity loss specifically. Giglio et al. (2023) measure public perceptions of biodiversity risk based on news reports and search engines, and then measure firm-level exposure to biodiversity risk. They also examine the pricing of biodiversity risk using data from 10-K statements, industry research, and positions in liability funds. However, whereas their study focuses primarily on firms in developed markets, the problem of biodiversity loss may be even more acute and relevant for capital markets in emerging economies. One concern is that emerging economies may pay more attention to GDP growth at the expense of environmental protection, especially biodiversity conservation, to catch up economically with developed countries and improve people's living standards. In the case of China, the world's largest emerging economy, its vast population and rapid economic growth over the past decades has led to severe ecological degradation and loss of biodiversity resources.[4] Recently, the Chinese government has attached great importance to protecting the ecological environment and biodiversity, emphasized the green transformation of economic development, and put forward a series of national strategies such as the construction of an ecological civilization and the strategy for sustainable development.

This major shift in attention from economic growth to ecological issues and sustainable development makes China a particularly good setting for studying the economic significance of biodiversity risk. In this paper we present macro-, meso-, and firm-level measures of biodiversity risk specific to China, and we examine how biodiversity risk relates to equity returns in the Chinese stock market. First, at the macro-government level, we develop indexes of aggregate attention to biodiversity based on biodiversity-related topics found in CCTV News, the China Environment News, and the Baidu Search Index. Second, at the industry-level we measure biodiversity risk based on the industry exposures of biodiversity- and climate-focused investment funds. Third, we measure firm-level biodiversity risk exposures based on textual analysis of annual reports

[4] According to China's Red List of Biodiversity, a total of 4,088 threatened species of higher plants, including critically endangered, endangered, and vulnerable species, accounted for 10.39% of the total number of species assessed, and 1,050 threatened species of vertebrates, excluding marine fish, accounted for 22.02% of the total number of species assessed. The 2017 Chinese Mammal Diversity Inventory shows that of the 11 endangerment factors, habitat loss, artificial use, human disturbance, environmental pollution, and anthropogenic poisoning accounts for 68%.

from over 5600 listed firm in China over the period 2000 – 2023. More specifically, we first classify the sentiment of all relevant sentences in annual reports through an improved BERT model. Based on this classification, we manually screen out positive sentences containing the keyword of biodiversity and further subdivide these sentences into two categories: those in which the company has taken practical actions in biodiversity conservation and those in which no practical actions have been taken. By combining the number of positive sentences that are related to biodiversity and accompanied by actual action, as well as the number of negative sentences, we construct our firm-level risk measure.

We find that over the past two decades, aggregate attention to biodiversity has been increasing steadily in China. Our results at industry and firm-level further indicate that biodiversity risks have been rising, with some industries being more exposed (e,g, Financials; Petroleum Processing, Coking and Nuclear) than others (e.g. IT, environmental protection).

Considering that attention to biodiversity issues has been rising, we subsequently ask the question if and how firm-level biodiversity risk matters to the Chinese stock market. Related literature suggests that firm-level biodiversity risk may relate to stock returns along alternative lines. On one hand, when investors either have certain 'tastes' for stocks with low biodiversity risk or when they consider such stocks a hedge against biodiversity risk, one could expect a positive cross-sectional relation between biodiversity risk and stock return in equilibrium (see e.g. Pástor et al., 2021, 2022; Garel et al., 2024; Coqueret et al., 2025). However, the cross-sectional relation between *firm-level* biodiversity risk and stock return may vary over time when *aggregate* attention for biodiversity risk varies over time. For example, in periods of unexpectedly rising aggregate concerns about biodiversity (risk), investor demand and willingness to pay for stocks with lower (higher) biodiversity risk exposure may increase (decrease), which could positively (negatively) affect their valuations and returns (see Pástor et al., 2022; Giglio et al., 2023; Ardia et al., 2023).

We document using cross-sectional models of stock returns that higher firm-level biodiversity risk exposure is associated with *lower realized* returns in the Chinese equity market. While this relation loses significance after controlling for year fixed effects, we subsequently find significant moderating effects consistent with a pricing effect: The relation between corporate biodiversity risk and stock returns is significantly more negative during and following increased aggregate attention for biodiversity issues. In addition, we estimate that firm-level biodiversity risk is more negatively related to returns when the firm belongs to an industry that has increased perceived biodiversity risk.

Beyond cross-sectional models of annual stock returns, we form portfolios of stocks with low firm-level biodiversity risk and with high risk, respectively. A low-minus-high-biodiversity-risk portfolio earned an average abnormal return of about 0.2 percent per week, controlling for Fama and French (2015) factor exposures. Moreover, over time, the weekly portfolio returns positively covary with unexpected rises in our aggregate biodiversity attention index derived from CCTV. Interestingly, we also observe a negative return response to aggregate attention shocks that occurred 6 to 7 weeks ago.

We delve deeper into investor interest in biodiversity risk by studying institutional investors' shareholdings. We find that institutional investors have lower equity shareholdings in firms with higher biodiversity risk, in particular funds and banks. Similar to our models of stock returns, we find in models of institutional ownership that changes in aggregate biodiversity attention significantly negatively moderate the effect of firm-level biodiversity risk.

As a robustness test, we examine whether biodiversity risk correlates with other factors than can drive expected stock returns. Specifically, we explore that possibility that biodiversity is mediated by corporate reputation. Firms with higher exposure to biodiversity risk exhibit weaker corporate reputation, but we find that biodiversity risk relates to stock returns even after controlling for this potential mediator.

This paper makes several contributions to the literature. Our study contributes to a scarce but growing body of research on the economics and measurement of biodiversity risk as well as biodiversity finance. For example, Dasgupta (2021) reviews the status of global biodiversity and potential drivers of biodiversity loss. Frank and Sudarshan (2024) link extinction of vultures in India to increased human mortality, and estimate yearly damages of nearly $70 billion. Flammer et al. (2025) focus on the importance of private capital in financing biodiversity conservation projects. Closely related to our study is literature that has provided mixed answers on the question whether the capital markets prices biodiversity, Giglio et al. (2023) introduce measures of biodiversity risk and study the pricing of biodiversity risk in the U.S. capital market. Consistent with biodiversity being priced, they find that returns of portfolios that hedge industry-specific biodiversity risk positively correlate over time with innovations in aggregate news about biodiversity risk.[5] In contrast, Garel et al. (2024) study the pricing of firm-level biodiversity impact, rather than biodiversity risk, using international data from a commercial rating vendor. They find that biodiversity impact on average did not exhibit a cross-sectional relation with stock return over the period 2019-2022, but do suggest a biodiversity premium has emerged in recent years. Coqueret et al. (2025) also use these biodiversity impact data to test for a biodiversity premium in the U.S stock market. They conclude that stocks with higher biodiversity impact has lower realized returns but higher expected returns in recent years in specific industries, which they attribute to rising attention for biodiversity risk. Extending these studies, our study focuses on the measuring biodiversity attention and risk in the Chinese market at firm-, industry- and aggregate level. We document significant interactions between firm-level, aggregate and industry-level measure of biodiversity risk in explaining cross-sectional variation in stock returns. These results are consistent with the idea that capital markets care about biodiversity risk in a large emerging economy like China although its significance may vary over time and across industries.

Our paper also extends two other recent studies that explore biodiversity risk in China. Ma et al. (2024) develops an aggregate biodiversity concerns index, independently for physical risk and transition risk, and they study how these aggregate concerns predict the time-series of aggregate stock returns and the time-series returns on portfolios that are formed on region, GDP, industry and state ownership. We extend their work by not only developing aggregate biodiversity news-based measures but also developing industry- and firm-specific indexes of biodiversity risk in China, and by analyzing how these three dimensions of risk matter in explaining the cross-section of individual stock returns in the Chinese equity market.[6] He et al. (2024) construct, based on firms' annual reports,

[5] Additionally, Giglio et al. (2024) model the economics of biodiversity loss, acknowledging that species interact within and across ecosystems functions. They suggest that biodiversity loss can affect future economic output, but the effect of species loss depends on the presence of other species within an eco-systems function and on the importance of the specific ecosystems function. They find that country-level CDS spreads vary with negative news about aggregate biodiversity loss, suggesting investors recognize the economic effects of biodiversity loss.

[6] Beyond equity markets, a growing literature documents that municipal bond yields may be affected by biodiversity loss. Chen et al. (2024) document that Chinese municipalities affected by tighter enforcement of biodiversity regulation experience higher yield spreads. Rizzi (2024) associates wetland loss with increased municipal bond credit spreads in the U.S.

measures of the count and frequency that biodiversity words are mentioned but they do no study their relevance to the Chinese stock market. Furthermore, concerning biodiversity risk measurement, we extend these papers as well as Giglio et al. (2023), by first classifying the sentiment of all relevant sentences in an annual report through an improved BERT model. Based on this classification, we manually screen out positive sentences containing the keyword of biodiversity and further subdivide these sentences into two categories: those in which the company has taken practical actions in biodiversity conservation and those in which no practical actions have been taken. This approach intends to more accurately measure a company's exposure to biodiversity risk, as some companies may exaggerate or embellish their actions to conserve biodiversity in their annual reports. Moreover, companies' statements on environmental issues such as biodiversity conservation in their annual reports are linked to economic and industry cycles (Boiral, 2016), which may mask their actual contribution to biodiversity conservation.

Our research also contributes to the literature on the influence of climate risk on the economic and financial system. Most of these studies have focused on the economic consequences of the physical and transition risks associated with climate change (Bernstein et al., 2019; Bolton and Kacperczyk, 2021, 2023; Engle et al., 2020; Choi et al., 2020; Baldauf et al., 2020; Pástor et al., 2021, 2022; Battiston et al., 2021; Alekseev et al., 2022; Van Benthem et al., 2022; Ginglinger et al., 2023; Li et al., 2024; LaCour-Little et al., 2024; Zhang, 2025). In fact, given the significant risks posed by climate change to biodiversity and the close connection between biodiversity loss and corporate operations, research based on a more detailed examination of biodiversity risk could offer a more direct understanding of the adverse effects of climate change.

Finally, this paper is of interest to regulators seeking to understand ways to balance economic development with environmental goals, and more specifically those aiming to encourage markets to promote biodiversity conservation in developing countries such as China. For example, China recently updated its National Biodiversity and Strategy action plan, with possible implications for biodiversity disclosures (Responsible Investor, 2024).[7] While our results suggest that biodiversity risks receive heightened attention in the capital

[7] Responsible Investor (2024), Investors welcome China's plans for biodiversity disclosure framework, https://www.responsible-investor.com/investors-welcome-chinas-plans-for-biodiversity-disclosure-framework/ (retrieved 19 December 2024)

market with implications for stock returns and ownership, it is conceivable that standardized firm-level disclosures of biodiversity risks and impacts will help the capital market to better incentivize corporations to manage their biodiversity footprint.

The remainder of this paper is organized as follows: Section 2 provides a detailed explanation of the study's data and relevant variables. Section 3 discusses the relationship between corporate biodiversity risk and stock returns, based on pooled cross-sectional regressions and portfolio analysis respectively. Section 4 focuses on institutional ownership regressions. Section 5 performs additional tests, and Section 6 concludes.

2. Data and measurement

2.1. Data and lexicon

In this study, we analyze biodiversity risk in the Chinese market from three perspectives: macro-government, meso-industry and micro-firm. Similar to Giglio et al. (2023) and Fan et al. (2024), we first examine the aggregate attention of the government, mainstream professional media, and the public to biodiversity from a macro perspective, with data sourced from the CCTV News, the China Environment News, and the Baidu Search Index, respectively. For this part of the study we collected daily data from September 1, 2013 to December 31, 2023. We collected daily content text data from the CCTV News, daily content text from the China Environment News, and daily searches for biodiversity keywords in the Baidu search engine[8]. CCTV News is the most watched and influential T.V. news program in China. It is the wind vane of Chinese politics, representing the Chinese government's position and attitude on relevant issues. The China Environment News is the only national environmental protection newspaper in the world under the supervision of the Ministry of Ecology and Environment of the People's Republic of China and adheres to the goal of preventing and controlling pollution, improving the ecology, promoting development, and benefiting the people. Baidu is the world's largest Chinese search engine, and the Baidu Search Index is a data-sharing platform based on Baidu's massive Internet user behavior data.

[8] The data are obtained from https://www.cctv.com, http://news.cenews.com.cn and https://index.baidu.com/v2/index.html.

To measure biodiversity risk indicators at the industry level, we collect using the AKSHARE database information on the holdings of 40 funds directly related to biodiversity and environmental protection from 2011 to 2023[9]. Table A.1 in the Appendix provides detailed information on these funds.

To measure firm-level biodiversity risk indicators, we collect from Cninfo the text of annual reports of 5,606 Chinese listed firms from 2000 to 2023. Cninfo covers all listed firms in Shanghai and Shenzhen markets.[10] Stock market data, data on firm characteristics, and other data used in this study are all obtained from the WIND and CSMAR databases.

Following related research that measures biodiversity risk based on textual analysis (e.g., Giglio et al., 2023), we begin by creating a biodiversity lexicon applicable to the Chinese market. To cover as many words related to biodiversity as possible, we use biodiversity as a keyword to search for all biodiversity-related studies in the China National Knowledge Infrastructure (CNKI), China's largest database of scientific papers covering different disciplines and areas of concern about biodiversity. We collect keywords from 38,260 studies since 2000, manually eliminate keywords unrelated to biodiversity, and end up with 446 terms directly related to biodiversity.

2.2. Measurement and discussion, validation

2.2.1. *Aggregate biodiversity attention indexes*

We first explore the characteristics of aggregate biodiversity attention in the Chinese market. We count the number of sentences containing at least one biodiversity term in the monthly CCTV News ($Frq_{Bio,t}^{CCTV}$) and the China Environment News ($Frq_{Bio,t}^{Cenews}$), and the number of searches for biodiversity terms on Baidu ($Frq_{Bio,t}^{Baidu}$), which are used to measure the attention paid to biodiversity by the government, mainstream professional media, and the public.

Figure 1 illustrates the monthly China Environment News-based biodiversity attention index. There is a clear upward trend over the sample period, especially since 2018, reflecting the increasing attention of mainstream professional media to the theme of

[9] The data are sourced from https://akshare.akfamily.xyz/.

[10] http://www.cninfo.com.cn/new/index.

biodiversity loss. We mark a number of biodiversity-related events in Figure 1 for $Frq_{Bio,t}^{Cenews}$, where there is a spike at the occurrence of these events such as the introduction of the new Environmental Protection Law 2015 and the 2020 “dual carbon” targets. Monthly CCTV News- and Baidu search-based biodiversity attention indexes are shown in Figure 2(a) and 2(b), respectively. The CCTV News-based biodiversity attention index, which could be interpreted as a representation of the attitude of the government, shows an increasing trend during the sample period, and the Baidu search-based biodiversity attention index gradually increases over time. These results suggest that the Chinese government’s and public’s attention to biodiversity loss is increasing. Although there is rising aggregate attention for biodiversity issues according to these indexes, we also observe clear time variation in index levels over time.

Figure 1. Cenews-based biodiversity attention index from 2013 to 2023

Figure 1 shows the monthly China Environment News-based biodiversity attention index from 2013 to 2023, along with biodiversity-relevant events announcements. **New Environment Protection Law**: In April 2014, the Environmental Protection Law was amended and adopted by the Chinese government, and will take effect in January 2015. **COP 12-15**: Dates of previous Conferences of the Parties to the United Nations Convention on Biological Diversity. **Reform of the Ecological Civilization System**: In September 2015, the Chinese government considered and adopted the General Programme for the Reform of the Ecological Civilization System. **Double Carbon Target**: In September 2020, China clearly set out its 2030 ‘peak carbon’ and 2060 ‘carbon neutral’ targets. **Henan Flood**: In July 2021, a major natural disaster occurred in Henan, China. **First National Ecology Day**: In June 2023, the Chinese government established 15 August each year as National Ecology Day.

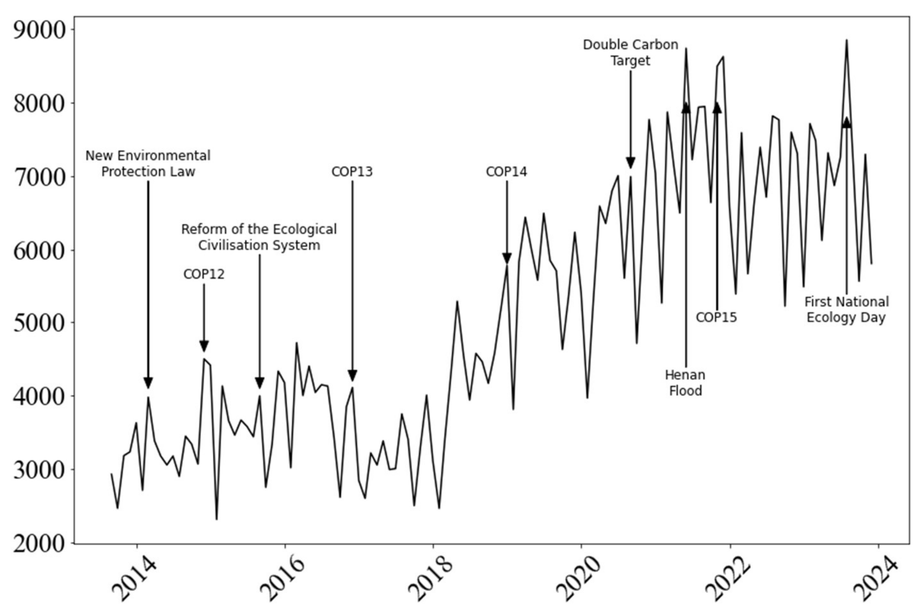
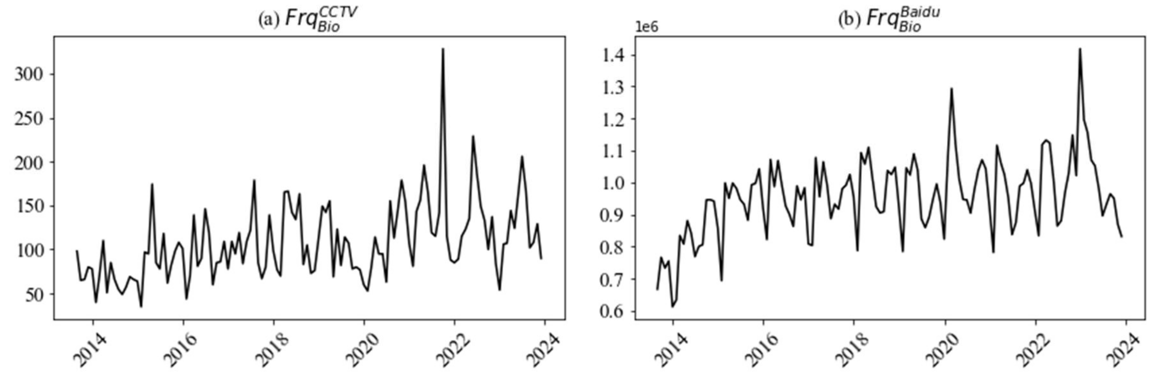


Figure 2. Aggregate attention indexes of biodiversity from 2013 to 2023

Note: Monthly CCTV News- and Baidu search-based biodiversity attention indexes from 2013 to 2023 are shown in Figure 2(a) and 2(b), respectively.



2.2.2. *Industry-level variation in attention based on fund-level weights*

While the rising aggregate attention to biodiversity documented in the previous could imply that biodiversity risk increasingly matters to Chinese capital markets, it is conceivable that investors perceive some industries more exposed to this risk than others. Hence, in this section, we extend our measure of aggregate attention to biodiversity with an industry-level measure of biodiversity risk exposure in the Chinese stock market. We measure industry-level biodiversity risk using information about investments undertaken by funds with an explicit biodiversity- and climate-focused mandate, similar to Giglio et al. (2023). As the impact of biodiversity loss on economic and financial systems becomes apparent, asset managers have been increasingly utilizing various instrument tools to mitigate biodiversity risk inherent in their clients' portfolios. Therefore, we construct an annual industry-level biodiversity risk exposure indicator using information about the industry exposures of 40 environmental and biodiversity funds:

$$BioRis_{t,f}^{I}=w_{t,m}^{I}-w_{t,f}^{I}, \tag{1}$$

where $w_{t,m}^{I}$ is the weight of industry I in the market portfolio at time t, $w_{t,f}^{I}$ is the weight of industry I in fund f at time t. The biodiversity risk exposure indicator for industry I is $BioRis_{t}^{I}=\sum_{f}^{F} BioRis_{t,f}^{I}/N$, with N being the number of funds holding industry I stocks. A larger $BioRis_t^I$ indicates that funds under weigh industry I relative to the weight in the market portfolio, i.e., industry I is more exposed to biodiversity risk. The industry classification is based on the 2012 edition of the CSRC (China Securities Regulatory Commission) Industry Classification, and we calculate biodiversity risk exposure indicators for a total of 58 secondary industries. A detailed description of each industry is given in Table A.3 in the Appendix.

Table 1. Holding-based biodiversity score of different industries

Note: This table gives the annual average value of biodiversity risk exposure indicator $BioRis_t^I$ of each industry. A larger $BioRis_t^I$ indicates that funds under weigh industry I relative to the weight in the market portfolio, i.e., industry I is more exposed to biodiversity risk.

Order	Industry Code	Mean	Order	Industry Code	Mean	Order	Industry Code	Mean
1	J66	0.1028	21	C28	0.0021	41	C13	-0.0022
2	C25	0.0372	22	C24	0.0016	42	M74	-0.0035
3	C15	0.0297	23	C33	0.0016	43	C21	-0.0042
4	J67	0.0289	24	A01	0.0015	44	K70	-0.0056
5	C27	0.0259	25	R86	0.0015	45	C42	-0.007
6	B06	0.0136	26	A03	0.0014	46	C29	-0.0074
7	G55	0.0105	27	D45	0.0014	47	C39	-0.0105
8	C37	0.0092	28	G58	0.0013	48	D46	-0.0125
9	E48	0.0089	29	S90	0.001	49	D44	-0.0133
10	C31	0.0081	30	G59	0.0008	50	C40	-0.0149
11	B09	0.008	31	M73	0.0007	51	C36	-0.0176
12	F51	0.0078	32	N78	0.0006	52	C35	-0.0181
13	C14	0.0074	33	C23	0.0004	53	C26	-0.0225
14	I64	0.0054	34	C19	0.0002	54	C30	-0.0244
15	G54	0.0052	35	C41	0.0002	55	C34	-0.0246
16	I63	0.0051	36	C22	0.0001	56	I65	-0.0256
17	C18	0.0038	37	E50	-0.0004	57	N77	-0.0293
18	C17	0.0028	38	F52	-0.0013	58	C38	-0.1338
19	O81	0.0027	39	C32	-0.0017			
20	B11	0.0022	40	L72	-0.0021			

Table 1 shows the annual averages of the biodiversity risk exposure indicator $BioRis_t^I$ for different industries and ranks them. The larger $BioRis_t^I$, the higher the risk exposure of industry I. Among the higher-ranked sectors are Petroleum Processing, Coking and Nuclear Fuel Processing industry (C25, mean = 0.0372), Pharmaceutical Manufacturing (C27, mean = 0.0259), and several mining and transport-related industries. Interestingly, we find that the Money and Financial Services industry (J66) faces the highest exposure to biodiversity risk, with a mean of 0.1028 for $BioRis_t^I$. The perceived relevance of biodiversity risk for financial services industry is interesting considering recent interest in the financial materiality of biodiversity concerns for the financial sector.[11] Financials fund a variety of business in other industries, making them exposed to different economic activities with biodiversity impact, such as deforestation and river pollution. It has been suggested that such practices not only exacerbate the loss of biodiversity but also threaten the long-term stability of financial assets (e.g. Sustainable Finance Platform 2020).[12] The three industries with the lowest biodiversity risk exposure are the Software and Information Technology Services (I65), the Environmental Protection and Management (N77) and the Electrical Machinery and Equipment Manufacturing (C38), which is intuitively consistent.

2.2.3. *Firm-level biodiversity risk exposure*

(1) *Constructing the measure of firm-level risk*

In this section we turn to measurement of biodiversity risk at the firm level. We construct several alternative measures of biodiversity risk based on the text of the annual reports of 5,606 listed firms for the period 2000 to 2023. First, we count the number of sentences containing at least one biodiversity term in the text of each listed firm's annual report ($Frq_{Bio,it}^{AnuRep}$) as an indicator of biodiversity concern at the micro-firm level. We then develop a firm-level biodiversity risk exposure that is mindful of positive ($Frq_{Bio,it}^{Pos}$), neutral ($Frq_{Bio,it}^{Neu}$) and negative ($Frq_{Bio,it}^{Neg}$) information. An improved BERT model is applied to the classification of sentences (Cui et al., 2021). Chinese text is complex and diverse, and traditional sentiment analysis tools, such as simple plain Bayesian classifiers, can be misled by the ambiguities in the text. The BERT model can accurately capture the meaning of

[11] Giglio et al. (2023) also measure biodiversity risk at industry level using holdings of funds, next to alternative measures based on textual analysis and surveys. Their holdings-based raking assigns relatively greater biodiversity risk exposure to banks and diversified financials.

[12] On the one hand, the loss of biodiversity leads to a reduction in the contribution of natural and ecological service systems to humankind, negatively affecting the industries and related business activities that rely on these services, and triggering physical risks such as business losses, closures and impairment of financial assets. The loss of biodiversity, which creates economic value in the form of food supply, carbon sequestration, water and air filtration, among others, can affect economic sectors such as agriculture and manufacturing, geographical regions and global trade, and can expose financial institutions with exposure to these economic activities or assets to risk. On the other hand, adjustments in government policies, changes in consumer preferences and technological advances may affect business activities and increase their operating costs, resulting in some financial assets becoming uncollectible or impaired, thereby creating transition risks.

words in different contexts by simultaneously considering the pre- and post-contextual information of the words through a bidirectional encoder. In addition, the BERT model significantly improves the accuracy and specialization of the model by training the language model on a prominent Chinese corpus and then fine-tuning it to suit a specific task. In total, we classify the sentiment of 369,762 sentences containing biodiversity terms as 92.2% neutral, 7.1% positive, and 0.7% negative.

Below are two examples of biodiversity-related mentions in firms' annual reports that received a positive sentiment classification from the improved BERT model:

> *During the year, the Company carried out the Xiluodu-Xiangjiaba-Three Gorges Joint Ecological Planning Experiment, using planning tools to create conditions suitable for fish spawning and breeding [2009, 600900].*

> *The company has organized and carried out the publicity of the Green City Steel Plant Index System, improved the responsibility system for promoting the Green Index, actively created a waste-free steel plant with "ultra-low emission of exhaust gas, zero emission of waste water and no solid waste", avoided negative impacts on the natural ecological environment, adhered to the harmonious development of the ecological environment with the surroundings and protected biodiversity, so as to avoid the occurrence of environmental pollution accidents [2023, 601005].*

The following are two examples of a biodiversity-related annual reports mention that received a negative sentiment classification from the improved BERT model:

> *The Company's steam supply and manganese ore mining, manganese electrolysis processing and other businesses have emissions of dust, noise, exhaust gas and wastewater and other pollutants. As the government has paid more attention to environmental protection in recent years, if stricter laws, regulations, systems and rules are introduced and the environmental protection level of the relevant industries is raised to a higher level, the Company will face the risk of increasing investment in environmental protection or may suffer the risk of environmental protection penalties [2021, 600116].*

> *In addition to certain amounts of pollutants such as waste water, waste gas and waste residues from coal mining and washing, the company has also caused some land subsidence and the destruction of public and civil facilities, which has had a certain impact on the*

regional ecological environment and biodiversity [2022, 600403].

However, during the data processing, we find that listed companies have exaggerated their contributions to biodiversity conservation in their annual reports. This aligns with the perspective of narrative economics---the prevailing view is that popular narratives that influence public perceptions and behavior percolate over time and ultimately affect the economy. This includes macroeconomic phenomena such as recessions and depressions, as well as microeconomic phenomena (Shiller, 2017). As the concept of sustainable development has gained prominence, news about biodiversity and descriptions of the potential consequences of biodiversity loss for various stakeholders have become increasingly important and relevant. Increasingly, listed firms are choosing to publish information on their biodiversity management and investments in their annual reports or ESG disclosure reports. However, some firms appear to be trying to raise awareness of their contribution to biodiversity by influencing the narrative in their reports. Firms with high biodiversity risk exposure may have an incentive to exaggerate their environmental performance.

Therefore, we further manually categorize positive biodiversity-related sentences in these reports. One category includes cases where firms explicitly mention taking concrete actions for biodiversity conservation ($Frq_{Bio,it}^{Pos\_Action}$), such as implementing conservation projects or establishing clear biodiversity-related policies. The other category includes statements that lack evidence of actual action ($Frq_{Bio,it}^{Pos\_No\text{-}Action}$).

Below is an example of positive statements in listed firms' annual reports that have no actual actions related to biodiversity conservation:

The company adheres to the concept of synchronous development of production and environmental construction, balancing long-term sustainable development with actively fulfilling its responsibilities for environmental protection. [2019,002166].

Below is an example of positive statements in listed firms' annual reports that demonstrate concrete actions for biodiversity conservation:

In 2014, the company focused on resource conservation and environmental friendliness, *emphasizing the development of new technologies and products with independent intellectual property rights. It combined landscape design and construction concepts with technological innovation, investing 39.3716 million yuan to research and develop multiple scientific projects. These included research projects such as "Research on Near-Natural Ecological Landscape Application Technologies", "Research on Biological and Engineering Technologies in Salt-Alkali Land Landscaping" and "Evaluation of Wetland Restoration Effects in Dongguan Ecological Park". [2014,002717].*

Similar to Giglio et al. (2023), we finally measure a company's biodiversity risk exposure (Sti_{Bio}^{Action}) using the difference between the number of negative sentences related to biodiversity and the number of positive sentences related to biodiversity with actual actions taken.

(2) *Characteristics of firm-level biodiversity risk exposure*

Figure 3 presents the annual average number of positive sentences with actual actions and without actions from 2000 to 2023 at the firm level. The fluctuation range for the number of positive statements without actual actions is between 1 and 1.8 ($Frq_{Bio,it}^{Pos\_No\text{-}Action}$), while the fluctuation range for the number of positive statements with actual actions is between 0 and 0.05 ($Frq_{Bio,it}^{Pos\_Action}$), with the former significantly exceeding the latter. Within the sampling period, sentences with actual actions and those without actions account for 2.2% and 97.8% of the total positive statements, respectively. These results indicate that although listed firms boast about their contributions to biodiversity in their annual reports, they rarely take concrete actions.

Figure 3. Number of positive sentences with actual actions and without actions from 2000 to 2023

Note: Yearly number of positive sentences with actual actions and without actions from 2000 to 2023 are shown in Figure 3. The left Y-axis of Figure 3 corresponds to the number of positive sentences related to biodiversity that do not mention actual actions for biodiversity conservation. The right Y-axis of Figure 3 corresponds to the number of positive sentences related to biodiversity that mention actual actions for biodiversity conservation

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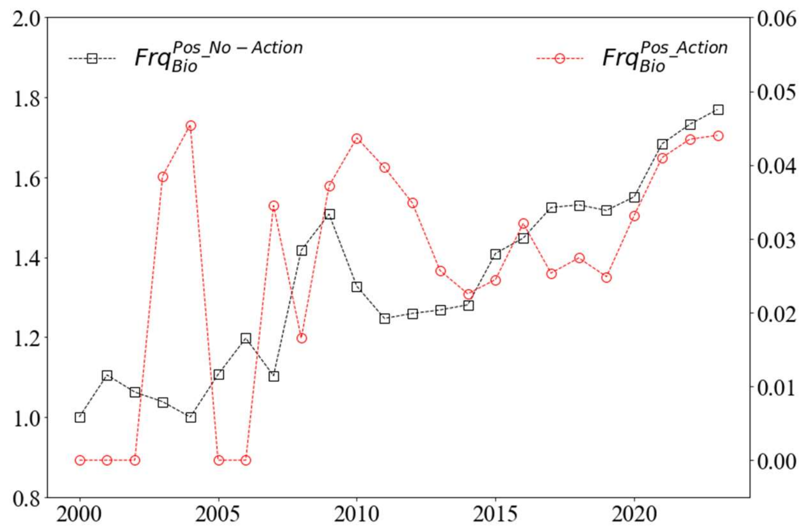
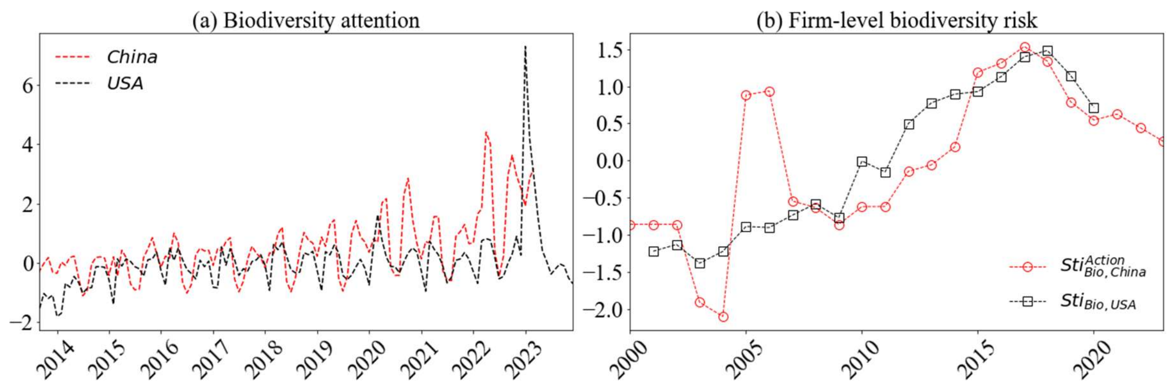


Next, we compare our results with those of Giglio et al. (2023), who focused on biodiversity risk in the U.S. market, using data from www.biodiversityrisk.org. These authors provide a general assessment of public perceptions of biodiversity risk based on news reports and search engines, and then measure firm-level exposure to biodiversity risk and examine the pricing of biodiversity risk using data from 10-K statements, industry research, and positions in liability funds. In Figure 4(a), we show the aggregate attention to biodiversity in the Chinese and American markets. We can see that the search volume of biodiversity terms based on Baidu and Google has been on an upward trend over the past decade, and the trends of the two indexes show a high degree of consistency, and even completely overlap and have peaks at some points. This similarity suggests that public concern about biodiversity has increased in both developed and developing markets, and that both indexes may have been influenced by specific events. As biodiversity loss is a global issue, this result is in line with expectations. In Figure 4(b), we show the average value of annual report-based biodiversity sentiment for all listed firms for each year among the US and Chinese markets. We observe that the exposure to biodiversity risks faced by listed companies in China has been increasing over the past 20 years, which is consistent with the rising attention for biodiversity in the U.S that Giglio et al. (2023) document.

Figure 4. Comparison with results of Giglio et al. (2023)

Note: Monthly Baidu search- and Google search-based biodiversity attention indexes from 2013 to 2023 are shown in Figure 4(a), we normalize the two indexes. In Figure 4(b), for each year, we show the average value of firm-level biodiversity risk for all listed companies.



3. Biodiversity risk and stock returns

3.1. Biodiversity risk and stock returns: theory and hypotheses

Having presented measures of biodiversity attention and biodiversity risk, we now turn to the question whether biodiversity risk matters to China's equity market. Literature to date provides two theoretical reasons why biodiversity matters for stock returns: a risk-based explanation (e.g. Giglio et al., 2023; Coqueret et al., 2025) and a "taste-based" explanation (Pástor et al., 2022; Coqueret et al., 2025). A typical risk-based argument is that firms with higher biodiversity risk exposure have higher expected returns to compensate investors for bearing more "transition risk", such as greater uncertainty about future legislation that may be necessary to combat biodiversity loss (e.g. Garel et al., 2024). In addition, certain (environmentally motivated) investors may have "tastes" or similar non-pecuniary preferences for stocks with low-biodiversity risk, which may cause these stocks to trade at relatively higher prices with lower expected return (e.g., Pástor et al., 2022; Coqueret et al., 2025). The hypothesis arising from both explanations is that stocks with higher biodiversity risk have a higher expected return in equilibrium, which is typically tested by analyzing realized stock returns. However, detecting such a "biodiversity premium" may require a sizeable time-series data on stock returns (Giglio et al., 2023). Furthermore, research including ours indicates that attention to biodiversity has become more prevalent in recent years (e.g., Giglio et al. 2023), which could imply that a long-run biodiversity premium has yet to materialize in the data.

Nonetheless, if biodiversity risk matters to the capital market, we could additionally expect that cross-sectional return differences between stocks with high and low biodiversity risk vary over time with changes in aggregate attention to biodiversity attention. There are again two theoretical arguments underlying this expectation. First, if markets price biodiversity risk, the returns of stocks with less biodiversity risk exposure should be higher (lower) relative to stocks with higher biodiversity risk exposure in times when aggregate biodiversity risk unexpectedly rises (falls). In other words, stocks with lower biodiversity risk exposure offer a hedge against aggregate biodiversity risk (Giglio et al., 2023). Second, beyond a risk explanation, unexpectedly rising aggregate attention for biodiversity issues may change investors' tastes and demand for stocks with lower biodiversity risk relative to stocks with high biodiversity risk. Even though stocks with lower biodiversity risk have a lower expected return in equilibrium, rising tastes temporarily cause these stocks to experience relatively higher realized stock returns while falling tastes can cause relatively lower returns (Pástor et al., 2022). Both reasonings imply that the returns of stocks with low firm-level biodiversity risk relative to stocks with high firm-level risk increase when *aggregate* attention to biodiversity unexpectedly rises, and decrease when aggregate attention unexpectedly falls. Such changes in aggregate biodiversity attention would proxy for news about aggregate biodiversity risk according to a risk-based explanation, while they proxy for changes in investors' non-pecuniary stock preferences according to a taste-based explanation. In the context of environmental risk, Pástor et al. (2022) show that "green" firms may have lower expected returns than "brown" firms but in periods with unexpected rises (declines) aggregate climate-risk concerns the stock prices of green firms relative to brown firms might increase (decrease). Similarly, Coqueret et al. (2025) recently estimated a positive premium on U.S. stocks with high biodiversity risk in terms of realized stock returns, but a negative premium in terms of expected return in specific sectors.

We therefore hypothesize that aggregate biodiversity attention shocks moderate the cross-sectional relation between firm-level biodiversity risk and stock returns in the Chinese stock market.

3.2. Cross-sectional models of stock returns

We first estimate in this section the relation between biodiversity risk exposure and individual stock returns based on the following general specification:

$$Ret_{it} = \alpha + \beta_1 Sti_{Bio,t\text{-}1}^{Action} + \sum \beta_k Controls_{k,t\text{-}1} + \gamma_t + \theta_f + \varphi_n + \varepsilon_t, \tag{2}$$

where Ret_{it} is the stock return of firm i in year t, considering reinvestment of cash dividends. $Sti_{Bio,t\text{-}1}^{Action}$ is the extent of biodiversity risk exposure of firm i in year t-1. $Controls_{k,t\text{-}1}$ indicates control variables in year t-1. Similar to Bolton and Kacperczyk (2023) and Garel et al. (2024), we include as controls several firm characteristics that are common predictors in literature explaining the cross section of stock returns. The set of firm characteristics include: firm size ($LnTa_{it\text{-}1}$) measured by the natural logarithm of total assets; the ratio of book equity to market capitalization ($BM_{it\text{-}1}$); financial leverage ($Lev_{it\text{-}1}$) measured by the ratio of total debt to total assets; asset tangibility defined as net property, plant, and equipment, divided by total assets ($Ppe_{it\text{-}1}$); capital expenditures divided by total assets ($Capex_{it\text{-}1}$); return on assets ($Roa_{it\text{-}1}$) measured by net income after tax divided by total assets; asset growth ($Assgro_{it\text{-}1}$) defined as the percentage change in total assets; the monthly stock return volatility calculated over the 1 year period ($Vol_{it\text{-}1}$); momentum ($Mom_{it\text{-}1}$) measured by the cumulative stock return over the 1 year period. Table 2 shows the summary statistics of variables that enter regressions. A detailed description of all the variables in this study is given in Table A.4 in the Appendix.

Table 3 reports the regressions of Ret_{it} on $Sti_{Bio,t\text{-}1}^{Action}$, controlling for different firm-level characteristics. The coefficients on $Sti_{Bio,t\text{-}1}^{Action}$ are all negative and significant at least at either the 5% level or 1% level in columns (1)-(5), indicating that firms with larger biodiversity risk exposure experienced lower returns than firms with smaller risk exposure. In columns (6) and (7), we further control for year fixed effects, and although the coefficients on $Sti_{Bio,t\text{-}1}^{Action}$ are not significant, they are both negative.

Table 2. Summary Statistics of main variables

Note: This table presents the summary statistics based on annual data over the period.

	#Obs.	Mean	S.D.	Min	Mdn	Max
Ret	13,338	0.117	0.547	-0.845	-0.001	6.200
Sti_{Bio}^{Action}	13,338	0.049	0.369	-4.000	0.000	5.000
LnTa	10,784	22.439	1.364	17.545	22.219	28.697
BM	10,784	0.651	0.258	0.018	0.649	1.601
Lev	10,784	0.449	0.342	0.008	0.439	31.467
Capex	10,784	0.052	0.050	0.000	0.037	0.519
Ppe	10,784	0.238	0.160	0.000	0.211	0.954
Roa	10,784	0.042	0.277	-29.018	0.047	6.288
Assgro	10,784	0.125	0.513	-0.961	0.072	33.060
Vol	10,784	0.121	0.062	0.013	0.108	1.147
Mom	10,784	0.001	0.019	-0.042	0.002	0.038

Table 3. Corporate biodiversity risk exposure and stock returns

Note: This table reports panel regressions of individual stock returns on corporate biodiversity risk exposure . Standard errors are clustered at the firm level. The *t*-values of coefficients are given in parentheses. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Fixed effects include year, industry and province fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Sti_{Bio,t-1}^{Action}$	-0.021**	-0.033***	-0.036***	-0.030**	-0.031**	-0.012	-0.010
	(-1.995)	(-2.709)	(-2.932)	(-2.392)	(-2.482)	(-1.108)	(-0.935)
$LnTa_{it-1}$		-0.106***	-0.110***	-0.117***	-0.122***	-0.055***	-0.061***
		(-16.509)	(-16.484)	(-17.073)	(-17.264)	(-11.213)	(-11.639)
BM_{it-1}		0.554***	0.565***	0.621***	0.635***	0.201***	0.254***
		(17.072)	(17.294)	(19.155)	(19.339)	(8.046)	(10.011)
Lev_{it-1}		0.111***	0.113***	0.157***	0.164***	0.047	0.087**
		(2.843)	(2.882)	(3.830)	(3.977)	(1.283)	(2.263)
$Capex_{it-1}$		0.430***	0.441***	0.432***	0.431***	-0.061	-0.096
		(3.725)	(3.786)	(3.614)	(3.578)	(-0.654)	(-1.009)
Ppe_{it-1}		0.152***	0.174***	0.151***	0.170***	0.055**	0.061*
		(4.473)	(4.933)	(3.683)	(4.057)	(2.023)	(1.830)
Roa_{it-1}		0.163***	0.162***	0.205***	0.209***	0.086**	0.121***
		(3.157)	(3.173)	(3.842)	(3.944)	(2.051)	(2.817)
$Assgro_{it-1}$		-0.007	-0.005	-0.007	-0.006	0.006	0.005
		(-0.940)	(-0.758)	(-0.922)	(-0.815)	(1.206)	(0.929)
Vol_{it-1}		-0.208**	-0.197**	-0.219**	-0.204**	-0.596***	-0.628***
		(-2.311)	(-2.189)	(-2.412)	(-2.242)	(-7.663)	(-7.970)
Mom_{it-1}		-0.007	0.004	-0.045	-0.026	-19.096***	-18.717***
		(-0.029)	(0.019)	(-0.189)	(-0.110)	(-12.814)	(-11.577)
Constant	0.114***	2.068***	2.130***	2.217***	2.345***	0.873***	0.931***
	(26.659)	(16.888)	(16.527)	(14.606)	(15.024)	(9.399)	(8.675)
Province FE	No	No	Yes	No	Yes	No	Yes
Industry FE	No	No	No	Yes	Yes	No	Yes
Year FE	No	No	No	No	No	Yes	Yes
Adj. R^2	0.0002	0.063	0.0678	0.076	0.080	0.362	0.372
#Obs.	13,338	10,784	10,784	10,784	10,784	10,784	10,784

These findings do not support the equilibrium prediction of a positive biodiversity risk premium. However, given that we find time-varying aggregate attention to biodiversity in China, we hypothesized that increased aggregate attention to biodiversity risk drives realized returns on stocks with low-biodiversity risk relative to return of stocks with high firm-level biodiversity risk. Investors may demand more stocks with lower biodiversity risk when aggregate attention for biodiversity issues rises, either because stocks with lower biodiversity risks offer a hedge against aggregate biodiversity-related risk (Giglio et al., 2023) or because investors experience in these periods stronger tastes for these stocks (Pástor et al., 2022). In such periods, the returns of stocks with high exposure to biodiversity risk might decrease relative to stocks with low exposure to biodiversity risk.

Hence, we expect a stronger negative relation between firm-level biodiversity risk and stock returns during periods of (unexpected) rises in aggregate biodiversity attention. For this reason, we examine how firm-level biodiversity risk $Sti_{Bio,t\text{-}1}^{Action}$ interacts with both current and lagged changes in the aggregate attention indexes that we developed in Section 2. We add the interaction term between $Sti_{Bio,t\text{-}1}^{Action}$ and changes in aggregate concerns about biodiversity (i.e, $\Delta Frq_{Bio}^{Cenews}$, ΔFrq_{Bio}^{CCTV} *and* $L.\Delta Frq_{Bio}^{Baidu}$) to our baseline model (2), as shown in columns 1-3 of Table 4. In column (1), the coefficients on the interaction terms $Sti_{Bio,t-1}^{Action} \times \Delta Frq_{Bio,t}^{Cenews}$ and $Sti_{Bio,t-1}^{Action} \times \Delta Frq_{Bio,t-1}^{Cenews}$ are negative and significant at least at the 5% level. Similar results are found for the coefficients on the interaction terms $Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{CCTV}$ and $Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{CCTV}$ in column (2). In column (3), the coefficients on the interaction terms $Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{Baidu}$ and $Sti_{Bio,t\text{-}1}^{Action} \times L.\Delta Frq_{Bio,t-1}^{Baidu}$ are not significant. Possibly, Cenews and CCTV news are more informative about the cross-section of stock returns compared to the Baidu index because the former two are policy windsocks of the Chinese government, to which investors may be more sensitive.

As an alternative moderator, in column (4) of Table 4 we also consider industry-level shocks in biodiversity concerns using our earlier documented measure of industry-level biodiversity risk. Because industry-level risk is based on industry weights in biodiversity- and climate-aware funds, rises in their values can be interpret as heightened investor concern about biodiversity risk in specific industries. The coefficient on $Sti_{Bio,t\text{-}1}^{Action} \times \Delta BioRis_{,t}{}^{I}$ is insignificant, while the coefficient on $Sti_{Bio,t\text{-}1}^{Action}$ interacted with $\Delta BioRis_{,t\text{-}1}{}^{I}$ is negative and significant. These results suggest that rising industry-level biodiversity risk exacerbates the negative impact of firm-level biodiversity risk exposure on stock returns with some delay.

Table 4. Aggregate biodiversity attention, firm-level biodiversity risk, and stock returns

Note: This table reports panel regressions of firm-level stock returns on corporate biodiversity risk in interaction with, respectively, aggregate biodiversity attention measures (columns 1 – 3) and industry-level biodiversity risk (column 4). $\Delta Frq_{Bio}^{Cenews}$, ΔFrq_{Bio}^{CCTV} and ΔFrq_{Bio}^{Baidu} denote the yearly changes in aggregate attention to biodiversity derived from Cenews, CCTV and Baidu. $\Delta BioRis^{I}$ denotes the yearly change in industry-level biodiversity attention. Standard errors are clustered at the firm level. The *t*-values of coefficients are given in parentheses. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Fixed effects include year, industry and province fixed effects.

	(1)	(2)	(3)	(4)
$Sti_{Bio,t\text{-}1}^{Action}$	-0.051***	-0.026*	-0.022	-0.026*
	(-4.070)	(-1.942)	(-1.226)	(-1.691)
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{Cenews}$	-0.105**			
	(-2.386)			
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{Cenews}$	-0.143***			
	(-3.116)			
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{CCTV}$		-0.308***		
		(-2.736)		
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{CCTV}$		-0.111**		
		(-1.994)		
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{Baidu}$			-0.175	
			(-1.239)	
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{Baidu}$			0.085	
			(1.434)	
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta BioRis^{I}$				-0.003
				(-0.066)
$Sti_{Bio,t\text{-}1}^{Action} \times L.\Delta BioRis_{\ t\text{-}1}^{I}$				-0.072**
				(-2.051)
$LnTa_{it\text{-}1}$	-0.082***	-0.082***	-0.082***	-0.123***
	(-13.049)	(-12.983)	(-13.024)	(-17.082)
$BM_{it\text{-}1}$	0.381***	0.383***	0.383***	0.630***
	(13.575)	(13.583)	(13.621)	(18.959)
$Lev_{it\text{-}1}$	0.107**	0.106**	0.106**	0.166***
	(2.370)	(2.353)	(2.354)	(3.925)
$Capex_{it\text{-}1}$	0.172	0.180	0.177	0.430***
	(1.348)	(1.412)	(1.386)	(3.456)
$Ppe_{it\text{-}1}$	0.130***	0.130***	0.130***	0.158***
	(3.213)	(3.211)	(3.222)	(3.695)
$Roa_{it\text{-}1}$	0.136***	0.136***	0.136***	0.212***
	(2.789)	(2.777)	(2.777)	(3.890)
$Assgro_{it\text{-}1}$	-0.003	-0.003	-0.003	-0.006
	(-0.479)	(-0.531)	(-0.508)	(-0.749)
$Vol_{it\text{-}1}$	-0.657***	-0.656***	-0.658***	-0.215**
	(-7.689)	(-7.668)	(-7.680)	(-2.322)
$Mom_{it\text{-}1}$	-0.411*	-0.464*	-0.416*	0.007
	(-1.666)	(-1.892)	(-1.695)	(0.030)
Constant	1.678***	1.681***	1.681***	2.384***
	(12.485)	(12.425)	(12.457)	(14.983)
Fixed effects	Yes	Yes	Yes	Yes
Adj. R^2	0.066	0.066	0.065	0.080
#Obs.	8,830	8,830	8,830	10,310

Taken together, these regressions provide some evidence that rising (declining) aggregate attention for biodiversity might drive down (up) stock prices of firms with high-biodiversity risk relative to low-risk firms. However, although positive shocks to aggregate biodiversity attention may fuel a negative relation between biodiversity risk and realized stock returns, we continue to find a negative coefficient on $Sti_{Bio,t\text{-}1}^{Action}$ even after controlling for these interaction effects. Hence, whereas studies such as Garel et al. (2024) and Coqueret et al. (2025) associate greater biodiversity impact with higher expected returns after taking into account changing aggregation attention to biodiversity, our sample does not reveal a clear positive biodiversity risk premium in expected returns on stocks in China. In addition, our findings are consistent with Pástor et al. (2022) in that stock returns might respond with a delay to aggregate biodiversity-related attention shocks, as the coefficients on $Sti_{Bio,t-1}^{Action} \times Frq_{Bio,t-1}^{Cenews}$ and $Sti_{Bio,t-1}^{Action} \times \Delta Frq_{Bio,t1-1}^{CCTV}$ are significant.

3.3. Portfolios formed on biodiversity risk exposure

Next to cross-sectional models, we explore an alternative approach to studying the pricing of risk that revolves around forming portfolios, similar to Giglio et al. (2023). Here, we study the economic significance of biodiversity risk in the Chinese stock market by analyzing a zero-cost stock portfolio (Cuculiza et al., 2023). For each year, we categorize stocks into three groups based on each firm's biodiversity risk exposure. Portfolio 3 contains stocks with the highest exposure to biodiversity risk. Portfolio 1 contains the stocks with the lowest biodiversity risk exposure. The remaining stocks are allocated to portfolio 2. The portfolios are updated annually, and we compute the market capitalization-weighted average of weekly returns (excess returns) of stocks in the portfolio. We use the residuals of the Fama-French factor model as the excess returns of the stock (Fama and French, 2015). In addition, we develop a "low-minus-high" biodiversity-risk portfolio, henceforth dubbed the *Low-minus-High-BR portfolio*. This portfolio can be thought of as a hypothetical zero-cost strategy that is long in the low-risk-exposure portfolio and short in the high-risk-exposure portfolio.

Table 5 shows the factor model regressions based on the weekly return series of each portfolio. In Panel A, the zero-cost strategy generates a positive and statistically significant *Alpha* of 0.3% per week when we control only for the market factor (*MKT*). Panel B shows that the zero-cost trading strategy generates a positive and statistically significant *Alpha* of 0.2% per week when we further control for the size (*SMB*) and value (*HML*) factors. Panel

C indicates that the zero-cost strategy generates 0.2% positive *Alpha* per week when we extend the model to include profitability (*RMW*) and investment (*CMA*) factors. These *Alpha* estimates thus imply that returns to going long on low biodiversity risk exposure and short high risk exposure are not entirely explained by common (risk) factor exposures. Directionally, these alphas are consistent with findings from the cross-section models of stock return that we estimated in Section 3.

Table 5. biodiversity risk-based portfolios: Factor model estimates

Note: This table reports estimations of the following factor model: $Rp_{it} - Rf_t = Alpha + \sum \beta_k Factors_{k,t} + \varepsilon_t$, where Rp_{it} denotes the return of each portfolio, Rf_t represents the risk-free rate, $Factors_{k,t}$ includes *MKT*, *SMB*, *HML*, *RMW* and *CMA*. *MKT* is the market value-weighted return on the market in excess of the risk-free rate, and *SMB*, *HML*, *RMW* and *CMA* are the size, value, profitability, and investment factors. For the *MKT*, *SMB*, *HML*, *RMW* and *CMA* factors, CSMAR provides data calculated by different methods. We estimate the above equation using weekly data from 2007 to 2023. The *t*-values are given in parentheses. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively.

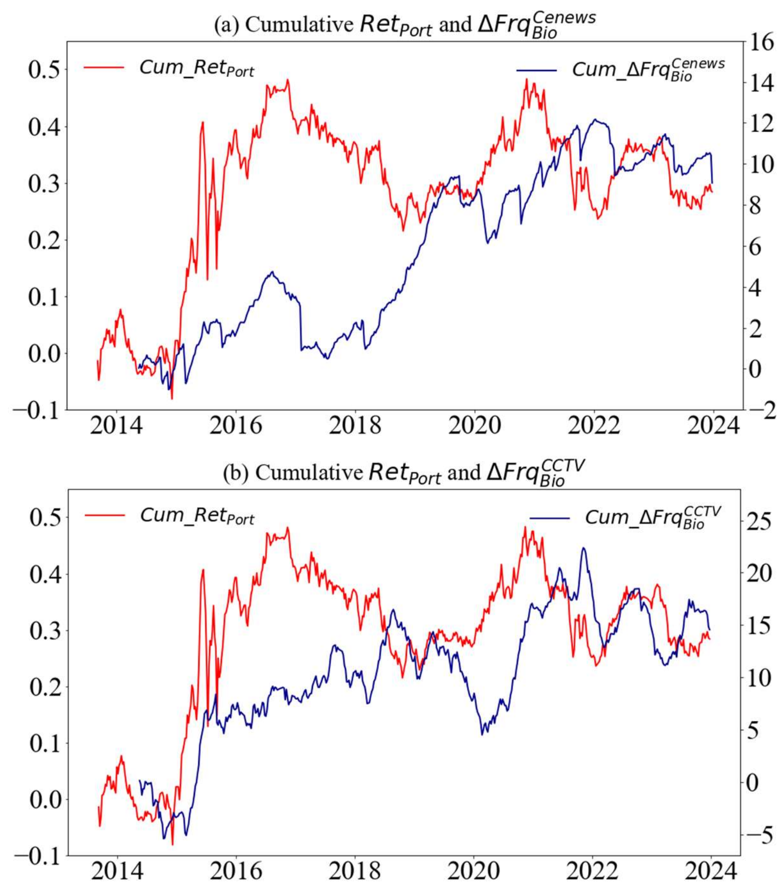
Panel A: One-factor model estimates				
	3 (High)	2	1 (Low)	Low-minus-High
Alpha	-0.042***	-0.044***	-0.045***	0.003**
	(-28.297)	(-55.347)	(-56.223)	(2.134)
MKT	0.783***	0.846***	0.726***	0.058
	(33.194)	(35.964)	(16.467)	(1.541)
Adj. R^2	0.560	0.599	0.238	0.003
#Obs.	865	865	865	865
Panel B: Three-factor model estimates				
	3 (High)	2	1 (Low)	Low-High
Alpha	-0.043***	-0.044***	-0.045***	0.002*
	(-29.453)	(-55.754)	(-56.066)	(1.730)
MKT	0.794***	0.841***	0.666***	0.129***
	(33.095)	(35.300)	(15.280)	(3.569)
SMB	0.051	0.158***	0.292***	-0.240***
	(1.203)	(3.738)	(3.771)	(-3.761)
HML	0.160***	0.080	-0.400***	0.560***
	(2.710)	(1.364)	(-3.721)	(6.308)
Adj. R^2	0.563	0.605	0.285	0.110
#Obs.	865	865	865	865
Panel C: Five-factor model estimates				
	3 (High)	2	1 (Low)	Low-High
Alpha	-0.043***	-0.044***	-0.045***	0.002*
	(-29.374)	(-55.254)	(-55.676)	(1.793)
MKT	0.801***	0.844***	0.681***	0.119***
	(32.548)	(34.533)	(15.353)	(3.247)
SMB	0.063	0.136**	0.216*	-0.153
	(0.920)	(1.993)	(1.748)	(-1.497)
HML	0.127*	0.041	-0.580***	0.707***
	(1.899)	(0.616)	(-4.808)	(7.085)
RMW	0.119	0.048	0.291	-0.172
	(1.161)	(0.471)	(1.570)	(-1.121)
CMA	0.151	0.132	0.642***	-0.491***
	(1.549)	(1.363)	(3.640)	(-3.363)
Adj. R^2	0.563	0.605	0.294	0.120
#Obs.	865	865	865	865

To shed further light on the pricing of biodiversity risk, we examine inspired by Pástor et al. (2022) and Giglio et al. (2023) how the time-series variation in the return of the *Low-minus-High-BR portfolio* varies with unexpected changes in aggregate biodiversity news. Our hypothesis as discussed in Section 3.1 is that the *Low-minus-High-BR portfolio* returns may positively covary with unexpected changes in our indexes of aggregate biodiversity attention. A risk-based explanation for this expected covariation is that shocks to our attention indexes may proxy for news about aggregate biodiversity risk, to which firms with lower firm-level risk exposure are less sensitive. In addition, the taste-based prediction is that heightened (lowered) aggregate attention to biodiversity may trigger stronger (weaker) investor preferences for firms with lower biodiversity risk exposure for reasons that are non-pecuniary. Rising preferences may drive up equity valuations of firms with low (high) exposure to biodiversity risk, while falling preferences would cause the opposite effect. Either way, both explanations imply that unexpected increases (decreases) in aggregate attention to biodiversity risk cause higher (lower) returns on the *Low-minus-High-BR portfolio*.

We measure shocks to aggregate biodiversity attention as prediction errors from AR(1) models applied to the underlying $Frq_{Bio,t}^{Cenews}$ and $Frq_{Bio,t}^{CCTV}$ indexes. To compute the prediction error in week t, we estimate an AR(1) model using the 36 weeks of $Frq_{Bio,t}^{Cenews}$ data ending in week $t-1$, and we set the prediction error to week t's realization of $Frq_{Bio,t}^{Cenews}$ minus the AR(1) model's prediction ($\Delta Frq_{Bio,t}^{Cenews}$). Using the same approach, we also calculate the prediction error $\Delta Frq_{Bio,t}^{CCTV}$. Figure 5 plots the cumulative returns of the zero-cost strategy and the cumulative shocks to aggregate biodiversity attention over the ten-year period ($Cum\_\Delta Frq_{Bio,t}^{Cenews}$ and $Cum\_\Delta Frq_{Bio,t}^{CCTV}$). The cumulative returns trend down initially but then trend up sharply from 2015 through 2017, subsequently stabilizing within a relatively constrained range. The evolutionary trends of $Cum\_\Delta Frq_{Bio,t}^{Cenews}$ (Figure 5a) and $Cum\_\Delta Frq^{CCTV}_{Bio,t}$ (Figure 5b) both indicate rising cumulative shocks to aggregate biodiversity attention indexes.

Figure 5. Cumulative returns of the Low-minus-High-BR portfolio and cumulative shocks of aggregate biodiversity attention

Note: This figure shows the evolution the weekly cumulative return of the *Low-minus-High-BR portfolio*, and the weekly cumulative shocks of aggregate biodiversity attention. The *Low-minus-High-BR portfolio* goes long in the portfolio with low firm-level biodiversity risk and short in the high-risk exposure portfolio. Biodiversity attention shocks are prediction errors from rolling AR(1) models fitted to weekly $Frq^{Cenews}_{Bio,t}$ and $Frq^{CCTV}_{Bio,t}$ indexes.

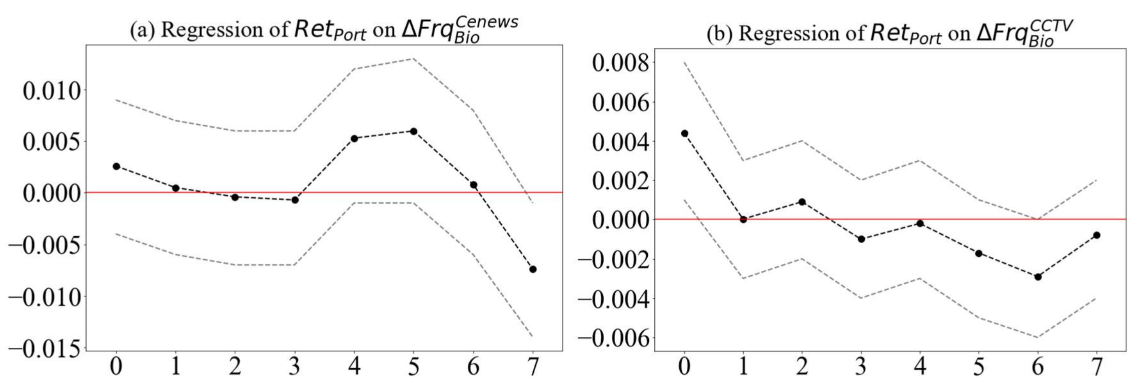


We subsequently regress the weekly returns of the *Low-minus-High-BR portfolio* on $\Delta Frq^{Cenews}_{Bio,t\text{-}\tau}$ ($\Delta Frq^{CCTV}_{Bio,t\text{-}\tau}$), while allowing for up to τ lags (τ = 0, . . . , -7 weeks). Figure 6 displays the estimated coefficients β_τ along with their 95% confidence intervals. Figure 6(a) plots the estimated coefficients β_τ from regressing $Ret_{port,t}$ on $\Delta Frq^{Cenews}_{Bio,t\text{-}\tau}$, whereas Figure 6(b) plots coefficients from regressing $Ret_{port,t}$ on $\Delta Frq^{CCTV}_{Bio,t\text{-}\tau}$.

The estimates of β_0 in Figure 6 are positive and significant at 5% in Figure 6(b). Hence, weekly returns of the *Low-minus-High-BR portfolio* positively covary with contemporaneous biodiversity attention shocks derived from CCTV. This positive contemporaneous relation is consistent with the idea investors price biodiversity risk. Interestingly, we also see an opposite response of portfolio returns to aggregate biodiversity news shocks occurring in the previous 6 weeks (Figure 6b) or previous 7 weeks (Figure 6a). These lagged responses may suggest that investors' immediate responses to aggregate biodiversity news shocks are somewhat corrected in later weeks. The results provide some evidence that stocks with different levels of biodiversity risk exposure are differentially sensitive to aggregate shocks to biodiversity news.

Figure 6. Response to biodiversity news shocks of Low-minus-High-BR portfolio returns

Note: This figure plots the coefficients from regressing returns of the *Low-minus-High-BR portfolio* on weekly shocks to biodiversity attention lagged by *t* weeks, for t = 0, . . . , 7 weeks. Weekly shocks to biodiversity attention are prediction errors from rolling AR(1) models fitted to the weekly $Frq_{Bio,t}^{Cenews}$ and $Frq_{Bio,t}^{CCTV}$ indexes. Dashed lines indicate 95% confidence intervals.



4. Biodiversity risk and institutional ownership

Our analyses of stock returns presented so far address the question whether biodiversity risk matters to the Chinese capital market as revealed by stock returns. In this section, we study equity ownership of Chinese firms in order to better understand how institutional investors consider biodiversity risk. If institutional investors value corporate biodiversity risk, we would expect that firms with higher biodiversity risk exposure have a different ownership structure than firms with lower exposure.

In Table 6, column 1, we first study how firm-level biodiversity risk exposure ($Sti^{Action}_{Bio,t\text{-}1}$) relates to total institutional ownership, controlling for firm characteristics and year-industry- and province-fixed effects. We measure the ownership of institutional investors using their shareholding for stock *i* in year *t* (Ini_{it}). The coefficient estimate for $Sti^{Action}_{Bio,it\text{-}1}$ in column 1 associates a 1% change in biodiversity risk with 0.054% lower ownership, indicating that institutional investors lower share ownership in firms with higher biodiversity risk. In columns 2-9, we further explore different types of institutional investors. We classify institutional investors into funds (Ini^{Funds}_{it}), QFII (Ini^{QFII}_{it}), broker (Ini^{Broker}_{it}), insurance ($Ini^{Insurance}_{it}$), trust funds ($Ini^{Entrust}_{it}$), non-banking financial institution ($Ini^{Financial}_{it}$), bank (Ini^{Bank}_{it}) and other (Ini^{Other}_{it}). We find that the coefficients on $Sti^{AnuRep}_{Bio,it\text{-}1}$ in regressions with Ini^{Funds}_{it} and Ini^{Bank}_{it} as dependent variable are negative, with values of -0.005 and -0.046 respectively, and significant at least at the 5% level. These results suggest that funds and banks are relatively more responsive to greater biodiversity risk exposure.

Our models of stock returns in Section 3 point to interaction effects suggesting that increased (decreased) aggregate attention for biodiversity issues push down (up) market valuations of firms with higher (lower) biodiversity risk. If institutional investors respond to biodiversity risk in the way suggested by our tests of returns, then we could expect that institutional ownership in stocks decreases with higher firm-level biodiversity risk, particularly when aggregate attention for biodiversity rises.

We report in Table 7 on models of total institutional ownership and we interact $Sti^{Action}_{Bio,it\text{-}1}$ with current and one-year lagged changes in aggregate attention to biodiversity. Consistent with our expectations, we find that firm-level biodiversity risk exposure interacts negatively with current and lagged changes in biodiversity attention indexes that we derived from Cenews and CCTV, and negatively with the one-year lagged change in the attention index from Baidu. On the whole, these results are consistent with the idea institutional investors prefer stocks with low firm-level biodiversity risk relative to stocks with greater biodiversity risk, especially when aggregate attention for biodiversity issues rises.

Table 6. Corporate Biodiversity Risk and Institutional Investor Shareholdings

Note: This table reports panel regressions of institutional share ownership on corporate biodiversity risk exposure. We measure ownership of institutional investors using their shareholding for *i* in year *t* (Ini_{it}). We classify institutional investors into the following categories: funds, QFII, broker, insurance, entrust, non-banking financial institution, bank and other. Standard errors are clustered at the firm level. The *t*-values of coefficients are given in parentheses. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Fixed effects include year, industry and province fixed effects. Table A.4 in the Appendix provides variable definitions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ini	Ini^{Funds}	Ini^{QFII}	Ini^{Broker}	$Ini^{Insurance}$	$Ini^{Entrust}$	$Ini^{Financial}$	Ini^{Bank}	Ini^{Other}
$Sti^{Action}_{Bio,t\text{-}1}$	-0.054***	-0.005**	-0.001	0.001	-0.000	0.001	-0.005	-0.046**	0.031
	(-3.213)	(-2.281)	(-0.670)	(0.317)	(-0.285)	(0.179)	(-0.353)	(-2.525)	(0.689)
$LnTa_{it-1}$	0.075***	0.004**	-0.003**	-0.011**	-0.001	0.002	-0.015**	-0.012	-0.004
	(6.932)	(2.189)	(-2.227)	(-2.235)	(-1.290)	(1.247)	(-2.151)	(-1.414)	(-0.114)
BM_{it-1}	0.140***	-0.068***	0.006	0.003	0.005	-0.019**	0.008	0.066	0.108
	(2.668)	(-9.976)	(1.271)	(0.556)	(0.854)	(-2.469)	(0.319)	(1.347)	(0.990)
Lev_{it-1}	0.038	0.022***	0.008	0.114*	0.000	0.002	0.013	-0.009	-0.220
	(0.414)	(2.886)	(0.554)	(1.870)	(0.027)	(0.304)	(0.276)	(-0.299)	(-1.122)
$Capex_{it-1}$	0.835***	0.196***	0.013	-0.054*	-0.028	-0.003	-0.026	0.662**	0.541*
	(3.523)	(8.460)	(0.680)	(-1.929)	(-1.077)	(-0.093)	(-0.502)	(2.569)	(1.879)
Ppe_{it-1}	0.495***	0.016*	0.014*	-0.013	0.008	-0.008	0.052	0.107*	0.332
	(4.905)	(1.833)	(1.787)	(-0.658)	(0.627)	(-0.725)	(1.577)	(1.690)	(1.325)
Roa_{it-1}	0.020	0.088***	0.042**	0.108*	-0.069**	0.001	-0.022	-0.130	-0.086
	(0.207)	(6.655)	(2.036)	(1.855)	(-2.281)	(0.087)	(-0.477)	(-1.520)	(-0.362)
$Assgro_{it-1}$	0.070***	0.006***	0.007	-0.010	-0.000	0.004***	0.001	-0.001	0.003
	(4.365)	(3.019)	(1.307)	(-1.057)	(-0.414)	(4.612)	(0.949)	(-0.021)	(0.505)
Constant	-1.217***	-0.022	0.064***	0.219**	0.063**	0.003	0.395***	0.213	0.420
	(-5.302)	(-0.543)	(2.850)	(2.258)	(2.398)	(0.104)	(2.831)	(1.205)	(0.533)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.057	0.115	0.050	0.026	0.061	0.031	0.181	0.500	0.092
#Obs.	10767	10265	1301	3747	1473	1950	184	202	1128

Table 7. Aggregate biodiversity attention, firm-level biodiversity risk, and institutional investor shareholdings

Note: This table reports panel regressions of institutional investor shareholdings on corporate biodiversity risk in interaction with, respectively, aggregate biodiversity attention measures (columns 1-3). $\Delta Frq_{Bio}^{Cenews}$, ΔFrq_{Bio}^{CCTV} and ΔFrq_{Bio}^{Baidu} denote the yearly changes in aggregate Cenews, CCTV and Baidu biodiversity attention. Standard errors are clustered at the firm level. The *t*-values of coefficients are given in parentheses. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Fixed effects include year, industry and province fixed effects.

	(1)	(2)	(3)
$Sti_{Bio,t\text{-}1}^{Action}$	-0.005	-0.012	-0.011
	(-0.423)	(-1.015)	(-0.889)
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{Cenews}$	-0.051**		
	(-2.104)		
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{Cenews}$	-0.052*		
	(-1.599)		
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{CCTV}$		-0.078**	
		(-2.598)	
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{CCTV}$		-0.078*	
		(-1.885)	
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t}^{Baidu}$			-0.029
			(-0.402)
$Sti_{Bio,t\text{-}1}^{Action} \times \Delta Frq_{Bio,t-1}^{Baidu}$			-0.114**
			(-2.082)
$LnTa_{t\text{-}1}$	0.106***	0.106***	0.106***
	(11.354)	(11.351)	(11.370)
$BM_{t\text{-}1}$	-0.096***	-0.094***	-0.095***
	(-2.978)	(-2.939)	(-2.977)
$Lev_{t\text{-}1}$	0.079**	0.079**	0.078**
	(2.129)	(2.131)	(2.121)
$Capex_{t\text{-}1}$	0.156	0.159	0.158
	(0.880)	(0.896)	(0.891)
$Ppe_{t\text{-}1}$	0.065	0.064	0.065
	(1.082)	(1.081)	(1.091)
$Roa_{t\text{-}1}$	0.053	0.053	0.052
	(1.330)	(1.331)	(1.321)
$Assgro_{t\text{-}1}$	0.041***	0.041***	0.041***
	(6.433)	(6.375)	(6.406)
Constant	-1.687***	-1.684***	-1.688***
	(-6.189)	(-6.181)	(-6.202)
Fixed effects	Yes	Yes	Yes
Adj. R^2	0.113	0.113	0.113
#Obs.	8,820	8,820	8,820

5. Additional test: mediating effect of reputation

Our analyses so far have revolved around the measurement and capital market relevance of biodiversity attention and biodiversity risks. While our results largely suggest that biodiversity risk matters to the stock market in China, it is possible that our measure of biodiversity risk correlates with other concepts that may relate to returns. A possibility is that firms with lower scores on biodiversity risk exposure are more reputable firms, and if so, the question arises whether the relation between biodiversity risk and stock return reflects an effect of corporate reputation. Following Yang et al. (2024), we select 12 corporate reputation evaluation indicators and use factor analysis to calculate the corporate reputation variable (Rpu_{it}). The larger the Rpu_{it}, the greater the corporate reputation. The following panel regression models are used:

$$Rpu_{it}=a_0+a_1 Sti^{Action}_{Bio,it-1}+\sum a_k\, Controls_{k,t-1}+\gamma_t+\theta_f+\varphi_n+\varepsilon_t, \tag{4}$$

$$Ret_{it}=b_0+b_1 Sti^{Action}_{Bio,it-1}+b_2 Rpu_{it-1}+\sum b_k\, Controls_{k,t-1}+\gamma_t+\theta_f+\varphi_n+\varepsilon_t, \tag{5}$$

where Rpu_{it} is the reputation variable. Table 8 reports on these additional tests involving corporate reputation as potential mediator. In columns (1)-(2) which have reputation as dependent variable, one can see that the coefficients on $Sti^{Action}_{Bio,it-1}$ are all negative and significant at the 1% level, indicating that firms with higher biodiversity risk exposure tend to be accompanied by lower reputations. In our model of returns, shown in column (3), the coefficient on $Rpu_{it\text{-}1}$ is positive and significant at the 1% level, suggesting that lower reputation reduces firms' stock return. Moreover, even after controlling for reputation the coefficient on biodiversity risk has a negative sign that is statistically significant. Hence we conclude that reputation is not a complete mediator of the relation between firm-level biodiversity risk exposure and stock return.

Table 8. Additional tests: corporate reputation

Note: This table reports panel regressions of corporate reputation on corporate biodiversity risk exposure, and regressions of stock returns on biodiversity risk while controlling for reputation. Reputation (Rpu_{it}) is derived from 12 corporate reputation evaluation indicators using factor analysis. The *t*-values of coefficients are given in parentheses. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Fixed effects include industry and province fixed effects. Table A.4 in the Appendix provides variable definitions. Columns (1)-(3) report the mechanism tests for corporate reputation.

	(1)	(2)	(3)
	Rpu	*Rpu*	*Ret*
$Sti^{Action}_{Bio,t\text{-}1}$	-0.040***	-0.049***	-0.039***
	(-4.534)	(-3.641)	(-3.122)
$Rpu_{i,t\text{-}1}$			0.031***
			(9.069)
$LnTa_{it\text{-}1}$	1.205***	1.203***	-0.159***
	(35.652)	(34.436)	(-17.655)
$BM_{it\text{-}1}$	-1.686***	-1.708***	0.672***
	(-11.369)	(-11.497)	(20.204)
$Lev_{it\text{-}1}$	-2.518***	-2.470***	0.118***
	(-11.308)	(-11.112)	(3.061)
$Capex_{it\text{-}1}$	2.469***	2.408***	0.215*
	(4.027)	(3.926)	(1.721)
$Ppe_{it\text{-}1}$	0.379*	0.426*	0.201***
	(1.693)	(1.890)	(5.479)
$Roa_{it\text{-}1}$	7.156***	7.092***	-0.014
	(9.577)	(9.559)	(-0.156)
$Assgro_{it\text{-}1}$	0.211	0.214	-0.018
	(1.603)	(1.634)	(-1.478)
$Vol_{it\text{-}1}$			-0.098
			(-1.005)
$Mom_{it\text{-}1}$			0.404
			(1.523)
Constant	-19.881***	-19.774***	3.007***
	(-28.614)	(-26.634)	(17.840)
Fixed effects	No	Yes	Yes
Adj. R^2	0.465	0.473	0.086
#Obs.	7,471	7,471	7,471

6. Conclusion

This paper takes a first step towards understanding the relevance of biodiversity risks for China's financial markets. We present new macro- meso- and firm-level measures of biodiversity risk specific to China, and subsequently explore how biodiversity risk matters to the Chinese equity market. Our measures indicate that biodiversity risk varies over time and across industries, and aggregate attention to biodiversity issues has risen sharply over the past two decades. Using our biodiversity risk measures, we provide new evidence that biodiversity risk matters for stock returns. We find a negative relation between firm-level biodiversity risk and stock returns that is amplified when aggregate attention to biodiversity risk increases. Similarly, the relation between firm-level risk and returns is negatively moderated by changes in industry-level risk. Complementing cross-sectional models, we document that a portfolio with low biodiversity risk earned a higher average weekly return than a portfolio with high biodiversity risk, even after controlling for Fama-French (2015) factor exposures. We provide some evidence that this return difference positively covaries over time with aggregate attention to biodiversity, consistent with the idea that biodiversity risk is priced in China. These results extend recent evidence that aggregate market concerns for biodiversity and environmental risks in the U.S. exhibit over time unexpected positive shocks, during which low-risk stocks experience price increases relative to high-risk stocks. Similar to our result on returns, institutional investors prefer holding stocks with low firm-level biodiversity risk relative to stocks with greater biodiversity risk, especially when aggregate attention for biodiversity issues is rising. Finally, we explore whether firm-level biodiversity risk relates to stock returns through corporate reputation. While our measure of corporate reputation is lower in firms with higher biodiversity risk, we continue to find that biodiversity risk relates to returns after controlling for reputation as potential mediator.

These results add to the growing literature on how biodiversity risk affects financial markets. Future research could proceed along various lines. Although we provide evidence that biodiversity risk matters to Chinese capital markets because firm-level biodiversity risk negatively relates to stock returns, standard theory would predict that firms with high biodiversity risk have higher expected returns going forward. Future research is encouraged to further explore biodiversity premiums in the Chinese stock market using longer time-series data on stock returns. Also, we leave open the question why weekly returns of a portfolio formed on biodiversity risk exhibit a lagged negative response to aggregate biodiversity attention shocks, which possibly indicates overreaction to biodiversity news. Finally, in future research, it would also be interesting to examine whether other market participants such as corporate management are aware of biodiversity risks and adjust corporate policies accordingly.

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Competing interests

The authors declare that there is no conflict of interest.

Authors' contributions

All authors contributed equally to idea conceptualization, investigations, and writing the manuscript.

Appendix

Table A.1 Description of funds related to biodiversity and environmental protection

Code	Name	Description
100056	Fortune Low Carbon Environmental Protection Mixed Securities Investment Fund	The fund mainly invests in listed companies that are engaged in or benefit from the theme of low-carbon environmental protection, and seeks to achieve returns in excess of the performance benchmark for fund shareholders through stock selection and risk control.
001856	E Fund Environmental Theme Mix A	/
001166	CCB Environmental Protection Industry Fund A	The fund is an equity fund that seeks to generate excess returns and long-term capital appreciation by selecting high quality listed companies that contribute to environmental protection, subject to effective risk control.
000409	Penghua Environmental Protection Industry Equity Fund	The fund is an equity-type fund that selects high quality listed companies in the environmental protection industry, subject to effective risk control, and seeks to generate excess returns and capital appreciation over the long term.
160634	Penghua CSI Environmental Protection Industry Index (LOF) A	The fund closely tracks its underlying index and seeks to minimize tracking deviation and error, aiming for an average daily tracking deviation of less than 0.35% and an annual tracking error of less than 4%.
004925	Changxin Low Carbon Environmental Protection Sector Quantitative Fund	The fund seeks to outperform its benchmark through active portfolio management and quantitative risk control, and by investing in high quality companies in the low carbon and environmental sectors.
007163	Axa Spdb Environmental New Energy A	The fund invests mainly in stocks of environmental protection and new energy related industries, seizing the investment opportunities of China's green economy transformation and upgrading, taking fundamental analysis as a basis, and striving for long-term and stable appreciation of the fund's assets under the premise of strict risk control.
012504	Guotai CSI Environmental Protection Industry 50 ETF C	The fund seeks to minimize tracking deviation and tracking error by investing primarily in the target ETF and closely tracking the underlying index.
016387	Forever Win Low Carbon Environmental Protection Intelligent Mix	The fund invests primarily in assets related to low carbon and environmental themes and seeks to achieve steady growth in net asset value over the medium to long term while controlling portfolio risk.
016061	Great Wall Environmental Protection Theme Mix C	The fund focuses on investments in listed companies with environmental themes and seeks to achieve long-term capital growth while controlling risk through a combination of quantitative and qualitative active strategies.
019032	E Fund Environmental Protection Theme Mix C	
021610	Guotai CSI Environmental Protection Industry 50 ETF E	The fund invests primarily in the target ETF and tracks the underlying index closely, seeking to minimize tracking deviation and tracking error.
000696	China Universal Environmental Protection Sector Equity Fund	The fund pursues a bottom-up strategy based on fundamental analysis and invests primarily in high quality listed companies in the environmental protection industry and seeks to achieve sustainable and steady growth of the Fund's assets under the premise of scientific and rigorous risk management.
001064	GF CSI Environmental Protection ETF Connect A	The fund invests primarily in the target ETF and tracks the underlying index closely, seeking to minimize tracking deviation and tracking error.
001975	Invesco Great Wall Environmental Advantage Stock Fund	Based on the research results of the research team of Jingshun Great Wall, the Fund will continue to explore listed companies with environmental advantages and share their green, efficient and sustainable growth in the context of China's economic growth to achieve long-term capital appreciation of the Fund's assets.
512580	GF CSI Environmental Protection ETF	The fund invests primarily in the target ETF and tracks the underlying index closely, seeking to minimize tracking deviation and tracking error.
002984	GF CSI Environmental Protection ETF Connect C	The fund invests primarily in the target ETF and tracks the underlying index closely, seeking to minimize tracking deviation and tracking error.
002259	Penghua Healthy Environment Mix	The fund is a hybrid fund that seeks to achieve excess returns and long-term capital appreciation through active and flexible asset allocation and the selection of healthy and environmentally friendly thematic stocks, while effectively controlling risk.
159861	Guotai CSI Environmental Protection Industry 50 ETF	The fund invests primarily in the target ETF and tracks the underlying index closely, seeking to minimize tracking deviation and tracking error.
012503	Guotai CSI Environmental Protection Industry 50 ETF Connect A	The fund invests primarily in the target ETF and tracks the underlying index closely, seeking to minimize tracking deviation and tracking error.
015060	China Energy Saving and Environmental Protection Stock C	The fund mainly invests in energy-saving and environmentally-friendly listed companies, and seeks to achieve steady and long-term appreciation of the fund's assets under the premise of effective management of investment risks.
015685	Penghua CSI Environmental Protection Industry Index	The fund closely tracks the underlying index and seeks to minimize tracking deviation and tracking error, aiming to keep the average daily tracking deviation within 0.35% and the annual tracking error within 4%.
000158	Fullgoal Low Carbon Environmental Protection Mix (Back-end)	The fund invests primarily in quoted companies engaged in, or benefiting from, the low-carbon environmental theme and seeks to outperform its performance benchmark for the fund's shareholders through stock selection and risk management.
001616	Harvest Environmental Low Carbon Stock Fund	The fund invests mainly in stocks related to environmental protection and low-carbon industries, taking advantage of investment opportunities arising from the transformation and upgrading of China's economy, and seeks to achieve long-term and stable appreciation of the Fund's assets under the premise of strict risk control.
398051	Zhong Hai Environmental New Energy Mix	Against the backdrop of deteriorating global environmental conditions, gradual climate warming and increasing pressure on China's energy conservation and emission reduction, the fund has adopted environmental protection as its investment theme, focusing on environmental protection and new energy industries with environmental responsibility and awareness, as well as industries and enterprises with growth potential and competitive advantages in environmental protection, in order to take full advantage of investment opportunities arising from the development of the environmental protection and new energy industries in the country, and to select individual stocks, seeking long-term appreciation of the fund's assets through active weighting. Combined with active weighting allocation, the fund aims to achieve long-term stable capital appreciation.
163114	Sws Mu CSI Environmental Protection Industry	The fund uses an index-based investment approach and aims to control the average daily tracking error between the fund's NAV growth rate and its benchmark performance of no more than 0.35% and the annual tracking error of no more than 4% through strict investment process constraints and quantitative risk management tools in order to achieve effective tracking of the underlying index.
164304	New China CSI Environmental Protection Industry	The fund uses a passive indexing methodology to achieve effective tracking of the underlying index through rigorous investment procedures and quantitative risk management tools. Under normal market conditions, the fund aims to control the average daily tracking error between the net value growth rate of the fund and the performance benchmark to no more than 0.35% and the annual tracking error to no more than 4%.

Table A.2 Biodiversity terms based on the biodiversity-related studies in the China National Knowledge Infrastructure (CNKI)

shoreline, dark diversity, semi-enclosed bays, semi-arid areas, semi-arid zones, semi-natural habitats, semi-natural vegetation, protected areas, protected area management, protected area objectives, protected area system, protected animals, protected area, protected area management, protected area construction, protected ecosystems, conserved biodiversity, conserved biology, conserved species, conserved grazing, conserved farming, conserved development, conservation development and construction, conservation biological control, conservation priority, conservation plants, conservation governance, conservation nature, endangered, herbaceous, herbaceous diversity, herbaceous plants, herbaceous plant diversity, herbaceous plant communities, grassland, grassland multifunctionality, grassland restoration, grassland establishment, grassland communities, grassland ecology, grassland ecosystem, grassland biology, grassland degradation, grassland resources, lawn autochthonous plants, grassland, grassland areas, grassland zoning, grassland ecological compensation, grassland ecosystem, grassland ecosystems, grassland biodiversity, grassland degradation, grassland restoration, grassland management, broad-leaved evergreen forests, mixed evergreen deciduous broad-leaved forests, ultra-micro eukaryotic zooplankton, tidal trench systems, intertidal zones, submerged plants, urban remnant forests, urban faunal habitats, urban riverine and lake wetlands, urban mangrove forests, urban lakes, urban green space systems, urban greening, urban birds, urban forests, urban habitats, urban ecology, urban organisms, urban wetlands, urban hydric soils, urban wilderness, urban wildlife, urban wild landscapes, urban vegetation, urban plants, urban nature, ruderal species, livestock and poultry genetic resources, pollinators, vertical zones, secondary metabolites, secondary forests, secondary natural forests, clumped logging, vulnerability, village ecological construction , macrobenthos, macrobenthic invertebrates, macrobenthic vertebrates, large marine protected areas, macroalgae, macrocarnivores, macroinvertebrate benthos, macroinvertebrates, macrofungi, large and medium-sized veterinary animals, band logging, single ecosystem function, freshwater, freshwater ecosystems, freshwater biodiversity, island seas, islands, island ecosystems, road greenspace, roads ecology, surface arthropods, surface arthropod diversity, surface water environment, surface water ecosystems, geographic resources, geomorphology, terrestrial arthropod communities, terrestrial mosses, terrestrial birds, earth's key belts, earth's environmental diversity, earth's community of life, earth system science, above-ground biomass, below-ground forests, below-ground biomass, groundwater pollution prevention and control, groundwater systems, groundwater remediation, terrain rapidly changing watersheds, geological heritage, low carbon, low carbon cities, low carbon technologies, low carbon green, low carbon transition, bottom surface macrofauna, bottom fishery organisms, benthic shellfish, benthic fauna, benthic organisms, typical habitat, typical habitats, typical ecosystems, apomictic material, apomictic foliage, protective forests for water transfer projects, butterflies, butterfly diversity, butterfly communities, butterfly habitats, butterfly species, dynamic environment, dynamic collapse, animals, animal conservation, zoogeographic zoning, animal diversity, animal welfare, animal activity, animal taxa, fauna, fauna, animal production management, animal bioacoustics, animal passages, animal breeding, animal resources, flora and fauna, flora and fauna resources, multiscale biodiversity, multifunctional reserve forests, multifunctional agriculture, multifunctional forests, multilevel artificial wetlands, multidimensional diversity, multi-dimensional biodiversity, multi-dimensional synergy, multi-species care, diversity conservation, diversity conservation and management, statutory protected areas, illegal fishing, illegal mining, illegal sand mining, non-flying minibeasts, non-cultivated habitats, non-agricultural habitats, non-human species, zooplankton, zooplankton diversity, zooplankton communities, zooplankton flora and fauna, zooplankton organisms, plankton community structure, planktonic bacteria, planktonic algae, phytoplankton, differences in phytoplankton community characteristics, perception and cognition, higher plants, alpine meadows, alpine meadows, alpine scrub, alpine mountains, alpine ecosystems, alpine degraded grasslands, alpine ecosystems, alpine tarragon meadows, alpine plants, high-carbon sink forestry, plateau lakes, plateau wetlands, inter-roots, inter-root bacteria, root secretion, root biomass, park ecosystems, functional insect groups, functional taxa, functional microbes groups, functional taxa, functional microbes, functional trait diversity, commensalism, commensal microbes, archaeal community structure, palaeoecology, palaeobotanicals, backbone streams, backbone tree species, key ecosystem services, key biodiversity areas, key species, critical ecological space, loss of keystone species, canopy structure, scrub-herb layer, scrubby grassland, shrubs, scrub layer, scrub survival, scrub willow, naturalized plants, diatomaceous algae, overfishing, overgrazing, coastal zone, oceans, marine, marine conservation, marine ecology, marine organisms, marine genetic resources, marine fish, marine nature conservation, river ecology, river and lake ecological conservation and restoration, river and lake ecosystems, estuarine ecosystems, horizontal ecological compensation, lake ecology, lake ecosystems, lake biodiversity, lake wetlands, environmental protection, environmental pollution , desert, desertification, wilderness, very small populations, very small populations of species, very small populations of wild plants, near-nature, mine environmental restoration, mine mining, mine development, mine ecology, insect diversity, forest harvesting, forest resources, understory herbaceous, understory layer, understory vegetation, understory plants, forestry ecology, forestry carbon sinks, watershed ecology, terrestrial ecological carbon sinks, green mining, birds, birds and animals, habitats, regional community scale, regional ecology, communities, tropical, forest, forest protection, forest harvesting, deforestation, forest communities, forest ecology, forest organisms, forest carbon sinks, forest degradation, forest species, forest vegetation, desertification, mountainous, coral, deep-sea, deep-sea mining, habitats, habitat protection, ecological security, ecological shorelines, ecological protection, ecological change, ecological compensation, ecological sustainability, ecological fragility, ecological function, ecological environment, ecological restoration, ecological health, ecosphere, ecological degradation, ecological crisis, ecosystem, ecosystem services, ecological restoration, biosecurity, biodiversity, biosphere, wetland, wetland ecology, diversity of fauna, diversity of tree species, aquatic environment, aquatic life, aquatic ecology, soil erosion, soil and water ecology, carbon sinks, endemic species, endemic plants, natural grasslands, natural forests, soil conservation, soil fauna, soil habitats, soil ecology, fallow forests, fallow wetlands, degradation, degraded grasslands, degraded grasslands, degraded forests, degraded ecosystems, degraded wetlands, degradation and restoration, retreating ponds to forests, retreating ponds to wetlands, microorganisms, pollution prevention and control, pollution hazards, species, county ecology, countryside habitats, countryside wetlands, native grasses, native plants, wilderness, wild, wildlife, wildlife, dominant species, priority conservation, fish, fish ecology, fisheries reserve, rainforest, native animals, native organisms, native conservation, in situ ecological restoration, rare and endangered, rare and endangered birds, rare and endangered species, rare and endangered plants, rare animals, rare animal conservation, rare wildlife, rare fish, rare germplasm resources, vegetation, vegetation conservation, vegetation diversity, vegetation communities, afforestation, plants, plant protection, plant diversity, flora, flora, plant communities, plant community diversity, plant ecology, phytoremediation, plant species, plant species, plant populations, populations, population protection, population dynamics, population diversity, population reproduction, population renewal, population size, population restoration, population structure, population density, population size, population characteristics, population composition, key conservation, key conservation animals, key conservation wildlife, key conservation wild plants, key conservation plants, key ecological functional areas, key biological species, resource protection, resource management, resource environment, resource ecology, resource decline, resource conservation, resource plants, resource plant diversity, nature protection, nature conservation, natural ecological protection, natural ecological space, natural ecological elements, natural resources

Table A.3 Description of different industry based on the 2012 edition of the CSRC (China Securities Regulatory Commission) Industry Classification

Industry Code	Industry Name	Industry Code	Industry Name
A01	Agriculture	C39	Computer, communication and other electronic equipment manufacturing
A03	Animal husbandry	C40	Instrument Manufacturing
B06	Coal Mining and Washing industry	C41	Other manufacturing industries
B09	Non-ferrous metal mining and dressing industry	C42	Comprehensive Utilization of Waste Resources
B11	Mining auxiliary activity industry	D44	Electricity, heat production and supply industry
C13	Agricultural and sideline food processing industry	D45	Gas Production and Supply
C14	Food manufacturing industry	D46	Water production and supply industry
C15	Alcohol, beverage, and refined tea manufacturing industry	E48	Civil engineering construction industry
C17	Textile industry	E50	Building decoration and other construction industries
C18	Textile, clothing and apparel industry	F51	Wholesale trade
C19	Leather, fur, feather and their products and footwear industry	F52	Retail trade
C21	Furniture Manufacturing	G54	Road transport
C22	Paper and paper products industry	G55	Water transport
C23	Printing and Recording Media Reproduction	G58	Loading, unloading, handling and forwarding
C24	Literary, Educational, Industrial, Sports and Recreational Goods Manufacturing Industry	G59	Warehousing
C25	Petroleum Processing, Coking and Nuclear Fuel Processing Industry	I63	Telecommunications, radio and television broadcasting and satellite transmission services
C26	Chemical raw materials and chemical products manufacturing	I64	Internet and related services
C27	Pharmaceutical manufacturing	I65	Software and Information Technology Services
C28	Chemical fiber manufacturing	J66	Money and financial services
C29	Rubber and plastic products industry	J67	Capital market services
C30	Non-metallic mineral products industry	K70	Real estate industry
C31	Ferrous metal smelting and rolling processing industry	L72	Business services
C32	Non-ferrous metal smelting and rolling processing industry	M73	Research and experimental development
C33	Metal Products Industry	M74	Professional and technical services
C34	General Equipment Manufacturing	N77	Ecological Protection and Environmental Management
C35	Special Purpose Equipment Manufacturing	N78	Public Facilities Management
C36	Automobile Manufacturing	O81	Other Services
C37	Railway, ship, aerospace and other transport equipment manufacturing industry	R86	Radio, television, film and video recording production industry
C38	Electrical machinery and equipment manufacturing	S90	Comprehensive

Table A.4 Description of the main variables

Variable	Definition	Measurement
$Frq_{Bio,t}^{CCTV}$	Aggregate biodiversity news index	Number of sentences containing biodiversity terms in CCTV News texts
$Frq_{Bio,t}^{Cenews}$	Aggregate biodiversity news index	Number of sentences containing biodiversity terms in China Environment News texts
$Frq_{Bio,t}^{Baidu}$	Aggregate biodiversity attention index	Number of searches for biodiversity terms on Baidu
$BioRis_t^I$	Industry-level biodiversity risk exposure	Difference between the weight of industry I in the market portfolio and its weight in biodiversity and environmental protection funds
$Frq_{Bio,it}^{AnuRep}$	Firm-level biodiversity attention index	Number of sentences containing biodiversity terms in annual report texts
Sti_{Bio}^{Action}	Firm-level biodiversity risk index	Difference between the number of negative sentences related to biodiversity and the number of positive sentences related to biodiversity with actual actions taken
Ret_{it}	Stock return	Return on stocks considering reinvestment of cash dividends
$LnTa_{it}$	Firm size	Natural logarithm of total assets
MB_{it}	Book-to-market ratio	Ratio of book equity to market capitalization
Lev_{it}	Financial leverage	Ratio of total debt to total assets
Ppe_{it}	Asset tangibility	Net property, plant, and equipment, divided by total assets
$Capex_{it}$	Capital expenditures over assets	Capital expenditures divided by total assets
Roa_{it}	Return on assets	Net income after tax, divided by total assets
$Assgro_{it}$	Asset growth	Annual percentage change in total assets
Vol_{it}	Volatility	Monthly stock return volatility calculated over the 1-year period
Mom_{it}	Momentum	Cumulative stock return over the 1-year period
Rpu_{it}	Corporate reputation	We select 12 corporate reputation evaluation indicators and use factor analysis to calculate the corporate reputation variable. The 12 corporate reputation assessment indicators include the ranking of the company's assets, revenues, net profit, and value within the industry from the perspective of consumers and society; the gearing ratio, current ratio, and long-term debt ratio from the perspective of creditors; earnings per share, dividends per share, and whether or not it is audited by the Big Four accounting firms from the standpoint of shareholders; and the sustainable growth rate, and the percentage of independent directors from the perspective of the company.
Ini_{it}	Ownership by institutional investors	Total shares held in firm 'i' at t by institutional investors, as percentage of total shares outstanding