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Biodiversity risk

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Abstract

We explore the effects of physical and regulatory risks related to biodiversity loss on asset values. We first develop a news-based measure of aggregate biodiversity risk and analyze how it varies over time. We also construct and publicly release several firm- and industry-level measures of exposure to biodiversity risk, based on (1) textual analyses of firms' 10-K statements, (2) the holdings of biodiversity-related funds, (3) firms' responses to a questionnaire fielded by the Carbon Disclosure Project, and (4) a large survey of finance professionals, regulators, and academics. Exposures to biodiversity risk vary substantially across industries in a way that is economically sensible and distinct from exposures to climate risk. We find evidence that biodiversity risks already affect equity prices: returns of portfolios that are sorted on our measures of biodiversity risk exposure covary with innovations in the aggregate biodiversity risk index. However, our survey indicates that market participants do not perceive the current pricing of biodiversity risks in equity markets to be adequate.

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JEL classifications: G10, G11, G12, Q5, Q53, Q57.

1. Introduction

Over the past decades, policymakers, investors, and researchers have increasingly sought to understand and manage the complex relationships between economic activity and the health of our planet. For example, a series of treaties have codified commitments to slow global warming, and there have been numerous efforts from the business and finance communities to address the various risks from climate change. On the academic side, the field of climate finance has rapidly developed into an active area of research (see Giglio et al. 2021a; Stroebel and Wurgler 2021; Hong, Karolyi, and Scheinkman 2020 for recent reviews). Yet climate change is only one facet of how the economy interacts with the natural world. In this article, we examine another important and distinct dimension: the economic risks associated with *biodiversity loss*.

While biodiversity—commonly understood as the diversity of genes, species, and ecosystems—has long underpinned human survival and well-being, recent decades have seen sharp declines driven by human activity. The 2019 *Global Assessment* of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2019), for instance, documented that current species extinction rates are ten to a hundred times higher than the historical average of the past 10 million years.

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Such biodiversity loss can have large negative consequences for the economy. A key reason is that biodiversity plays a fundamental role in the provision of *ecosystem services*, an important (though often ignored) factor of production alongside other factors like capital and labor (see, e.g., Daily et al. 1997, 2000; Heal 2000; Dasgupta, Kinzig, and Perrings 2013; Giglio et al. 2024).[1] These ecosystem services include provisioning services such as food, fuel, and timber, as well as regulating services such as pollination, the provision of clean air and water, and pest control. The effect on aggregate economic output from a loss of such ecosystem services is generally difficult to compensate for by increasing capital or labor (Dietz and Neumayer 2007; Ekins et al. 2003). As a result, early estimates of the annual economic value provided by ecosystem services are in the tens of trillions of dollars (Costanza et al. 1997).

The negative effects of biodiversity loss on economic activity are likely heterogeneous across sectors and firms (Giglio et al. 2025b). For example, some industries may be more exposed to the *physical* biodiversity risks due to their dependence on ecosystem services in the production process. Similarly, firms located near ecosystems at risk of collapse are more exposed to the physical risks from further biodiversity declines.[2] In addition to the physical risks from biodiversity loss, *transition* risks from regulatory responses to biodiversity loss—such as those resulting from policy commitments made at the recent COP15 conference in Montreal—can also have substantial effects on economic activity and asset values, especially for industries that directly interact with and impact the natural environment.

The goal of this article is to quantify how biodiversity risks vary in the cross-section of firms and industries and to study whether asset values have begun to reflect these risks. To motivate our analysis, we first conduct a survey of the perceptions of biodiversity risks among 668 finance academics, professionals, public sector regulators, and policy economists from around the world. The survey shows broad and substantial concerns about the economic effects of biodiversity loss over relatively near-term horizons. Around 70 percent of respondents perceive physical and transition biodiversity risks to have at least moderate financial materiality for firms in the United States, with private sector respondents reporting the highest perceived financial materiality of these risks.

We next move to quantify the aggregate amount of biodiversity risk over time. A key issue with measuring risks such as those related to biodiversity loss is that they often unfold slowly over long horizons, making it hard to quantify risk and risk exposures using standard statistical tools. To overcome these challenges, we follow the approach developed in Engle et al. (2020) and build a biodiversity risk index using *news* about such risks extracted from newspaper coverage of topics associated with biodiversity loss.

Specifically, we construct a biodiversity news index by analyzing articles in the *New York Times* (NYT). We first develop a biodiversity dictionary containing a list of relevant terms such as "ecosystem" and "deforestation" that is used to identify articles in the NYT that cover biodiversity risks. We classify the sentiment of these articles using the Bidirectional Encoder Representations from Transformers, or BERT, a standard model from the natural language processing literature. The article-level sentiment is aggregated to compute a daily "NYT-Biodiversity News Index." We validate the index by showing that it spikes around important events regarding biodiversity risk (e.g., during ecological

[1] While it is true that in some instances—such as those involving invasive species—more diverse ecosystems may be less stable, a large literature in ecology has documented positive "biodiversity-stability" and "biodiversity-productivity" relationships that highlight that declines in biodiversity generally weaken an ecosystem's ability to provide ecosystem services (see reviews of this literature in Hooper et al. 2005; Giglio et al. 2024). This literature also highlights that not all species loss is equally damaging to the provision of ecosystem services: losing a species that is unique in its ability to perform its role in its ecosystem—sometimes called a "keystone species"—is more damaging than losing a different species that competes with other species to perform a given function.

[2] There are also non-pecuniary benefits associated to biodiversity, for example if some individuals put an intrinsic value on the existence of species. In this article, we focus on the part of the value that comes from the contribution to economic production

disasters or around new regulations to limit biodiversity loss). This high-frequency measure allows us to quantify the immediate impacts of changes in expectations about—or increased attention to—damages and regulations related to biodiversity loss, even if they might only materialize in the future.

To assess whether this aggregate biodiversity risk is reflected in asset prices, we start from the observation that the impacts of biodiversity risk realizations are heterogeneous across firms and industries. For example, diverse ecosystems are key to the production of food and nature-based materials such as timber (Duarte et al. 2009; Liang et al. 2016; Paul et al. 2020; Porto et al. 2020; Steffan-Dewenter et al. 2007), making those industries particularly exposed to physical biodiversity risks. In addition, many medicines, including antibiotics and cancer drugs, are derived from natural compounds found in plants, animals, and microorganisms, so the pharmaceutical industry is also exposed to this risk. Similarly, utility firms with large footprints in environmentally sensitive areas—including firms operating wind and solar farms—may be disproportionately affected by biodiversity transition risks.

However, while it is intuitive to expect biodiversity risk exposures to be heterogeneous across firms, the absence of standardized disclosure frameworks for physical and transition biodiversity risks makes it hard to quantify these exposures. We thus propose and compare several new ways to measure firms' biodiversity risk exposures; we publicly release these measures of exposure to biodiversity risk at www.biodiversityrisk.org.

Our first set of measures of biodiversity risk exposures, available at the firm level, is based on textual analysis of firms' 10-K statements to identify discussions of biodiversity-related risks. The second measure is created at the industry level from our survey of academics and professionals. The survey asked respondents to select the industries most negatively affected by biodiversity loss, distinguishing explicitly between physical and transition risks. Our third measure of biodiversity risk exposures is based on the holdings of five biodiversity-related funds. It is calculated by comparing the weight of an industry in the market portfolio to its weight in the biodiversity funds' portfolios, based on the assumption that industries that are underweighted relative to the market are negatively exposed to biodiversity risks. The last measure is derived from firms' responses to the CDP (Carbon Disclosure Project) Climate Change Questionnaire, where firms disclose whether their activities impact biodiversity-sensitive areas. All these measures are meaningfully correlated in the cross-section: industries ranked high on biodiversity risk exposure on one measure generally also rank high on the other measures. The sectors with the highest average biodiversity risk exposures include Energy, Utilities, Real Estate, Food, and Pharmaceuticals, while firms in the Communication Services, Software, and Technology sectors have minimal direct exposures to biodiversity risks.

We then use our measures of news about aggregate biodiversity risk as well as our firm- and industry-level risk exposures to explore the extent to which biodiversity risks are currently incorporated into equity prices. To do so, we form equity portfolios of industries sorted by their biodiversity risk exposures. The portfolios hold long positions in industries with *low* biodiversity risk exposures and short positions in industries with *high* biodiversity risk exposures. If biodiversity risk is priced, the return of these biodiversity-risk-sorted portfolios should covary with the aggregate biodiversity news index, effectively behaving like a hedge portfolio for biodiversity risk. We find that the correlations between the returns of our biodiversity hedge portfolios and AR(1) innovations in the biodiversity risk index are positive, with magnitudes as large as 0.2. These correlations are comparable to those obtained by climate hedge portfolios when evaluated against aggregate climate news (see Engle et al. 2020; Alekseev et al. 2024) and, more generally, to the hedging performance of portfolios built to hedge other macro risks such as consumption or GDP (Gross Domestic Product) (see Giglio and Xiu 2021).

To explore if our measures of biodiversity risk exposure are simply recasting information from other firm characteristics, we compare the hedge performance of our measures with that of hedge portfolios constructed using other firm characteristics—specifically, the 212 characteristics in the "factor zoo" of Chen and Zimmermann (2022). We find that our biodiversity hedge portfolios perform significantly better than this universe of characteristics in hedging aggregate biodiversity risk. Overall, the evidence suggests that biodiversity risk has been at least partly priced in the cross-section of US equities over the last decade.

We conclude by reviewing evidence from our survey on market participants' perceptions of whether biodiversity risks are *adequately* priced in financial markets. About half of the respondents believe that these risks are not sufficiently priced across stock, commodity, sovereign debt, and real estate markets, while 14 percent to 19 percent of respondents believe that they are correctly priced. Only a handful of respondents believe that biodiversity risks are overpriced in these asset markets (while about 35 percent of respondents have no opinion).

Throughout the article, we explore the relationship between biodiversity risks and climate risks. The two risks are conceptually distinct, as biodiversity risk focuses on the threats to the variety of life on Earth and its consequences, while climate risk relates to the potential negative consequences of a change in the climate. As discussed in Giglio et al. (2024), the effects on aggregate output of these two types of risk realizations can be quite different, though they are obviously related. Despite this conceptual distinction, the two risks are interconnected through a "twin-crises multiplier" whereby climate change can exacerbate biodiversity loss, and biodiversity loss can drive climate change, for example, through the destruction of carbon sinks (Giglio et al. 2025a). Given the recent academic and policy interest in climate change and its economic implications, it is important to distinguish the two types of risk not only qualitatively, but also quantitatively. We do so in several ways. First, we show that the aggregate biodiversity news index behaves differently from an analogously constructed climate news index; second, we document that climate risk exposures and biodiversity risk exposures are only weakly related in the cross-section of industries; and finally, we show that portfolios built for hedging biodiversity risk do not perform well at hedging climate risk.

Our work contributes to a growing literature that studies the interaction between financial markets, asset prices, and the health of our planet. Much recent research has studied the physical and transition risks relating to climate change (e.g., Alekseev et al. 2024; Engle et al. 2020; Giglio et al. 2025b; Pástor, Stambaugh, and Taylor 2021; Sautner et al. 2023b; Bolton and Kacperczyk 2020, 2021a, 2021b, 2023; Ilhan et al. 2023; Grippa, Schmittmann, and Suntheim 2019; Bolton and Kacperczyk 2025; Pástor, Stambaugh, and Taylor 2022; Choi, Gao, and Jiang 2020; Giglio et al. 2021a; Bernstein, Gustafson, and Lewis 2019; Baldauf, Garlappi, and Yannelis 2020; de Boyrie and Pavlova 2020; van Benthem et al. 2022; Acharya et al. 2023, 2025).

Much less work has been done to understand the effect of biodiversity risks on the economy and on asset prices. The key challenge is measuring its dynamics and firms' evolving exposures. To our knowledge, this article is among the first to quantify aggregate biodiversity risk and firms' and industries' exposures. By addressing this research gap, we respond to the call for more research in Karolyi and Tobin-de la Puente (2022) and provide publicly available data sources to spur follow-up work on biodiversity risks at www.biodiversityrisk.org. In the last two years, several other time series measures of biodiversity risk have emerged. Incident-based measures, such as Xiong (2023), track the frequency of reported biodiversity incidents occurring within that country using RepRisk data, while news-based indices, such as Ma, Wu, and Zeng (2024), capture sentiment in media coverage. These efforts provide complementary measures to our NYT-Biodiversity News Index. Estimates of cross-sectional exposure to biodiversity risk have also improved over time. Garel et al. (2024) and Coqueret, Giroux, and Zerbib (2025) use the Corporate Biodiversity Footprint

(CBF) from Iceberg Data Lab to assess firms' biodiversity impact, and thus their transition risk exposures. Garel et al. (2025) construct firm-level nature dependence measures using the ENCORE database. Other papers rely on ESG subindicators related to nature and biodiversity (Xin et al. 2023; Xiong 2023; Naffa and Czupy 2024; Hoepner et al. 2023). Becker, Di Girolamo, and Rho (2025) use MSCI Geographic Segment Exposure to Fragile Ecosystems, which assesses firms' operational presence in biodiversity-sensitive areas. Our measures are built from financial and disclosure data, and they are publicly available, replicable, and link directly to financial outcomes. Each, however, has limitations: 10-K measures depend on disclosure quality, surveys are updated infrequently, holdings data cover only limited periods, and CDP relies on voluntary reporting. Cross-geography measures of physical and transition risk exposure have also been explored (e.g., Bouyé et al. 2024; Huang et al. 2024). For example, Giglio et al. (2024) construct ecologically founded country-level measures of ecosystem fragility, while Chen, Cong, and Ponticelli (2023) build a dataset mapping the geographic locations of all National Nature Reserves in China.

Other researchers that examine how biodiversity risk is priced in equity markets include Garel et al. (2024), who find a biodiversity premium emerging following the Kunming Declaration (see Xiong 2023; Kalhoro and Kyaw 2024, for related results). Further evidence is provided by Coqueret, Giroux, and Zerbib (2025), who highlight a biodiversity risk premium in expected returns in US sectors most exposed to biodiversity risks, consistent with the finding by Naffa and Czupy (2024) that biodiversity-screened portfolios yielded lower risk-adjusted returns compared to randomly selected portfolios in the United States from 2013 to 2023.[3]

2. Biodiversity risks: perception and measurement

The economic and financial risks associated with biodiversity loss can be broadly divided into physical risks from the actual loss of biodiversity and transition risks from responses by regulators and consumers to reduce biodiversity loss (see OECD 2019; IFC 2019).

Physical risks encompass the financial and economic effects of the loss of biodiversity and the associated ecosystem services. For example, firms relying on specific natural resources, such as timber, may face scarcity or quality issues due to deforestation or habitat loss. This can lead to increased raw material costs and deteriorating supply chains. Similarly, biodiversity loss can negatively affect the R&D process in the pharma and biotech sectors. In addition to such direct effects, biodiversity loss can raise the likelihood of the emergence of various diseases and increase vulnerability to damages from climate change, for instance by reducing carbon sequestration capacity (Giglio et al. 2025a).

Besides the physical risks associated with biodiversity loss, firms may also be affected by risks from an increased focus of regulators and consumers on the preservation of biodiversity. For example, policies aimed at protecting biodiversity, such as land-use regulations and sustainable forestry requirements, may result in changes to asset values across a range of industries. Biodiversity transition risks also come from changing consumer preferences, such as shifts away from palm oil by consumers concerned about its effect on deforestation.

[3] Several studies explore the pricing of biodiversity risks in fixed income markets. Giglio et al. (2024) find that news about biodiversity loss increases credit default swap spreads more for countries with more depleted ecosystems. Similarly, Agarwala et al. (2022) show that downgrades of sovereign bonds are associated with growing nature-based risks. Examining infrastructure firms, Hoepner et al. (2023) show that firms with better biodiversity risk management enjoy more favorable financing conditions, reflected in lower CDS slopes. Cherief, Sekine, and Stagnol (2022) highlight that corporate bond spreads for firms in biodiversity-intensive sectors widen following acute biodiversity events in Australia and Brazil. In municipal bonds, Rizzi (2022) finds that losses in wetland areas are associated with increased yields and borrowing costs due to heightened downside risk and extreme weather uncertainty. Finally, Chen, Cong, and Ponticelli (2023) find that the "Green Shield Action," a regulatory initiative to enforce biodiversity preservation in China, significantly increased bond yields for municipalities with national nature reserves. In the real estate market, Rizzi (2022) finds that home prices decrease when upstream wetlands are lost and increase when wetlands are gained, highlighting the impact of biodiversity loss and restoration on property values.

In addition, legal and reputational biodiversity risks affect firms by increasing the cost of causing ecological disasters such as oil spills.

In this section, we aim to better understand the importance and evolution of biodiversity risks from an aggregate perspective. We first discuss findings from a survey of academics, financial professionals, and regulators about the relative importance of various biodiversity risks over different time horizons. We then describe a new measure of aggregate biodiversity risk over time and highlight that the time-series movement of biodiversity risk is distinct from that of climate risk, which has been studied extensively in the academic literature.

2.1 Perceptions of the importance of biodiversity risks

To measure perceptions of the importance of biodiversity risks, we surveyed finance researchers, professionals, and public sector employees in Q1 2023. To reach academics, we collected email addresses of about 4,500 faculty at the top 100 finance departments.[4] To reach practitioners, we contacted about 7,000 NYU Stern and Yale SOM graduates working in finance. To reach those involved in policy, we invited about 3,000 researchers or policymakers working in the finance-related groups of about thirty-five relevant public sector institutions to participate in our survey (see Supplementary Appendix A.4 for the full list of these institutions).[5]

In total, we received 668 complete responses for an overall response rate of about 4.5 percent.[6] Forty-eight percent of responses were from academic researchers, 34 percent from financial professionals, and 18 percent from financial regulators or public-sector employees. Our respondents' locations tilt toward North America (62 percent) and Europe (23 percent), with respondents from Asia and the Rest of the World making up 9 percent and 5 percent respectively. Supplementary Appendix Table A.1 contains summary statistics and cross-tabulations of the demographic information reported by the survey respondents.

Supplementary Appendix A.1 shows the flow of the survey. The first question asked respondents about how worried they were about ecosystem and species diversity loss. About 70 percent of respondents expressed substantial personal concern about each type of biodiversity loss.

To assess perceptions of the financial and economic implications of biodiversity risks, we asked survey participants to rate the financial materiality of physical and transition risks for US firms and to indicate the expected time horizon of these risks. Table 1 reports responses across different groups. Overall, both types of biodiversity risks are widely perceived as material—especially by private-sector respondents and those located in Africa, South America, and Australia. About 70 percent of respondents rated both physical and transition risks as at least moderately financially material. Roughly 20 percent believe these risks are already materializing, with transition risks generally expected to emerge earlier than physical risks.

Supplementary Appendix Table A.2 shows several responses to an open-ended question asking if there were any particular ways in which biodiversity risks are important in participants' professional lives. Respondents mentioned both physical risks ("I co-run an investment fund in farmland and timberland, which are directly affected by these risks") and transition risks ("Regulatory risk related to biodiversity is a chief driver of long-term uncertainty in the energy markets in which I work"). Many survey participants discussed

[4] We used the ranking maintained at ASU (Arizona State University) based on the total number of articles published in the *Journal of Finance*, *Journal of Financial Economics*, and *Review of Financial Studies* from 2010 through 2023.

[5] While our survey respondents include a broad range of market participants, a recent survey by Gjerde et al. (2025) focuses specifically on global firms, gathering their views on nature risk exposure, management practices, and investor interest.

[6] This response rate is comparable to that in other surveys used by finance researchers, such as 7.5 percent in Stroebel and Wurgler (2021) and 2.5–4 percent in Giglio et al. (2021b).

Table 1. Biodiversity risk perceptions.

For the first two blocks, participants were asked: "Biodiversity risks for investors and firms are often divided into (i) physical risks coming from actual changes in biodiversity (e.g., reduced pollinators, freshwater scarcity) and (ii) transition risks coming from changes in the regulatory environment to combat biodiversity loss (e.g., the Clean Water Act). Please rate the financial materiality of these risks for corporations in the United States. 1- Physical Risk; 2- Transition Risk." For the last two blocks, participants were asked: "Over what time horizon, if any, do you expect these biodiversity risks to materialize?," where biodiversity risk is either the physical risk or transition risk. The percentage breakdowns in the table are to be read in columns within blocks. Biodiversity concern is defined as the maximum of a respondent's ratings for physical and transition biodiversity risk importance.

		Role			Location				Biodiversity concern			
	Pooled	Academic institution	Private sector	Public sector	North America	Europe	Asia	ROW	Very high	High	Low	No concern
Physical risk importance (%)												
Not at all important	8	9	9	5	9	6	9	6	1	3	9	100
Slightly important	24	26	23	20	26	20	26	14	6	27	91	0
Moderately important	35	37	28	40	34	36	38	26	19	69	0	0
Very important	34	28	40	35	31	38	28	54	73	0	0	0
Transition risk importance (%)												
Not at all important	7	7	6	11	8	6	7	9	1	1	9	100
Slightly important	20	22	19	18	22	19	19	11	8	17	91	0
Moderately important	42	46	34	46	40	50	36	40	26	82	0	0
Very important	30	25	41	25	30	25	38	40	66	0	0	0
Physical risk materialization (%)												
Already today	23	18	29	24	24	18	19	29	32	15	12	13
1 to 5 years	10	8	10	14	9	9	5	23	11	9	8	7
5 to 30 years	46	51	43	41	45	52	43	43	45	57	36	7
More than 30 years	17	18	14	19	17	17	22	3	10	17	35	30
Never	5	6	4	1	4	4	10	3	1	2	9	43
Transition risk materialization (%)												
Already today	20	16	27	17	23	14	16	23	27	14	15	10
1 to 5 years	26	28	25	24	25	29	22	34	33	23	15	7
5 to 30 years	41	44	34	47	40	44	43	34	33	54	41	13
More than 30 years	8	7	10	7	9	7	9	3	4	7	20	27
Never	5	5	4	6	3	7	10	6	2	2	9	43

mechanisms through which biodiversity loss affects the economy, for example through the exposures of specific industries (as in the examples above), or at the aggregate level (as in the following responses: "Biodiversity risks are a serious threat to financial stability and the resilience of financial companies"; "Loss of biodiversity and area for animals to move closer to cities, causing a great chance for diseases to spread to humans, which may cause another pandemic").

2.2 Measuring aggregate biodiversity risk

Table 1 suggests a substantial degree of concern about biodiversity risks across respondents with a wide range of backgrounds. In this section, we construct a new index that allows us to measure attention and concern related to biodiversity risks over time.

While biodiversity loss can have large economic costs, it is a slow-moving process, with many of the most severe outcomes materializing over decades (see Magurran 2021). This makes it difficult to quantify biodiversity risks or to measure assets' exposures to them. To address this challenge, we build on the insights of Engle et al. (2020), who argue that when dealing with long-term risks such as climate change or biodiversity loss, exposures can be studied through higher-frequency measures of *news* about or attention to future damages (see also Ardia et al. 2023; Stecula and Merkley 2019; Alekseev et al. 2024). Based on this idea, we construct an index of biodiversity *news* as reported in the NYT.

2.2.1 The NYT-Biodiversity News Index

The first step to building our measure of biodiversity news is to identify news articles that cover biodiversity. To do so, we build a Biodiversity Dictionary that contains one hundred words common in discussions related to biodiversity loss (see Supplementary Appendix Table A.3). These words were selected based on their cosine similarity to the term "biodiversity" in Google's *word2vec* implementation.[7] Using this dictionary, we identify a sentence as biodiversity-related if it contains at least one of these terms, excluding instances of unrelated combinations such as "software ecosystem" (see Supplementary Appendix A.4 for details) and excluding the word "climate change" to allow us to capture biodiversity news separate from climate news.[8] We identify articles containing at least two 'biodiversity-related sentences' as covering biodiversity.

News about biodiversity loss can either be positive or negative; for example, an article can report that biodiversity loss is progressing faster or slower than previously anticipated. To separately identify such news stories, we adopt the BERT model to classify each of the selected biodiversity sentences to determine whether it expresses a positive or negative sentiment (Devlin et al. 2019). Sentences with positive sentiment get assigned a score of "+1," negative sentences get assigned a score of "−1," and neutral sentences get assigned a score of "0." For example, the following sentence gets classified as having a positive sentiment: "*Populations soon rebounded, improving water quality and bringing more whales, sharks, rays, seals, dolphins and other animals closer to the beach than they've been since the middle of the last century.*" In contrast, a negative sentiment is assigned to "*Environmental problems remain, including overfishing and the erosion and deforestation left from earlier*

[7] We use the pre-trained vectors trained on part of Google News dataset (about 100 billion words). The model contains 300-dimensional vectors for 3 million words and phrases.

[8] We test the robustness of the index by constructing three additional indices: one using all hundred terms from the Biodiversity Dictionary, one using terms from the Biodiversity Dictionary excluding those in the Climate Dictionary (Appendix Table A.4), and one excluding terms in the Climate Change Dictionary (Appendix Table A.5). Terms in red are the common terms that are related to both biodiversity and climate/climate change. Appendix Table A.6 presents the monthly correlations across these indices. The index using all terms is highly correlated with climate risk measures due to its inclusion of the commonly covered term "climate change," whereas the indices excluding climate-related terms show lower correlations with climate risk. This finding highlights the importance of removing words related to climate change from the biodiversity dictionary. The high correlation among the three indices that implement such a removal indicates the robustness to the exact keywords that are excluded.

eras." Supplementary Appendix Table A.7 presents further examples of biodiversity-related sentences alongside their BERT sentiment classifications. We assign an article to have positive (negative) sentiment if the average sentence sentiment score for all biodiversity sentences in the article is positive (negative). About 8.4 percent of articles get classified as positive, 72.0 percent as neutral, and 19.6 percent as negative.

To measure the overall sentiment of biodiversity news on a given day, we construct the NYT-Biodiversity News Index as the number of negative biodiversity articles minus the number of positive biodiversity articles on that day. Therefore, higher values of the NYT-Biodiversity News Index correspond to more negative news about biodiversity risks. Since news related to biodiversity risk is relatively infrequent, we generally aggregate this daily measure of biodiversity news to the monthly level by averaging daily values over each month.

Figure 1 plots the monthly NYT-Biodiversity News Index and adds labels to events relevant to biodiversity loss. The index spikes around salient biodiversity-related events, such as changes to the Endangered Species Act (ESA) in 2019 and the release of biodiversity-related reports. There are also events with positive news about biodiversity risks, leading to a negative biodiversity news index; these include articles on the thriving of previously threatened coyotes, foxes, and sea turtles. We have explored other ways of constructing our biodiversity news index, for example by measuring an article's sentiment as the average sentiment of all biodiversity-related sentences in that article, and by measuring the per-period overall biodiversity sentiment as the average sentiment of all biodiversity-related articles. Our key results are similar using these alternative approaches to constructing the aggregate biodiversity news index.

Text-based measures of biodiversity risk have several limitations. First, any keyword selection might lead researchers to omit relevant terms or include unrelated contexts, introducing noise. We assess the robustness of our methodology by constructing alternative NYT-based indices with different keyword sets and find high correlations across the different indices (Supplementary Appendix Table A.6). Second, machine learning models are prone to misclassification. To evaluate the accuracy of our approach, we manually classified the sentiment of 100 randomly chosen biodiversity-related sentences from the NYT. The 'confusion matrix,' reported in Panel A of Supplementary Appendix Table A.9, shows

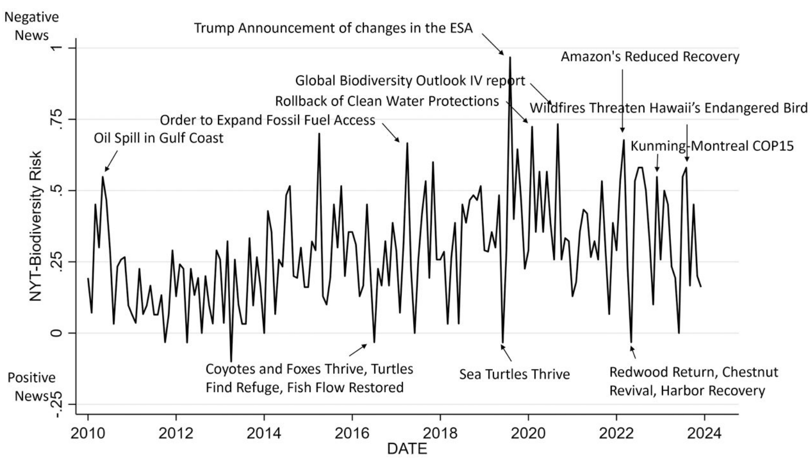

Figure 1. NYT-Biodiversity News Index.

Note: Monthly NYT-Biodiversity News Index from 2010 to 2023, annotated with biodiversity-relevant news announcements. ESA: Endangered Species Act. Higher values correspond to more negative news.

an average precision (the probability that a human classifier agrees with a classification made by the machine) of 81.42 percent and recall (the probability that the machine classifier agrees with the classification made by the human classifier) of 73.83 percent. We report misclassification examples in Supplementary Appendix Table A.10. Supplementary Appendix Table A.11 shows the 100 sentences for which we compared the machine classification to the human classification, which can provide a sense of the ambiguities involved in the classification. Reassuringly, while there are several examples in which human classification and machine classification disagree on whether a sentence is negative or neutral (or positive or neutral), there are no examples where a sentence with a negative classification by one party is assigned a positive classification by the other party.

2.3 Biodiversity risk versus climate risk

As discussed above, climate risk and biodiversity risk are related but distinct concepts. In this section, we explore the relationship between the two risks quantitatively, by comparing our biodiversity risk series with a corresponding climate risk series.

To do this, we first build a new climate news series, the NYT-Climate News Index, by applying the methodology described in Section 1.2, identifying climate-related sentences with the terms "climate change" and "global warming." As alternatives to our own climate news series, we also consider four of Faccini, Matin, and Skiadopoulos's (2023) climate news indices: international climate summits, global warming, natural disasters, and the climate policy index. These indices are designed to capture news about the respective topics, which correspond to different aspects of climate risk. These measures, which cover news about both physical and transition climate risks, are available at a daily frequency between January 2000 and June 2023. We aggregate them to the monthly frequency by taking the average of the daily series.

Table 2 shows the pairwise correlation across these various news indices using monthly data from 2010 to 2023. The first column is the NYT-Biodiversity News Index, the next column is the NYT-Climate News Index and the last four columns are the Faccini, Matin, and Skiadopoulos (2023) indices. The correlation between the biodiversity news index and the five climate news indices ranges between −0.11 and 0.43. These results suggest that while climate risk and biodiversity news are related to some extent, they are not the same.

Figure 2 illustrates the differences between the biodiversity and climate news series. The solid black line and black annotations correspond to the NYT-Biodiversity News Index and related biodiversity risk events, while the dotted gray line and gray annotations

Table 2. Correlation across measures of aggregate risk.

Pairwise monthly correlation across biodiversity and climate risk measures. NYT-Biodiversity News and NYT-Climate News use data from January 2010 to December 2023, while Faccini, Matin, and Skiadopoulos (2023) indices span from January 2010 to June 2023.

	(1)	(2)	(3)	(4)	(5)	(6)
Biodiversity risk measures						
(1) NYT-Biodiversity News	1.00					
Climate risk measures						
(2) NYT-Climate News	0.43	1.00				
(3) Faccini, Matin, and Skiadopoulos (2023): international summit	−0.11	−0.14	1.00			
(4) Faccini, Matin, and Skiadopoulos (2023): global warming	0.10	0.51	0.21	1.00		
(5) Faccini, Matin, and Skiadopoulos (2023): natural disaster	0.21	0.64	−0.06	0.41	1.00	
(6) Faccini, Matin, and Skiadopoulos (2023): climate policy	0.20	0.50	0.11	0.76	0.41	1.00

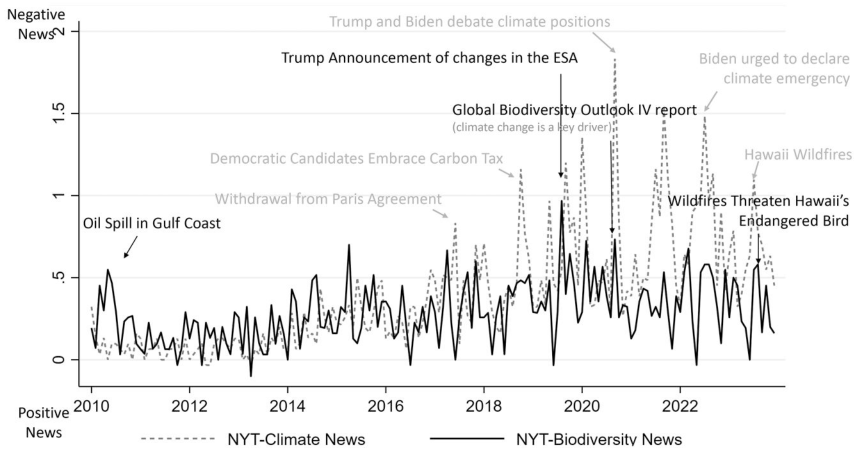

Figure 2. NYT-Biodiversity News versus NYT-Climate News.

correspond to the NYT-Climate News Index. Note that both series are generated with the same method and are based on the same data: articles published in the NYT; they differ only in the keywords used to select the articles.

Months with negative biodiversity-related news do not necessarily correspond to months with negative climate news. For example, in August 2019, the Trump administration announced that it would change the way the ESA was applied, making it easier to remove a species from the endangered list and weakening protections for threatened species. This led to substantial negative newspaper coverage of biodiversity-related topics, and thus a sharp increase in the NYT-Biodiversity News Index, while the NYT-Climate News Index remained relatively stable. Similar events include the 2010 Gulf Coast oil spill, which increased risks to various ecosystems. Conversely, climate-related events, such as the withdrawal from the Paris Agreement and discussion of carbon taxes, did not result in spikes in the biodiversity news index. Finally, some natural disasters were followed by both negative climate and negative biodiversity news: for example, the 2023 Hawaii Wildfires were connected to climate change but also caused habitat and species loss. Similarly, the release of the Global Biodiversity Outlook report, which highlighted climate change as a driver of biodiversity loss, resulted in spikes in both climate change and biodiversity news.

3. Measuring biodiversity risk exposures

Beyond quantifying aggregate biodiversity risk, we are also interested in exploring how biodiversity risk exposures vary across different firms and industries. For instance, the World Economic Forum (2020) states that the three sectors most reliant on natural capital are construction, agriculture, and food & beverages. Based on this assessment, firms in those sectors would be most substantially exposed to physical biodiversity risks. Similarly, sectors with substantial land use, such as the energy sector, might be particularly impacted by biodiversity transition risks. To improve our understanding of the effects of biodiversity risk on the economy, we need a systematic way to quantify these cross-sectional risk exposures.

A number of data vendors provide measures of firms' physical and transition *climate* risk exposures, though there are substantial questions about the quality of these measures (see, e.g., Billio et al. 2021). Similar data for firms' biodiversity risk exposures are not broadly available, and standardized disclosure frameworks for biodiversity risk are still under development (Taskforce on Nature-related Financial Disclosures 2025).[9]

In this section, we therefore propose and compare several new ways to measure firms' biodiversity risk exposures, using different data sources: (1) firms' 10-K statements; (2) the opinions elicited in our survey of financial professionals, academics, and regulators; (3) the portfolio holdings of funds focused on biodiversity; and (4) firms' responses to the CDP Climate Change Questionnaire, which recently added a module focused on biodiversity risks. The first measure is available at the firm level, while the others are only available at the industry level. We publicly release our measures of biodiversity risk exposure at www.biodiversityrisk.org. In additional analyses in the Supplementary Appendix, we report results from an attempt to distinguish between transition risk and physical risk by exploiting recent large language models (GPT-4.0) to parse the text of the NYT as well as that of the 10-K statements.

3.1 Measures of biodiversity risk exposure of firms and industries

3.1.1 10K-Biodiversity-Count Score

Our first firm-level measure of biodiversity risk exposure is based on textual analysis of firms' 10-K statements.[10] We identify biodiversity-related sentences in 10-K statements using regular expression searches for the same biodiversity dictionary used to construct the NYT-Biodiversity News Index, again excluding sentences with unrelated terms. If a 10-K statement contains at least two sentences related to biodiversity, we assign a 10K-Biodiversity-Count Score of "1" to this company in that year; if there is no mention of biodiversity-related terms, we assign a score of "0." We find that about 4.2 percent of all 10-K statements mention biodiversity between 2015 and 2023. The following are two examples of biodiversity-related sentences from 10-K statements, the first referencing transition risk exposures, and the second referencing physical risk exposures.

> In addition, future regulation of, or litigation concerning, the use of timberlands, the protection of endangered species, the promotion of forest biodiversity, and the response to and prevention of wildfires, as well as litigation, campaigns, or other measures advanced by environmental activist groups, could also reduce the availability of the raw materials required for our operations. [Enviva Partners LP, 2017 10-K filing]
>
> If this infrastructure were to become damaged due to natural or other disasters such as the oil spill that resulted from the Deepwater Horizon incident in 2010, then it is possible that environmental damages to the area and ecosystem could result. If these environmental damages occurred, they could have a material adverse effect on the Company's business, results of operation, and financial condition. [Omega Protein, 2015 10-K filing]

[9] Some data providers have begun to offer tools for biodiversity impact assessments, as summarized by Finance for Biodiversity Foundation. Examples include the Biodiversity Footprint for Financial Institutions (BFFI), the Biodiversity Impact Analytics powered by the Global Biodiversity Score (BIA-GBS), the Corporate Biodiversity Footprint (CBF), the Global Biodiversity Score for Financial Institutions (GBSFI), and the Global Impact Database (GID), the Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) database, and the Integrated Biodiversity Assessment Tool (IBAT).

[10] A 10-K statement is a comprehensive report filed annually by publicly listed companies with the U.S. Securities and Exchange Commission (SEC). It provides a detailed overview of a company's performance, including both structured financial metrics and unstructured textual information, such as management's discussion and analysis, business overview, and risk factors. We collect firms' 10-K statements from 2001 to 2023 through the SEC's EDGAR database.

3.1.2 10K-Biodiversity-Negative Score

The 10K-Biodiversity-Count Score combines mentions of biodiversity as both a risk and an opportunity for firms. To separate such mentions, we construct a second measure of biodiversity risk exposure, the 10K-Biodiversity-Negative Score, based on sentiment analysis of the 10-K sentences mentioning biodiversity-related terms. Specifically, we use the BERT model to classify each biodiversity-related sentence into positive, neutral, and negative sentiments. The two previous 10-K excerpts are assessed to have a negative sentiment by BERT; the following are two examples of a biodiversity-related 10-K mention that received a positive sentiment classification from BERT (Supplementary Appendix Table A.8 presents further examples).

> We believe that the growth of hemp could significantly reduce deforestation by providing the same products that trees are able to supply. [Celexus Inc, 2019 10-K filing]
> The Company follows Sustainable Forestry Initiative ("SFI") Standards that promote sustainable forest management in North America through the use of core principles, objectives, performance measures and indicators to protect water quality, biodiversity, wildlife habitat, species at risk, and forests which have exceptional conservation value. [Deltic Timber Corp, 2017 10-K filing]

About 5.4 percent of biodiversity-related sentences are classified as positive, 19.4 percent as negative, and the remaining as neutral. For each firm-year, we count the number of positive and negative sentences and compute the firm's 10K-Biodiversity-Negative Score as the number of negative biodiversity sentences minus the number of positive sentences (firms that do not mention biodiversity-related topics in their 10-K statement and firms that only include neutral sentences are assigned a score of 0). Between 2015 and 2023, among 10-K statements mentioning biodiversity-related issues, 27.6 percent do so in a predominantly negative way and 5.6 percent in a predominantly positive way.

3.1.3 10K-Biodiversity-Regulation Score

When firms mention biodiversity in their 10-K statements, some explicitly express their concerns about the biodiversity risks stemming from stricter regulations. To directly measure these regulation-related biodiversity risks faced by firms, we construct a third 10-K-based measure that selects biodiversity risk sentences that also contain at least one of the following terms: "law(s)," "regulation," "Act," "ESA," "discharge," or "restriction." Supplementary Appendix Table A.8 shows several examples of such sentences. We assign a 10K-Biodiversity-Regulation Score of "1" if the 10-K statement of a company contains at least two biodiversity risk sentences and at least one of them is a biodiversity regulation risk sentence. Between 2015 and 2023, about 3.2 percent of all 10-K reports (and 75.5 percent of all 10-K reports discussing biodiversity) discuss biodiversity-related regulation risks.

Just as we did for the NYT classification, we validate the machine classification of the 10-K statements. To do this, we manually classify one hundred randomly chosen biodiversity-related sentences from the 10-K filings, and assess sentiment classification (10K-Negative Score) and policy relevance (10K-Regulation Score). The confusion matrices in Panels B and C of Supplementary Appendix Table A.9 show an average precision of 83.61 percent and recall of 78.6 percent, with misclassification examples in Supplementary Appendix Table A.10. As before, there are no examples where one classifier assigns it a label of negative sentiment and the other a positive sentiment.

3.1.4 Survey-Based measures of biodiversity risk exposures

We construct another measure of biodiversity risk exposures—this time at the industry level—based on responses received in our survey of finance academics, professionals, and regulators. The survey asked participants to select the industries that they believe to be most negatively affected by (1) physical risks arising from biodiversity loss, and (2) biodiversity-related transition risks (see Supplementary Appendix Figure A.4). We provided fifteen possible industry options to choose from, created by combining several of the twenty-four 4-digit GICS industries.[11] We quantify an industry's physical and transition biodiversity risk exposure as the share of survey respondents who select each industry as being particularly affected by the risk.

3.1.5 Holding-based measure of biodiversity risk exposures

In response to growing concerns about the economic effects of biodiversity loss, some asset managers have introduced investment vehicles designed to help investors mitigate biodiversity risks in their portfolios. Our next approach to measuring biodiversity risk exposures builds on information about the holdings of these funds. To construct the holding-based biodiversity score, we explore five biodiversity-related funds: HSBC World ESG Biodiversity Screened Equity ETF, AXA IM ACT Biodiversity Equity ETF, Ossiam Food for Biodiversity ETF, Xtrackers World Biodiversity Focus SRI UCITS ETF, and Xtrackers USA Biodiversity Focus SRI UCITS ETF. These biodiversity ETFs were designed to hold companies that are acting positively for biodiversity by reducing or limiting the negative impact of human activities on biodiversity.

We obtain data on these funds' portfolio holdings from Bloomberg and focus on North American common stocks. We obtain prices from CRSP and GICS industry codes[12] from Compustat by merging the stocks on their CUSIP identifiers. We define the holding-based biodiversity score of fund f for industry I as:

$$HoldingScore^{I}_{t,f} = \frac{w_{I,t,M} - w_{I,t,f}}{w_{I,t,M}}, \tag{1}$$

where $w_{I,t,M}$ is the weight of industry I in the market portfolio at time t and $w_{I,t,f}$ is the weight of industry I in the fund's portfolio (i.e., based on the industry's market capitalization).[13] When a fund underweights an industry relative to the market, the score will be positive: we interpret this as the industry being negatively exposed to biodiversity risk in the sense that it should perform relatively poorly upon the realization of negative biodiversity news. We compute this score for each fund and then average across funds to get the industry-level holding-based score (the average pairwise correlation of $HoldingScore^{I}_{t,f}$ across the funds is 0.31). Since these ETFs were set up relatively recently, we only use data from December 2023.

3.1.6 CDP-based measure of biodiversity risk exposures

Our final measure of biodiversity risk exposure uses responses obtained from the CDP Climate Change Questionnaire. Questions related to biodiversity risk exposures have been included since 2022 and are shown in Supplementary Appendix Figure A.7. To quantify a firm's exposure to biodiversity risks, we assign a score of "1" if the firm has activities in or

[11] Specifically, Automobiles & Components (GICS code 2510), Consumer Durables & Apparel (GICS code 2520), and Household & Personal Products (GICS code 3030) are pooled into "Auto, Durables and Household Products." Consumer Services (GICS code 2530), Retailing (GICS code 2550), and Food & Staples Retailing (GICS code 3010) are pooled into "Consumer Services and Retailing." Banks (GICS code 4010) and Diversified Financials (GICS code 4020) are pooled into "Banks and Diversified Financials." Software & Services (GICS code 4510), Technology Hardware & Equipment (GICS code 4520), Semiconductors & Semiconductor Equipment (GICS code 4530), Telecommunication Services (GICS code 5010), and Media & Entertainment (GICS code 5020) are pooled into "IT and Communication Services."

[12] We used the GICS 2023 classification and did not adjust for any GICS changes.

[13] This measure does not differentiate between neutral and negatively exposed firms, as the biodiversity-focused funds we study are long-only. As a result, industries excluded from biodiversity funds—whether neutral or harmful—all receive the same weight $w_{I,t,f} = 0$, and the same HoldingScore of 1.

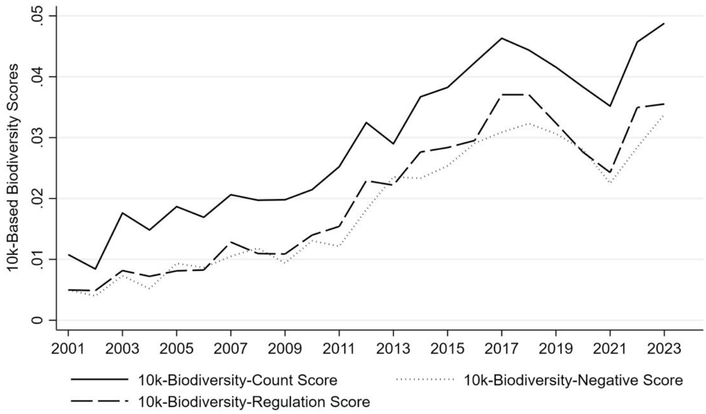

Figure 3. Proportion of biodiversity-related mentions in 10-K over time. *Note*: This figure shows the share of firms with non-zero biodiversity-related mentions in their 10-K statements from 2001 to 2023. The solid line indicates firms mentioning biodiversity (10K-Biodiversity-Count Score); the dotted line shows negative biodiversity sentiment (10K-Biodiversity-Negative Score); and the dashed line captures mentions to biodiversity-related regulation (10K-Biodiversity-Regulation Score). Shares are calculated by dividing the number of firms with non-zero scores by the total number of firms filing a 10-K each year.

near biodiversity-sensitive areas and the activity could negatively affect biodiversity; otherwise, we assign a score of "0." We focus on the responses of US firms. A total of 633 firms participated in the biodiversity module, with 4.9 percent of these firms having activities with negative impact located in or near biodiversity-sensitive areas. We aggregate the firm-level exposure measures to the industry level by calculating the value-weighted average of the firm-level scores.

3.2 Biodiversity risk exposures over time

While we can only construct the survey-, holdings-, and CDP-based measures of biodiversity risk exposures at one point in time, the availability of historical 10-K statements allows us to construct a time series of firms' self-reported exposures to biodiversity risks.

Figure 3 shows our three 10K-based biodiversity risk exposure measures between 2001 and 2023, averaged across all firms in each period. Across all firms, self-reported biodiversity risk exposures have generally been growing over time, from about 1 percent of firms mentioning biodiversity-related terms in the early 2000s, to a peak of almost 5 percent of firms in 2023. This increase is largely driven by a corresponding increase in the number of mentions of biodiversity regulation risks. Consistent with this, the sentiment with which firms discuss biodiversity-related issues has declined over time.

3.3 Biodiversity risk exposures across firms and industries

In this section, we compare biodiversity risk exposures across firms and industries. First, we examine the extent to which firm characteristics drive biodiversity risk exposure. To do this, we proxy for firm-level biodiversity exposure using the average of the three 10K-based measures and regress that measure on firm size (log assets) and market-to-book ratio:

$$\text{Biodiversity Exposure}_{i,t} = \alpha + \beta_i^{Size}\text{Size}_{i,t} + \beta_i^{MB}\text{MB}_{i,t} + \delta_t + \gamma_g + \varepsilon_{i,t}. \quad (2)$$

Table 3 shows the regression results. Biodiversity exposure is negatively associated with the market-to-book ratio, suggesting that growth firms face lower exposure than value firms. Larger firms also exhibit greater biodiversity risk. However, these characteristics explain only 1 percent of the variation in firm-level biodiversity risk exposures. Including

Table 3. Firms' characteristics and biodiversity exposure.
This table reports regressions of biodiversity exposure on firm characteristics. Biodiversity exposure is the average of 10K-Biodiversity-Count, 10K-Biodiversity-Negative, and 10K-Biodiversity-Regulation Scores. Regressions are estimated at the firm–year level. Standard errors are clustered at the firm level. *T*-statistics are in parentheses. Significance levels: ***$P<.01$; **$P<.05$; *$P<.1$.

	Biodiversity exposure		
	(1)	(2)	(3)
Log assets	0.005***	0.001	−0.001
	(4.66)	(1.32)	(−1.13)
Market to book	−0.002***	−0.000**	−0.001**
	(−5.73)	(−2.23)	(−2.21)
Year FE	No	No	Yes
Industry FE	No	Yes	Yes
N	49,184	49,184	49,184
R^2	0.01	0.12	0.13

industry fixed effects increases the R^2 by 11 percentage points. When including industry and year fixed effects, the relationship between size and biodiversity exposure disappears.

3.3.1 Comparison across different measures

Next, we compare the biodiversity risk exposures of different industries across our various measures. For this analysis, we aggregate the 10K-based firm-level exposure measures to the industry level by calculating the value-weighted average of the firm-level scores. Table 4 reports the cross-industry correlations of biodiversity exposures according to the different measures. We use 10-K statements from 2015 to 2023 to do the cross-sectional comparison. The table highlights that our industry-level measures of biodiversity risk exposures are substantially correlated: industries that are assessed to have high biodiversity risk exposures on one measure also have high exposures using the other measures.

Panel (a) of figure 4 shows the biodiversity risk exposures of different industries. To construct this figure, we first rank each industry from least exposed (rank = 1) to most exposed (rank = 24) on each of our measures, and then average the ranks across our measures.[14] The sectors with the highest average biodiversity risk exposures are Energy, Utilities, Real Estate, Food, Beverage & Tobacco, and Pharmaceutical, Biotechnology & Life Sciences. This ranking aligns with economic intuition, as these highly ranked sectors are all directly dependent on natural resources.[15] On the other hand, firms in the Communication Services, Software, and Technology sectors—firms which have minimal direct interaction with natural ecosystems—appear the least exposed to biodiversity risks.

[14] Appendix Figures A.6 shows the industry-level exposure measures separately for each of our measures. Appendix Table A.12 reports the industry rankings for each measure. The industries are sorted by their average ranking across the seven measures, excluding the "Survey: Average" score. Industries at the top are most exposed to biodiversity risk, while those at the bottom have the lowest exposure to biodiversity risk.

[15] This pattern is consistent with Nature Action 100's sectoral impact assessments (Finance for Biodiversity Foundation 2023), which use footprinting tools to identify industries with the greatest biodiversity impact. Their rankings place Food, Beverage & Tobacco, Materials, Energy, Capital Goods, Retailing, Utilities, and Pharmaceuticals in the top seven riskiest industries. The high exposure of Energy and Utilities in particular reflects well-documented biodiversity risks from fossil fuel extraction and infrastructure projects. The Deepwater Horizon oil spill, for example, caused lasting ecological damage, while hydropower projects like Brazil's Belo Monte Dam have disrupted aquatic habitats. Pharmaceuticals rely on biodiversity for drug discovery, as seen in the near-extinction of the Pacific Yew tree, which threatened the supply of paclitaxel (Taxol), a key cancer drug. In the Food, Beverage & Tobacco sector, pollinator declines have already reduced yields for crops like coffee, cocoa, and almonds, highlighting the sector's dependence on ecosystem stability. These examples illustrate the strong link between industry activities and biodiversity risk exposure that are consistent with our more systematic assessments of industry-level exposures.

Table 4. Industry-level correlations of biodiversity scores.

Note: Industry-level Pearson correlations of 10K-based, Survey-based, Holding-based, CDP-based Biodiversity Scores, and Quantity-based Climate Exposure Score. The 10K-based Biodiversity Scores are averaged from 2015 to 2023. Survey-based Scores are from Q1 2023. Holding-based Score is from Q4 2023. CDP-based Score uses data from 2023. The Quantity-based Climate Exposure Score is estimated with data from 2010 to 2019 inclusive, and is taken from Alekseev et al. (2024).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10k-based scores									
(1) 10k: Negative	1.00								
(2) 10k: Count	0.70	1.00							
(3) 10k: Regulation	0.80	0.96	1.00						
Survey-based scores									
(4) Survey: Transit.	0.53	0.42	0.42	1.00					
(5) Survey: Physical	0.26	0.20	0.18	0.82	1.00				
(6) Survey: Average	0.41	0.32	0.31	0.95	0.96	1.00			
Holding-based scores									
(7) Holding	0.39	0.03	0.22	0.27	0.08	0.18	1.00		
CDP-based scores									
(8) CDP-based	0.89	0.87	0.91	0.58	0.30	0.46	0.29	1.00	
Climate exposure scores									
(9) Quantity-based	0.05	0.01	0.05	−0.15	0.16	0.01	−0.01	−0.10	1.00

Panel (b) of figure 4 separately shows physical and transition risk exposures across industries as elicited in our survey.[16] Our survey participants perceive distinct heterogeneities among industries in terms of their biodiversity risk exposures: industries that are perceived to be exposed to physical biodiversity risks are not necessarily the same as industries that are perceived to be exposed to transition biodiversity risks, though the two measures are substantially correlated. For example, our respondents perceive the "Food, Beverage & Tobacco" sector to be most exposed to physical biodiversity risks, and the "Energy" sector most exposed to transition biodiversity risks.

To better understand the observed variation in biodiversity risk exposures across industries, we next consider the top industries in terms of average risk exposures and discuss the ways in which biodiversity risks affect those industries. To help with these interpretations, Supplementary Appendix Figure A.8 provides word clouds with the terms that are most frequently mentioned in biodiversity-related sentences extracted from 10-K statements for each industry, with term sizes proportional to their frequency.[17] Supplementary Appendix Figure A.9 shows the biodiversity risk exposure disaggregated to 6-digit GICS industry codes. Supplementary Appendix A.4.4 provides further discussion on how biodiversity risks impact industries with high exposure, including materials and real estate sectors.

3.3.2 Energy sector

Our survey respondents assessed firms in the energy sector to have the highest biodiversity transition risk due to the potential impact of energy firms' operations on biodiversity. For instance, oil spills and habitat destruction during drilling activities can lead to the loss of species and ecosystems, and entail substantial reputational and legal risks. The industry

[16] Appendix Table A.13 shows the correlations of average industry rankings across different groups of survey respondents. The rankings are similar across subgroups, with the correlation ranging from 0.82 to 0.99. For example, the pairwise correlations between industry rankings reported by academics, private-sector employees, and public-sector employees are above 0.95.

[17] To plot the word cloud, we extract biodiversity sentences using the same Biodiversity Dictionary for companies within each sector and aggregate these sentences into a "Biodiversity Vocabulary," which amounts to the list of unique terms and the associated frequency with which each term appears.

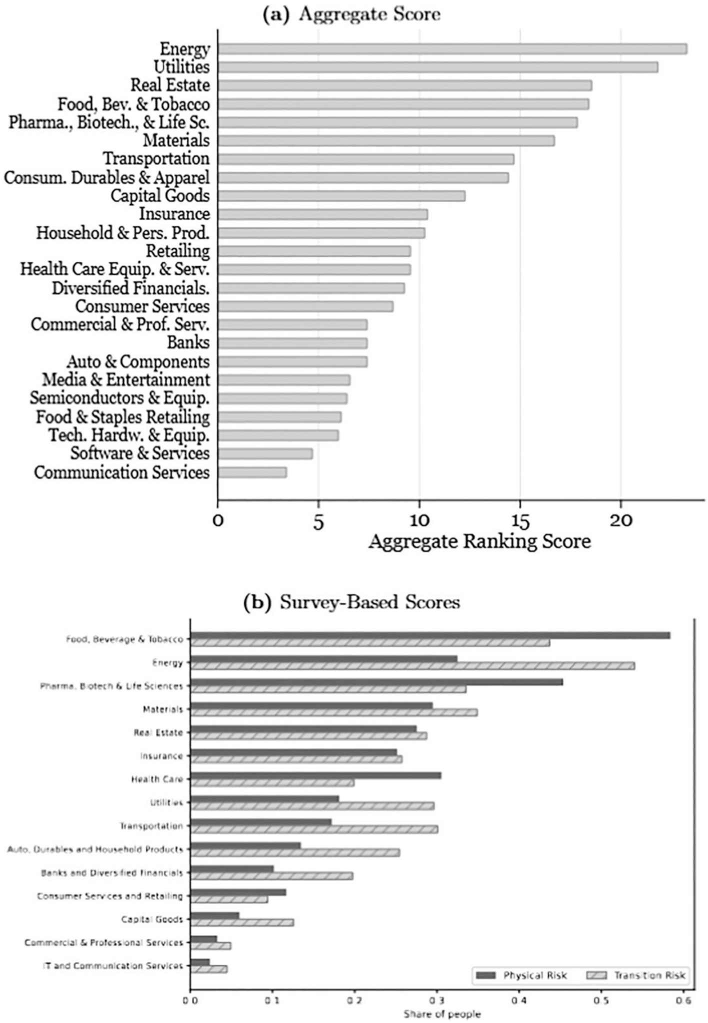

Figure 4. Industry-level biodiversity risk exposure. *Note*: Panel (a) shows the average industry exposure ranking based on the simple average of all biodiversity risk measures. The 10K-based Biodiversity Scores are averaged from 2015 to 2023. Survey-based Scores are from Q1 2023. Holding-based Score is from Q4 2023. CDP-based Score uses data from 2023. Panel (b) presents physical and transition risk exposures measured by survey responses. The blue bars represent survey-based physical risk, while the red bars indicate survey-based transition risk. Industries are sorted by the average of these two survey-based measures.

also faces regulatory risks, as governments introduce stricter environmental regulations and guidelines to prevent further biodiversity loss. Examples of firms in the energy sector describing such biodiversity risk exposures in their 10-K statements include:

> If one of our LNG terminals or pipelines may adversely affect a protected species or its habitat, we may be required to develop and follow a plan to avoid those impacts. [Cheniere Energy Inc, 2024 10-K filing]

> A critical habitat designation could result in further material restrictions on federal land use or on private land use and could delay or prohibit land access or development. [Earthstone Energy Inc, 2019 10-K filing]

3.3.3 Utilities

Firms in the utilities sector are affected by both physical and transition biodiversity risks. Physical risks matter, for example, when the degradation of watersheds affects water quality and availability, which in turn impacts water utilities. On the transition risk side, regulations and laws on species and habitat protection may limit utility firms' operations. In addition, regulations on waste discharges, such as the Clean Water Act, elevate utility firms' costs, especially those in water utilities.

Interestingly, firms producing renewable electricity—often viewed as beneficiaries of the climate transition—have among the most negative biodiversity risk exposures within the utilities sector (Supplementary Appendix Figure A.9). This reflects the land-intensive nature of constructing wind and solar power facilities, which makes them subject to stringent land-use regulations aimed at protecting biodiversity. Additional regulations affect specific renewable sources: hydropower development is constrained by rules protecting fish populations, while wind projects face restrictions related to the unintentional killing of migratory birds.

> Our ability to meet the existing and future water demands of our customers depends on an adequate supply of water. Drought, governmental restrictions, overuse of sources of water, the protection of threatened species or habitats or other factors may limit the availability of ground and surface water. [American Water Works Company Inc, 2015 10-K filing]
> The Company is also subject to laws regarding the protection of wildlife, including migratory birds, eagles, threatened and endangered species. Federal and state environmental laws have historically become more stringent over time, although this trend could change in the future. [Clearway Energy Inc, 2022 10-K filing]

3.3.4 Real estate

The real estate industry is exposed to various biodiversity risks. For example, developments in areas with high biodiversity might face restrictions or require mitigation measures to minimize habitat destruction, adding costs and delays to projects.

> The sale or development of properties may also be restricted due to environmental concerns, the protection of endangered species, or the protection of wetlands. [St Joe Co, 2002 10-K filing]

3.3.5 Food, beverage, and tobacco

The food industry faces significant physical biodiversity risks due to its dependence on biodiversity for essential raw materials.

> Physical risks include the increasing frequency of extreme weather events and natural disasters and effects on water availability and quality and biodiversity loss. These impacts increase risks to the global food production and distribution system and to the safety and resilience of the communities where we live, work and source our ingredients, and could further decrease food security for communities around the world. [Mondelez International Inc, 2022 10-K filing]

> Climate change, agricultural and other factors, such as wildfires, disease, pests, extreme weather conditions, water scarcity, biodiversity loss and competing land use, impact the quality and quantity of grapes available to us for the production of wine from year to year. Our vineyards and properties, as well as other sources from which we purchase grapes, are affected by these factors. [Vintage Wine Estates, 2023 10-K filing]

3.3.6 Pharma and biotech

The Pharmaceuticals, Biotechnology & Life Sciences sector is exposed to substantial physical biodiversity risks. For example, in the last 40 years, about 60 percent of all new chemical entities in the field of antibacterials were based on or derived from natural products (Newman and Cragg 2020). Biotechnology companies establish natural product libraries of microorganisms retrieved from soil, plant, and marine sources for drug discovery. Biodiversity loss therefore reduces potential pharmaceutical development options.

> Other potential physical impacts due to climate change include reduced access to high-quality water in certain regions and the loss of biodiversity, which could impact future product development. These risks could disrupt our operations and its supply chain, which may result in increased costs. [Iovance Biotherapeutics Inc, 2022 10-K filing]
>
> We focus on the use of biodiversity as a means of natural product drug discovery, while also using traditional chemical discovery and development techniques. [Cubist Pharmaceuticals Inc, 2000 10-K]

3.4 Climate risk exposures versus biodiversity risk exposures

Just as aggregate biodiversity news is distinct from aggregate climate news (see Section 1.3), firm- and industry-level exposures to biodiversity risk are distinct from climate risk exposures. The bottom row of Table 4 shows that our measures of biodiversity risk exposure at the industry level are essentially unrelated to the "quantity-based climate exposure" measure developed in Alekseev et al. (2024). This measure identifies industries that investors buy and sell in response to changes in their beliefs about climate change, and Alekseev et al. (2024) show that long-short portfolios based on this exposure characteristic have the ability to hedge news about climate risks. Figure 5 shows a corresponding scatter plot, where biodiversity risk exposure is measured by the average ranking across our seven biodiversity risk measures, excluding the "Survey: Average" score. A higher ranking indicates higher risk.

Industries with high biodiversity risk exposures are broadly distinct from industries with high climate risk exposures. There are several reasons for this. First, an industry may be highly exposed to biodiversity risk because its operations are dependent on particular ecosystems or species that are not necessarily affected by climate change. Second, from a regulatory perspective, some industries might have a more significant direct impact on ecosystems and habitats rather than contributing to climate change. As a result, they would be more affected by biodiversity regulation than climate regulation. For example, as described above, biodiversity regulation provides challenges for renewable energy firms, while climate regulation provides many opportunities.

4. The pricing of biodiversity risk

A recent body of research in economics and finance has documented that starting around 2010, various measures of firm-level exposures to climate risk have been priced in asset markets (e.g., Bolton and Kacperczyk 2023; Engle et al. 2020; Alekseev et al. 2024; Acharya et al. 2022). In this section, we explore whether biodiversity risk—a category of

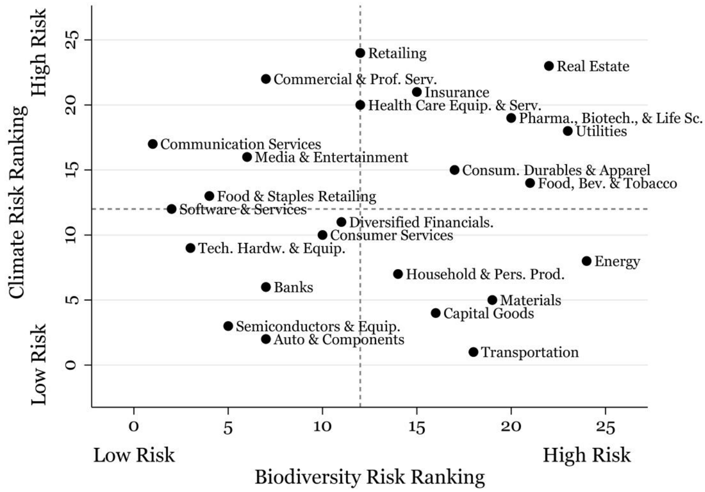

Figure 5. Industry ranking by biodiversity risk and climate risk. *Note*: Scatterplot of industry biodiversity risk ranking and climate risk ranking. The biodiversity risk exposure is measured by the average ranking across the seven biodiversity risks, excluding the "Survey: Average" score, and the climate risk exposure is measured by climate quantity betas estimated based on pooled data from 2010 to 2019 inclusive, and is taken from Alekseev et al. (2024).

risk that has also attracted the attention of market participants in recent years—appears to affect prices in equity markets. To do this, we combine our quantitative measures of aggregate news about biodiversity risk with our industry-level measures of biodiversity risk exposures.

4.1 Empirical approach

We begin by forming portfolios of industries sorted by their biodiversity risk exposures[18]. If biodiversity risk is priced—and if our measures of exposure to this risk are correct—we would expect the price of these portfolios to move with the arrival of (aggregate) news about or attention to biodiversity risks. For example, when negative biodiversity news arrives (or when attention to this type of risk increases), the valuations of highly exposed industries should drop, while the valuations of less exposed industries should drop by less (or even increase). Put differently, if biodiversity risks are priced, we should expect the return to a biodiversity risk-sorted portfolio to covary with the aggregate biodiversity risk news series: it should behave like a *hedge portfolio*.[19]

To implement our test, we measure innovations in biodiversity news, $BiodiversityNews_t$, by averaging the daily values of our aggregate NYT-Biodiversity News Index within each month and computing values of $BiodiversityNews_t$ as residuals from a monthly AR(1) model. We then construct portfolios that go long firms with low biodiversity risk exposures—that is, firms that are not affected or might even benefit from realizations of biodiversity risks—and short firms with high biodiversity risk exposures, those firms negatively affected by biodiversity risk realizations.[20] We construct eight such portfolios using the

[18] We obtain stock-level data from CRSP and Compustat, focusing on North American common stocks (share codes 10 and 11; exchange codes 1, 2, and 3). We exclude stocks priced below $5 and the bottom 20 percent by market cap at each date. GICS industry codes are merged from Compustat using CUSIP identifiers.

[19] Note that researchers sometimes refer to the presence of risk premia when asking whether a risk is "priced." That language refers to the compensation for risk required by investors, which has as a necessary (but not sufficient) condition that prices of exposed firms move with risk realizations. We focus on the latter pattern because estimating risk premia would require a much longer time series.

[20] Since all exposure measures were designed such that higher values are associated with higher biodiversity risk exposures, the portfolios would go long industries with low scores and short industries with high scores.

three 10K-based biodiversity scores, the three survey-based scores, the fund holding-based score, and the CDP-based score. We construct all portfolios using exposure measures at the industry level, aggregating the firm-level 10K-based scores to the industry level by taking the value-weighted average of the firm-level values.

To determine the portfolio weight of each industry, we take two approaches. In our main rankings-based approach, the portfolio's position in each industry is the industry's biodiversity score percentile in the industry distribution, −50. For example, the portfolios take a long position of 50 in the industry with the lowest biodiversity score and short a position of −50 in the industry with the highest biodiversity score.[21] We show that our findings are robust to a second approach that holds positions in each industry as the cross-sectionally demeaned biodiversity scores in that year, taking long positions for industries with below-average scores (and risk exposures), and short positions for industries with above-average scores. In each period, we compute excess returns of each portfolio by subtracting the risk-free rate from the value-weighted industry returns.

Figure 6 reports monthly correlations between the various portfolios' excess returns and innovations of the NYT-Biodiversity News index using data from 2010 to 2023.[22] We include individual rank-based portfolios for our various industry exposure measures, a portfolio that averages the industry rank across different exposure measures before forming portfolios, and a portfolio averaging the three time-varying 10-K–based industry ranks. We also include a portfolio that uses the average values of the alternative approach to creating industry weights described in the previous paragraph. We focus on the period after 2010, since we do not expect markets to price biodiversity risk before that time (see the discussion in Alekseev et al. 2024; Acharya et al. 2022). All correlations are positive, with magnitudes from around 0.07 to 0.22. The left column in Table 5 reports these correlations together with bootstrapped standard errors. It highlights that, despite substantial noise in both stock prices and our measures of biodiversity risk and risk exposures, most of these correlations are statistically significant. The largest correlation is achieved by the portfolio sorted on the average across our various biodiversity risk exposure rankings. Quantitatively, the observed correlations are comparable to those obtained by climate hedging portfolios when evaluated against aggregate climate news (Engle et al. 2020; Alekseev et al. 2024), and to the hedging performance of portfolios built to hedge other macro risks such as consumption or GDP (see Giglio and Xiu 2021).

A natural question is whether our measures of biodiversity risk exposure are simply recasting information from other firm characteristics beyond size and value, which we already explored above. To study this, we investigate whether using other characteristics would yield similarly good hedging portfolios for aggregate biodiversity news as the ones based on our measures of biodiversity risk exposure.

In comparing our measures of exposures with other characteristics, one important consideration is that, in general, we do not have a clear prior on whether the various characteristics should be associated with a high or low exposure to biodiversity risk. For example, we do not know ex-ante if a portfolio that goes long value companies and short growth companies (HML) should covary positively or negatively with biodiversity risk. Building a hedging portfolio using alternative characteristics therefore requires estimating the sign of the relationship between the biodiversity news and the characteristic—the biodiversity beta—using a mimicking portfolio approach (as in Engle et al. 2020; Alekseev et al. 2024).

21 When ranking the industries, equal observations are assigned the same rank, calculated as 1 plus the number of values lower than those equal observations.

22 The 10-K–based portfolios are rebalanced annually using the prior year's filing to avoid look-ahead bias. In contrast, the survey-, holdings-, and CDP-based biodiversity scores are constructed at a single point in time, and the portfolio weights derived from these scores remain fixed throughout the analysis. Correlations between the biodiversity hedge portfolios and biodiversity innovations are estimated over the full sample period from 2010 to 2023 using these fixed portfolio weights. Since the weights do not reflect contemporaneous risk exposure, these correlations are weaker than those of the 10-K–based portfolios.

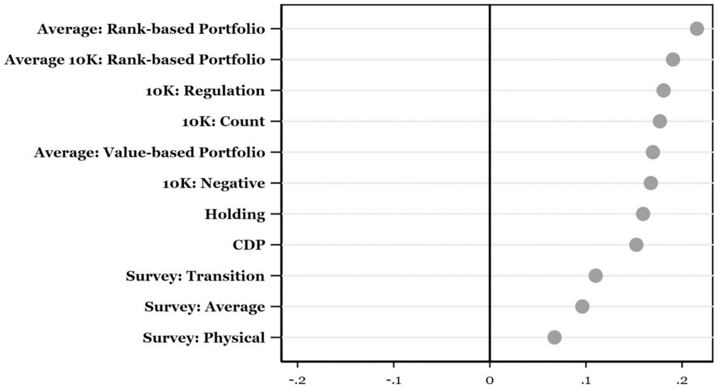

Figure 6. Biodiversity hedge performance of various portfolios. *Note*: Dot plot of monthly return correlations for various biodiversity hedge portfolios with AR(1) innovations of NYT-Biodiversity News Index using data from 2010 to 2023.

Table 5. Biodiversity and climate hedge performance of various portfolios.
Monthly *correlations* for various biodiversity hedge portfolios' returns with biodiversity and climate news series AR(1) innovations using data from 2010 to 2023. Each row represents a hedge portfolio, whereas each column corresponds to a hedge target. The last row shows the simple average of correlations with hedge targets for all portfolios. All news series are coded such that high numbers indicate negative news. Therefore, positive correlation coefficients indicate successful hedges. *P*-values are calculated using a bootstrap of 1,000 iterations. Bootstrapped standard errors are in parentheses. Significance levels: $^{***}P<.01$; $^{**}P<.05$; $^{*}P<.1$.

	Hedge target	
	NYT-Biodiversity News	**NYT-Climate News**
Average: rank-based portfolio	0.22^{***}	0.03
	(0.08)	(0.10)
10K: regulation	0.18^{**}	0.09
	(0.08)	(0.08)
10K: count	0.18^{**}	0.13^{*}
	(0.07)	(0.07)
Average: value-based portfolio	0.17^{**}	0.06
	(0.08)	(0.09)
10K: negative	0.17^{**}	0.09
	(0.07)	(0.08)
Holding	0.16^{**}	0.04
	(0.07)	(0.09)
CDP	0.15^{*}	0.08
	(0.08)	(0.09)
Survey: transition	0.11	−0.02
	(0.07)	(0.09)
Survey: average	0.10	−0.03
	(0.07)	(0.09)
Survey: physical	0.07	−0.02
	(0.07)	(0.08)
Average	0.15^{***}	0.05
	(0.05)	(0.06)

The mimicking portfolio approach uses historical data to combine a set of assets into a portfolio that is maximally correlated with a given biodiversity shock. To obtain the mimicking portfolios, we estimate the following regression:

$$BiodiversityNews_t = wR_t + \varepsilon_{c,t}, \quad (3)$$

where $BiodiversityNews_t$ denotes the (mean zero) biodiversity hedge target in month t, w is a vector of N portfolio weights, and R_t is a vector of demeaned excess returns. The portfolio weights are estimated each month using a five-year rolling window.[23] When the vector R_t contains one characteristic-sorted return only (e.g., HML), the weight w represents the relation between that characteristic and the biodiversity beta. For example, if we build a hedging portfolio using HML and estimate $w > 0$, then we expect value stocks to hedge biodiversity risk going forward; if $w < 0$, we expect growth stocks to hedge this risk.

Panel (a) of figure 7 shows a histogram of the out-of-sample correlations of mimicking portfolios built using the 212 characteristics obtained from Chen and Zimmermann (2022) individually. The red bar represents the "Average: Rank-based Portfolio." Of course, there is a large amount of sampling variation, so among the many mimicking portfolios, some correlate more and some less with biodiversity news; but none performs as well as our economically motivated measure.[24]

Panel (b) of figure 7 shows the monthly out-of-sample return correlations for the portfolios built using the average biodiversity risk measure, and four mimicking portfolios built with the Fama-French Three Factors (Market, SMB, and HML), the Fama-French Five Factors (Market, SMB, HML, RMW, and CMA), and with all 212 characteristics and all 24 industries, each selected by LASSO to avoid over-fitting.[25] The portfolio built on the average biodiversity exposure measure has by far the highest correlation with innovations in the NYT-Biodiversity News Index.[26]

Overall, we find that the returns of portfolios sorted on various measures of biodiversity risk exposure covary positively with realizations of biodiversity news. These correlations are generally statistically significant and larger than correlations achievable using alternative characteristics. These findings suggest that our measures of both risk and exposure are reasonable, and that biodiversity risks are already reflected in equity valuations.

4.2 Hedging biodiversity risk versus climate risk

To further explore the similarities and differences between climate and biodiversity risk, we also compute the monthly correlations between the returns of the biodiversity risk hedge portfolios and climate risk realizations. Specifically, column 2 of Table 5 reports the correlations between the various biodiversity hedge portfolio returns and innovations in

[23] Appendix Figure A.10 presents the portfolio weights of mimicking portfolios, constructed using Fama-French factors and twenty-four industry returns, estimated with OLS on the full sample. The results show almost no significant factor loadings.

[24] In Appendix A.4.3 we statistically compare the hedging performance of our biodiversity exposure measures, which are motivated a priori, with that of the 212 stock characteristics. The test explicitly takes into account the multiple testing problem associated with the 212 characteristics, which are not economically motivated—i.e., the fact that among the "characteristics zoo," we would expect some to be correlated with biodiversity risk well just by chance. To adjust for multiple testing, we use the method of Benjamini and Hochberg (1995). We find that the decent hedging performance of some of the 212 characteristics is indeed due to chance: none of them is significant after adjusting for the multiple testing problem.

[25] When the Lasso model fails to produce a prediction, for example, due to over-penalization or insufficient data, we impute the predicted value as zero, consistent with the model's behavior when it selects no features.

[26] Appendix Figure A.11 shows the hedge performance of a mimicking portfolio that includes Fama–French factors in addition to our biodiversity-risk-sorted portfolios. When needing to estimate the loading on these biodiversity-risk-sorted portfolios (and the Fama–French factors), the out-of-sample hedging performance declines significantly. Table 3 indicates that larger firms and those with higher market-to-book ratios face greater biodiversity risk, though this relationship was quite weak. Based on this prior, we also construct portfolios long in small, low market-to-book firms and short in their counterparts. Their near-zero or negative correlations with biodiversity risk (Appendix Figure A.11) suggest that biodiversity risk is not simply a proxy for size or value.

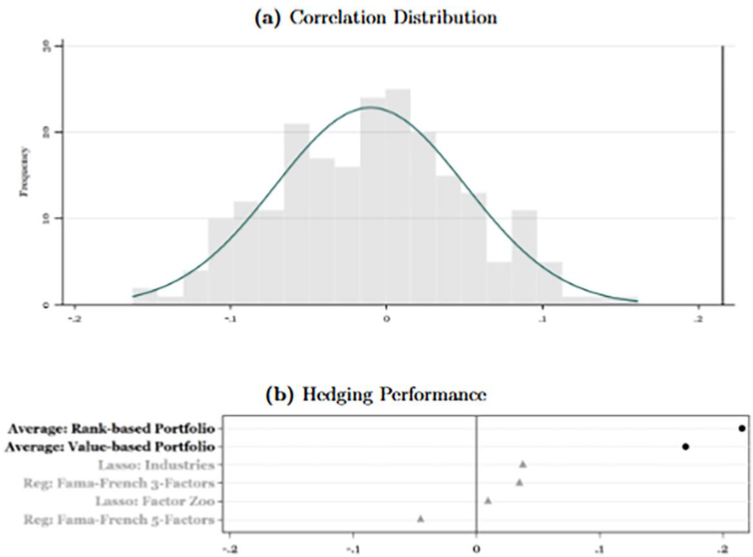

Figure 7. Hedging biodiversity risk using the factor zoo. *Note*: Panel (a) shows the histogram of the out-of-sample correlations for mimicking portfolios with AR(1) innovations of the NYT-Biodiversity News Index using data from 2010 to 2023. The gray bars represent mimicking portfolios built using each of the 212 characteristics. The red bar is the "Average: Rank-based Portfolio." Panel (b) shows the dot plot of monthly out-of-sample return correlations for various hedge portfolios with AR(1) innovations of the NYT-Biodiversity News Index using data from 2010 to 2023. Each dot represents one correlation coefficient. The portfolios with blue labels are built based on the average of all biodiversity risk measures, using ranking-based and value-based approaches. The portfolios with red labels are the mimicking portfolios constructed with 24 industries, 212 characteristics, Fama–French Five Factors, and Fama–French Three Factors, and estimated each month using a 5-year rolling window.

the NYT-Climate News index introduced in Section 2. While our various biodiversity hedge portfolios perform well in terms of hedging biodiversity risk, they have, on average, close-to-zero correlations with realizations of news about climate risk. This is consistent with our finding of distinct realizations of aggregate climate and biodiversity risks and the fact that climate and biodiversity risk exposures are not strongly correlated at the industry level.

4.2.1 Robustness and additional analyses

We conduct a number of additional analyses to confirm the robustness of our baseline results and to extend them further.

While our baseline hedge portfolios are constructed using biodiversity risk exposures aggregated at the GICS 4-digit industry level, the underlying risk exposures based on 10-K, CDP, and biodiversity ETF holdings are, in principle, available at the firm level. To examine the impact of hedge asset granularity on our results, Supplementary Appendix Figure A.12 presents the hedging performance of portfolios constructed with 72 GICS 6-digit industries and 175 GICS 8-digit industries. These portfolios are based on the average rankings across the 10-K, CDP, and holding-based measures. While the hedge portfolios continue to perform reasonably well with more finely disaggregated assets, their performance diminishes somewhat as more assets are included, highlighting the tradeoff between the noise in exposure estimation and the ability to capture true differences in exposures within industries.

We also assess the hedging performance of our procedure under alternative dictionaries used to filter the textual data for constructing the aggregate biodiversity news series, as described in footnote 8. The results, shown in Supplementary Appendix Figure A.13, highlight that the hedging ability of our portfolios remains similar when the dictionary is changed, though they weaken somewhat when climate change words are included (because the news series will then be more informative about climate events and less about biodiversity events).

In an extension to our baseline results, we show in Supplementary Appendix Figure A.14 that in the period 2000–2009, the hedging ability of the various portfolios is substantially weaker, and, in many cases, nonexistent. This finding is in line with the observation in other work that financial markets paid little attention to climate and nature-related risks prior to 2010 (see the discussions in Acharya et al. 2022; Alekseev et al. 2024). As a result, we would not have expected news realizations to lead to price movements of exposed firms.

We also explore, in Supplementary Appendix A.3, whether using the recent advances in large language modeling can help us make progress in distinguishing physical and transition biodiversity risk. As discussed above, this distinction is quite subtle and hard to detect using textual data: for example, when policymakers act to reduce physical risks, they often create transition risk. The Supplementary Appendix uses LLM (Large Language Model) to try and disentangle the two types of risk both for the aggregate news series and the firm-level exposures. The results, while encouraging, are somewhat mixed, suggesting that these tools need to be further refined before being able to consistently distinguish physical and transition risks.

4.2.2 Survey evidence on the adequacy of biodiversity risk pricing

While the prior section suggests that biodiversity risks are at least somewhat reflected in equity prices, it is less clear whether the current pricing is adequate to reflect the underlying risks. Answering this question is challenging, and requires taking a quantitative view on the nature of the risks and the ways they would affect the cash flows of different firms.

To provide some initial insights into this important question, we asked the respondents to our survey whether they believed that prices across a range of asset classes appropriately reflected biodiversity risks. Table 6 highlights that about half of all survey respondents believed that asset markets underpriced biodiversity risks across equity markets, commodity markets, sovereign debt markets, and real estate markets (in addition, about 35 percent of respondents had no particular views on the pricing of these risks, while fewer than 5 percent of respondents believed that these risks were overpriced). These responses are consistent across respondents from different institutions and locations. We also find that people who are worried about biodiversity are more likely to believe that asset markets have not yet priced biodiversity risks appropriately, while people with no concern think it is overpriced.

5. Conclusion

Ecosystem services play a fundamental role in the economy and risks stemming from biodiversity loss can affect firms through many channels. Yet, those risks can be difficult to quantify and study systematically. The goal of this article is to introduce measures of aggregate biodiversity risk as well as measures of firms' and industries' exposures to these risks; to connect and validate these two; to study the pricing of biodiversity risks in financial markets; and to publicly release our biodiversity exposure measures at www.biodiversityrisk.org to facilitate more research on this important topic.

Given the complexity of biodiversity risk, our article integrates multiple sources of information—including textual data, cross-sectional pricing information, and survey evidence—and develops methods to combine them into quantitative series that can be analyzed jointly. We view this work as a starting point for quantitative analyses of biodiversity risk.

Table 6. Current pricing of biodiversity risks in asset markets.
Participants were asked: "To what extent do you think that physical or transition biodiversity risks are currently priced in the following asset markets?," where asset markets are either stock markets, real estate markets, commodity markets, or sovereign debt markets.

		Role			Location				Biodiversity concern			
	Pooled	Academic institution	Private sector	Public sector	North America	Europe	Asia	ROW	Very High	High	Low	No Concern
Stock market (%)												
Not enough	48	43	53	61	45	53	60	69	71	53	30	6
Correct	17	23	11	15	18	17	13	23	11	26	33	23
Too much	3	3	5	3	5	1	2	0	2	2	8	29
No opinion	32	31	32	21	33	28	25	9	16	19	29	42
Commodity market (%)												
Not enough	43	39	46	55	39	47	57	63	65	45	24	3
Correct	19	25	14	17	20	21	15	20	13	29	39	23
Too much	3	2	5	5	5	1	0	6	1	2	8	29
No opinion	35	35	35	22	36	30	28	11	20	24	29	45
Sovereign debt market (%)												
Not enough	43	39	44	58	41	48	50	60	65	45	29	3
Correct	14	20	10	8	16	13	12	9	6	23	33	19
Too much	2	2	2	4	2	1	2	6	0	2	3	26
No opinion	41	39	44	30	41	38	37	26	29	30	35	52
Real estate market(%)												
Not enough	46	42	48	61	45	51	53	54	66	51	32	3
Correct	16	22	12	9	17	15	13	20	10	23	32	29
Too much	2	1	3	3	2	2	0	3	0	1	5	26
No opinion	37	35	38	27	37	32	33	23	24	25	32	42

Following the research agenda described in Giglio et al. (2026), many extensions and refinements could be pursued, including the development of more advanced methods to measure biodiversity risks using additional data sources, such as earnings calls; spatial measures of biodiversity risk at the country and county level; an integrated study of the pricing of biodiversity risk across asset classes; and a more sophisticated distinction between the effects and pricing of transition and physical risks.

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Supplementary material

Supplementary material is available at *Review of Finance* online.

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Conflicts of interest: The authors declare that they have no conflicts of interest.

Data availability

The data underlying this article were provided under license by CRSP, Compustat, Bloomberg and CDP. The datasets were purchased through our institutions. We have included scrambled versions of each of these datasets in the package to ensure that the code can be run without error, although the results from the scrambled data do not have any economic meaning and do not match the results from the article.

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