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Do Investors Care About Biodiversity?

Finance Working Paper N° 905/2023
December 2023

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ECGI Working Paper Series in Finance

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Abstract

This paper introduces a new measure of a firm’s negative impact on biodiversity, the corporate biodiversity footprint, and studies whether it is priced in an international sample of stocks. On average, the biodiversity footprint does not explain the cross-section of returns. However, a biodiversity footprint premium (higher returns for firms with larger footprints) began emerging after the Kunming Declaration in October 2021, which capped the first part of the UN Biodiversity Conference (COP15). Consistent with this finding, stocks with large footprints lost value in the days after the Kunming Declaration. The launch of the Taskforce for Nature-Related Financial Disclosures (TNFD) in June 2021 had a similar effect. The results indicate that investors started to require a risk premium upon the prospect of, and uncertainty about, future regulations or litigation to preserve biodiversity.

Keywords: Biodiversity, Corporate Biodiversity Footprint, Stock returns

JEL Classifications: G12, G30, Q5

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Abstract

This paper introduces a new measure of a firm's negative impact on biodiversity, the corporate biodiversity footprint, and studies whether it is priced in an international sample of stocks. On average, the biodiversity footprint does not explain the cross-section of returns. However, a biodiversity footprint premium (higher returns for firms with larger footprints) began emerging after the Kunming Declaration in October 2021, which capped the first part of the UN Biodiversity Conference (COP15). Consistent with this finding, stocks with large footprints lost value in the days after the Kunming Declaration. The launch of the Taskforce for Nature-Related Financial Disclosures (TNFD) in June 2021 had a similar effect. The results indicate that investors started to require a risk premium upon the prospect of, and uncertainty about, future regulations or litigation to preserve biodiversity.

Keywords: Biodiversity, Corporate Biodiversity Footprint, Kunming Declaration, Natural Capital, Nature, Stock Returns, Taskforce for Nature-Related Financial Disclosures (TNFD)

JEL Classification: G12, G30, Q57

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1 Introduction

Biodiversity, the variety of living organisms in all habitats, is deteriorating at an unprecedented and alarming speed. Between 1970 and 2018, the world has seen a 69% loss of monitored wildlife (WWF 2022), and biosphere integrity is one of the overstepped planetary boundaries (Rockström et al. 2009; Steffen et al. 2015). Biodiversity collapse jeopardizes the goods and services humans obtain from ecosystems, with potentially far-reaching economic implications (World Bank 2020).[1] In addition, biodiversity loss may bring about a new "era of pandemics" (IPBES 2020). While the UN Convention on Biological Diversity (CBD) entered into force in 1993 and several Conferences of the Parties (COPs) to the CBD have adopted plans to protect biodiversity, most goals have not been achieved (CBD Secretariat 2020). Recent globally coordinated steps toward protecting biodiversity include the Kunming Declaration of 2021 and the Montreal Agreement of 2022.

Given the potentially dramatic financial consequences of the loss of biodiversity, financial market regulators increasingly pay attention to the topic (NGFS and INSPIRE 2022), and the Taskforce on Nature-related Financial Disclosures (TNFD), modeled after the Taskforce on Climate-related Financial Disclosures (TCFD), was launched in 2021. However, the link between biodiversity and finance has received little attention by academics. As noted by Karolyi and Tobin-de la Puente (2023), no studies in the top-10 finance journals reference biodiversity.[2] In this paper, we take a step toward filling this gap by introducing to the finance literature a science-based measure, the corporate biodiversity footprint (CBF), and

1. While "biodiversity" is an ecological term, the economic term "natural capital" if often used to emphasize the role of nature in supporting human economic activity and well-being. Indeed, the World Economic Forum (2022) estimates that half of the world's gross domestic product stems from industries that depend on nature and ecosystem services (e.g., construction, agriculture, and tourism).

2. By contrast, the economics of biodiversity have received early and substantial attention (e.g., Weitzman 1992, 1993; Metrick and Weitzman 1998; Heal 2003, 2004; Dasgupta 2021).

exploring whether investors price this footprint.

The CBF measure was developed by Iceberg Data Lab (IDL) and aggregates the biodiversity loss caused by a firm's annual activities related to land use, greenhouse gas (GHG) emissions, water pollution, and air pollution. To quantify this loss, the CBF builds on the concept of Mean Species Abundance (MSA), which measures the relative abundance of native species in ecosystems, compared to their abundance in undisturbed ecosystems. The CBF metric express this loss in terms of km^2.MSA. It quantifies the biodiversity loss along the entire value chain, not just the direct impact of a firm. Thus, the CBF metric contains scope 1, 2, and 3 components, whereby scope 1 measures the environmental pressure of the firm's direct activities, such as the area artificialized or occupied due to its business activity, scope 2 the pressures induced by the purchase of electricity, heat, and cooling, and scope 3 all indirect pressures (products sold or purchased, or investments made).[3]

Our international sample represents the universe of listed firms for which CBF data are available from IDL over the years 2018-2021. It consists of 2,106 firms from 34 countries. While the sample period includes only a few years, the most important global policy developments concerning biodiversity are also quite recent. Retail & Wholesale, Paper & Forest, and Food are the sectors with the largest average biodiversity footprints, which reflects these sectors' pressures from intensive land use or air pollution.[4] While there is a sizeable industry component in the CBF, there is large heterogeneity within industries. This is a strength of

3. Alternative metrics to MSA exist, e.g., Potentially Disappeared Fraction (PDF) and Species Threat Abatement and Restoration (STAR). We discuss these concepts below. As biodiversity received more attention, more data options are becoming available. For example, ISS ESG launched in 2022Q3 and MSCI plan to launch in 2024 biodiversity impact measures that build on a combination of MSA and PDF. Since 2023, S&P offers a tool utilizing STAR. To our knowledge, these data providers do not offer (yet) a time-series comparable to that of IDL.

4. While the biodiversity impact from land use is mostly indirect for Retail & Wholesale (e.g., because of sold food and beverage products), it is direct for Paper & Forest and Food (e.g., because of deforestation and farming). Retail & Wholesale has a high negative air pollution impact because of pollution related to shipping activities in the value chain.

the CBF metric as it allows the exploration of granular within-industry variation. Capturing such variation is important, because several institutional investors recently started negative screening policies in which they exclude the laggards within certain sectors (e.g., La Banque Postale Asset Management 2022). Larger firms have a more negative impact on biodiversity, and the CBF metric also relates positively to a firm's carbon emissions, which represent one channel through which firms harm biodiversity.

The CBF metric correlates with whether firms have been targeted by the investor coalition Nature Action 100, which released in June 2023 a list of 100 firms to engage with in order to tackle biodiversity and nature loss.[5] Almost 70% of Nature Action 100 targets locate in the top quintile of the CBF distribution. Using textual analysis, we find that biodiversity terms are mentioned in only 5.1% of our sample firms' earnings conference calls. This low number is consistent with Giglio et al. (2023), who find that only 3.8% of US firms' 10-K statements mention biodiversity terms. As a result, the correlation between the CBF and the number of biodiversity-related terms in earnings calls is just 8.3%. Notably, many large-CBF firms, including many NA100 targets, do *not* discuss biodiversity in their earnings calls.

How can a firm's CBF be expected to correlate with its stock returns? A first possibility is that large-CBF stocks earn higher returns as they potentially face transition risks. Transition risks may result from legal fines or compliance with an increasingly demanding regulatory environment regarding biodiversity preservation. The theory by Pástor and Veronesi (2012) implies that policy uncertainty associated with future regulation or litigation leads to investors requiring a risk premium for holding large-CBF stocks. Consistent with this prediction, recent studies show that investors demand compensation for exposure to carbon (Bolton and Kacperczyk 2021, 2023) or pollution (Hsu, Li, and Tsou 2023) risks.

5. Nature Action 100 is supported by institutional investors representing $27 trillion in assets under management or advice as of 2023.

A second possibility is that large-CBF stocks earn higher returns due to mispricing, which may originate from unexpected cash flows shocks. A negative biodiversity impact is an externality, and some firms may, therefore, not invest in mitigating or reducing their biodiversity impacts. As a result, they enjoy unexpectedly higher earnings and returns. A third possibility is that large-CBF stocks earn lower returns. Evidence shows that brown (green) stocks had lower (higher) returns due to unexpected shifts in investors' preferences for green stocks (Pástor, Stambaugh, and Taylor 2022), and as climate attention or concerns increased (Ardia et al. 2023; Choi, Gao, and Jiang 2020; Engle et al. 2020). If growing concerns about biodiversity loss gradually shifted investor preferences, then large-CBF stocks see lower returns.

These channels compete against the null hypothesis that the CBF is unrelated to returns. This result may arise, first, because measuring and disclosing a firm's biodiversity impact is more complex and less well-developed than measurement and disclosure of the corporate carbon footprint. Second, whereas the personal experience of phenomena attributable to climate change affects investors' perceptions of the problem (Choi, Gao, and Jiang 2020; Di Giuli et al. 2022), such experience is less likely for signals of biodiversity loss, presumably leading to lower investor awareness. Third, even if investors have a sense of biodiversity harm, to the extent that they ignore impact materiality, they are unlikely to price the CBF metric.

We examine the pricing of the biodiversity footprint by regressing monthly stock returns of firms on their one-year lagged CBF values (i.e., we relate 2019-2022 returns to 2018-2021 CBF values). We rely on a characteristics-based approach, which has the advantage that it does not require assumptions about the underlying asset pricing model. On average, we find no evidence that the CBF metric is related to returns between 2019 and 2022. However, a firm's biodiversity footprint started to be priced following major biodiversity-related policy changes. In October 2021, the first part of the UN Biodiversity Conference (COP15) concluded with the Kunming Declaration (2021). Similar to the Paris Agreement, the Kunming Declaration calls for countries to act urgently to protect biodiversity by aligning financial flows to support the conservation and sustainable use of biodiversity. The event arguably increased both investor awareness about the loss of biodiversity and the prospect of and uncertainty about future biodiversity regulations or litigation. Between the Kunming Declaration and December 2022, a one-standard deviation higher log(CBF) value is associated with 18.5 basis points higher returns (or 2.2% annualized).

We conduct an event study to examine closely whether and how investors revised their valuations of large-CBF stocks around the Kunming Declaration.[6] If the declaration raised investor awareness of biodiversity issues and the prospect of regulations aimed at preserving it, we would expect investors to revise downward their valuation of large-CBF stocks. Indeed, in the three days following the declaration, relative to the three days before, large-CBF stocks experienced a cumulative stock price decline of 1.14%, relative to small-CBF stocks.

The signing of the Kunming Declaration is a salient event, but this does not preclude the possibility that other events had similar effects. In fact, the launch of the TNFD on June 4, 2021 was another salient event that contributed to raising awareness of biodiversity issues and associated transition risks (though it was primarily about disclosure). In the three days after the TNFD launch, relative to the three days before, investors reduced their valuation of large-CBF stocks by 1.5%, relative to low-CBF stocks.This result is consistent with investors revising downward their valuation of large-CBF stocks because the TNFD launch (also) raised awareness of biodiversity transition risk, and because it increased the

6. The central declaration was made on October 13, 2021. Because the outcomes of the declaration were not determined beforehand, the event qualifies as a plausible shock to investors' expectations regarding the transition risks faced by firms with large biodiversity footprints. COP15 was marked by tense talks and a deep divide between wealthy and developing countries, which made the final agreements uncertain until the day of the announcement (Eihorn 2022; Mychasuk 2022).

odds of firms being targeted by litigation on the basis of disclosed information.[7]

Our evidence suggests that investors started to anticipate that new regulations or litigation will target firms with a large biodiversity footprint. The event study results indicate that around relevant events (Kunming, TNFD) the prices of large-CBF stocks were bid down. Higher returns of large-CBF stocks followed. Thus, consistent with Pástor and Veronesi (2012)'s model, the increase in policy uncertainty associated with these events leads to investors demanding a biodiversity footprint premium. To corroborate this interpretation further, we demonstrate that the premium earned by large-CBF stocks is larger in countries with low biodiversity protection; firms in such countries face greater transition risks due to the prospect of future "catch-up" regulation. In sum, the CBF metric appears to reflect exposure to biodiversity transition risk, and our results reflect the pricing of such risk. Consistent with the risk premium interpretation, we also demonstrate that large-CBF firms had higher implied costs of capital, a proxy for expected returns, after the Kunming Declaration.

By contrast, these results are difficult to reconcile with unexpectedly high cash flows at high-CBF stocks: i) the negative event study returns are inconsistent with unexpectedly higher cash flows at high-CBF stocks (we would expect the opposite); and ii) it is conceptually unclear why unexpectedly higher earnings at high-CBF firms would only materialize after Kunming. Our evidence is also hard to explain by unexpected shifts in investor preferences after the Kunming Declaration, as this channel predicts that high-CBF stocks earn lower returns in the months after Kunming.

7. The TNFD launch was just four months before the Kunming Declaration, so we do not claim that October 2021 was a unique point defining the regime shift. Unsurprisingly, we draw similar inferences if we relate returns to the CBF for the period after June 2021 (instead of October 2021). We cannot detect differential return dynamics between high- and low-CBF firms around the Montreal Agreement, which constitutes the second part of the COP15. This indicates that this summit did not provide additional information regarding firms' exposures to transition risks (possibly as the outcomes were more anticipated compared to the Kunming Agreement).

A potential concern is that our results are driven by firms' carbon emissions, rather than their broader biodiversity impacts. Carbon emissions negatively affect biodiversity, and these emissions also enter the CBF computation. However, we demonstrate that our results hold when controlling for carbon emissions or regulatory climate change exposure (Sautner et al. 2023). They are also unchanged if we use an "emissions-free" CBF metric.

We contribute to a new literature on biodiversity finance. Closely related is Giglio et al. (2023) (GKSZ henceforth), who construct measures of U.S. firms' biodiversity risk to assess the covariation of returns of portfolios sorted on the industry-average of that measure with biodiversity news. The industry-level measures are compiled from a binary firm-level indicator for disclosures on biodiversity issues in 10-Ks. GKSZ's approach complements ours in terms of methodology, focus, and sample. The feature of the CBF metric is that it quantifies the impact of a firm on biodiversity, and it does so for an international sample. By comparison, GKSZ identify U.S. firms which communicate biodiversity-related information in their 10-Ks. As we show, the vast majority of our sample firms, including those with large CBF values, do not disclose biodiversity information in their 10-Ks. We also complement GKSZ in that we document how investors revised their valuation of large- versus small-CBF firms following global biodiversity agreements.

Our complementary approaches are useful. As explained by Cenedese, Han, and Kacperczyk (2023) for the case of climate transition risk, there are two principal approaches to measure biodiversity risk, one based on the actual footprint and another one based on textual analysis. The first approach's benefit is that it provides a quantitative link to a specific objective function, biodiversity impact in our case, whereas the second approach's benefit is its forward-looking nature. The CBF metric quantifies exposure to biodiversity transition risk, but it is not forward-looking, that is, it does not take into account whether a firm has set targets, or taken strategic actions, to reduce its footprint. Such future efforts may affect investor perceptions of a firm's biodiversity performance. In contrast, textual analysis of 10-Ks (or of earnings calls) can be useful to identify firms' willingness to take actions to reduce their footprints. Further, by construction, the CBF quantifies the impact of a firm's activities on biodiversity, but it does not provide information regarding physical risks from biodiversity loss, which can be captured from corporate text. Hence, textual analysis of corporate disclosures could be more useful to assess actions that firms put in place to reduce their biodiversity footprint, and firms' exposure to biodiversity physical risk. A limitation of text-based approaches is that they rely on firms communicating or disclosing information, which *currently* still limits the ability to measure biodiversity risk in this way.[8]

Other papers on biodiversity finance include Flammer, Giroux, and Heal (2023), who examine the use of private capital to finance biodiversity conservation and restoration, and Hoepner et al. (2023), who study 68 infrastructure firms to show that firms with better biodiversity risk management have more favorable financing conditions (lower CDS slopes). Xin et al. (2023) relate MSCI's biodiversity exposure and management scores to returns and operating performance, but find no relationships in their sample between 2013 and 2020.

8. This will likely change in the future, with more firms discussion biodiversity issue. Recent advances in textual analysis relying on sophisticated machine-learning approaches also hold some promise, though currently even with such approaches only a minority of firms are identified to communicate biodiversity-relevant information (Schimanski et al. 2023).

2 Biodiversity footprint: Quantifying biodiversity loss

2.1 Biodiversity loss and MSA

Our measure of a firm's impact on biodiversity is the corporate biodiversity footprint or CBF, which is constructed by IDL. The data provider developed the measure to provide a science-based indicator that helps investors measure and manage their investments' impact on biodiversity. The CBF metric reflects the extent to which ecosystems affected by a firm's activities have been degraded from their pristine natural state. It aggregates biodiversity loss caused by annual firm activities resulting from multiple environmental pressures, such as, land use, nitrogen deposition, emissions, or release of toxic compounds.

The CBF metric is based on the concept of MSA, a scientific approach to quantify biodiversity loss. MSA was proposed during the development of the GLOBIO3 model, the objective of which is to simulate the impact of different human pressure scenarios on biodiversity. The CBF methodology uses MSA because: i) it offers the largest and most robust toolbox, in terms of damage functions, in the scientific literature; ii) it is a holistic approach that adapts well to appraising portfolios, unlike more microscopic indicators which are better-fitted to project analysis; and iii) it is endorsed by the scientific community and multilateral organizations (e.g., CBD, IPBES and IPCC), and recommended by the UN.

MSA measures the relative abundance of native species in an ecosystem, compared to their abundance in undisturbed ecosystems. It thereby captures the conservation status of an ecosystem in relation to its original state, that is, undisturbed by human activities and pressures. An area with an MSA of 0% has completely lost its original biodiversity (or is exclusively colonized by invasive species), whereas an MSA of 100% reflects a biodiversity level equal to an original, undisturbed ecosystem. IA Figure A.1 provides an illustration of

MSA variation for forest and grassland, and IA Section B.5 a numerical example.

To capture the area over which MSA is affected by a firm's activities, the biodiversity footprint is expressed in terms of km^2.MSA. The CBF metric measures the potential negative change in MSA due to a firm's activities, by translating its combined degradation of nature into km^2. In other words, if one combines all of the firm's negative impacts on biodiversity, the CBF metric expresses this impact in terms of square kilometers of "artificialized" or "denaturated" land. For example, a CBF value of -100km^2 means that 10% of the original biodiversity is lost over an area of 1,000km^2, or that a proportionally lower amount of biodiversity, 1%, is lost over the larger area of 10,000km^2. In this paper, we multiply the CBF score by -1, so that higher values indicate a more negative impact on biodiversity.

2.2 From MSA to CBF

Building on the MSA concept, the CBF metric is calculated in three steps, which we summarize in this section. IA Section B explains each step in detail, drawing on an example from Danone. First, IDL assesses the products purchased and sold by a firm throughout its value chain and allocates the firm's products and services sold and bought by sector.[9] This step is based on IDL's internal physical input/output model ("Wunderpus"), which is a proprietary and enhanced version of EXIOBASE, a detailed multi-regional environmentally extended supply-use and input-output database. Second, IDL calculates the firm's environmental pressures based on the flows and purchases of goods and services its business depends on, considering four pressures: land use, GHG emissions, air pollution, and water pollution. These four pressures are calculated along the whole value chain of the firm, appraising its

9. IDL in its documents primarily refers to NACE, the statistical classification of economic activities in the European Union (EU). IDL collects activities on the "NACE4" level, which refers to a 4-digit level of specificity within the NACE classification system, providing a relatively detailed view of a firm's activities. NACE is similar to the NAICS (North American Industry Classification System).

processes, products, and supply chains using a life-cycle analysis. Third, IDL translates these four estimated pressures, using pressure-impact functions, into one biodiversity impact unit, expressed in km^2.MSA. It also aggregates the different impacts into an overall absolute impact. IA Figure A.2 illustrates the three steps involved in the calculation of the CBF metric and how each pressure is translated into a quantified impact on biodiversity in km^2.MSA.

2.3 CBF applications in practice

The CBF metric is used by major institutional investors, including BNP Paribas Asset Management, AXA Investment Managers, Robeco, and Mirova, to measure the biodiversity impact of their investment. The data are also used by the three biodiversity-related funds to screen and manage stocks (HSBC World Biodiversity Screened Equity ETF, Ossiam Food for Biodiversity ETF, and AXA IM ACT Biodiversity Equity ETF). These funds are used by GKSZ to build one of their biodiversity risk measures. Finally, the CBF metric is now part of the measures recognized by TNFD for risk management and disclosure purposes.

2.4 Limitations of MSA and CBF

The CBF metric comes with limitations, some of which originate from how MSA measures biodiversity loss. Finance for Biodiversity (2022), NGFS and INSPIRE (2022), and OECD (2023) discuss these limitations and also mention other measurement approaches. Specifically, MSA does not allow the tracking of loss of specific species or classes of species, and it treats all specifies as equally valued (independent of whether they are threatened). An increase in a common species might in turn hide that another species gets extinct. The MSA concept also does not allow a comparison with the absolute number of species prevalent in an area. Further, arguably limited information is available about the assumptions used in the

GLOBIO model, which constitutes a key element in the MSA calculation, and some argue that the GLOBIO model is biased towards the most studied species and ecosystems.

Some alternative metrics to MSA exist, with two having received attention by investors and regulators as they can also be constructed for a large set of firms. PDF, the first metric, is similar in spirit to MSA and measures the percentage of species that are lost due to environmental pressures, such as land use or climate change, over some time frame on $1m^2$ land or $1m^3$ water. It ranges between 0% (no species disappeared) and 100% (all specifies disappeared). Importantly, PDF does not reflect the decline in the population of a given species. Some data providers started to construct and make available PDF-based metrics, usually in combination with MSA. For example, ISS ESG launched a biodiversity impact tool in 2022Q3, with PDF- and MSA-based metrics for large set of firms, and MSCI is planning to introduce metrics based on MSA and PDF in 2024.[10] STAR, the second metric, contains a threat abatement and a restoration component. The first component measures for a specific area the risk of extinction of species, calculated as the sum of the risks of extinction weighted by their threat status. The calculation excludes species where extinction is not a concern. The second component indicates the potential for restoration. In 2023, S&P started offering a Nature and Biodiversity Risk Profile utilizing the STAR method.[11]

Beyond these limitations, the CBF metric has shortcomings when MSA is applied in a corporate context. Notably, because of limited data availability, large parts of the data used for the CBF calculation are based on sector averages and estimations, rather than granular,

10. To our knowledge, these databases typically do not (yet) contain historical data, but primarily data for the most recent year; IDL was one of the first-movers in developing a MSA-based metric.

11. Other metrics exist too, but with more limited scope. The Biodiversity Intactness Index (BII) reflects the change in the state of nature under land use changes (also calculated relative to a reference state). The Biodiversity Impact Metric (BIM) builds on MSA, but focuses only on a firm's supply chain to measure biodiversity impact. There is also work on using geospatial, satellite, or acoustic data to measure biodiversity loss, which—when combined with data on a firm's locations—can lead to alternative firm-level metrics.

firm-specific information. Finally, the CBF metric does not yet capture soil degradation and invasive species, and only partially captures the impact on freshwater and marine biodiversity.[12]

2.5 Climate transition risk and CBF

Biodiversity loss and climate change are interrelated, making it important to conceptually and empirically address potentially confounding effects of carbon emissions. Climate change, which is generated by GHG emissions, negatively affects biodiversity. This indicates a positive correlation between a firm's carbon footprint and its impact on biodiversity, as reflected by the CBF. Carbon emissions are, therefore, also modelled in the CBF as a source of environmental pressure. There is also a reverse effect from biodiversity on climate change, as the loss of natural sinks, such as oceans, vegetation, and soils, accentuates climate change.

While correlated, there are also fundamental differences, and even conflicts, between the two environmental concepts. Efforts by firms to lower carbon emissions (e.g., to achieve net-zero targets) may lead to more biodiversity loss and a larger biodiversity footprint. Specifically, several solutions that address climate change by reducing carbon emissions have a negative impact on biodiversity (see, e.g., Paulson 2023). For example, many U.S. solar farms are being built on forested land, resulting in a big impact on natural ecosystems and habitats. Likewise, renewable energy and electric cars require metals, such as lithium or cobalt, the mining and extraction of which have severe impacts on local biodiversity.[13]

As we will show below, empirically, the principal component of the CBF is land use, which

12. Finance for Biodiversity (2022) provide an overview table covering some alternatives. According to that analysis, the CBF measure is the only currently available measure on a firm level that seeks to cover Scope 3 downstream impacts.

13. Beyond these specific examples, GKSZ show that an aggregate biodiversity index behaves differently from an aggregate climate news index Engle et al. 2020, suggesting that periods of high media coverage of biodiversity issues differ from periods of high media coverage of climate change issues.

indicates that a firm's biodiversity footprint is not identical to a firm's carbon footprint. However, in light of the conceptual links between biodiversity loss and carbon emissions, we document below that our results are robust to accounting for a firm's carbon footprint.

3 Data, summary statistics, and sample selection

3.1 Data sources and sample construction

Our sample construction starts with all 2,724 publicly listed firms for which i) data on the biodiversity footprint are available from IDL between 2018 and 2021, and ii) a match in Compustat/CRSP exists. We drop 480 firms with missing monthly returns or control variables, or with negative total assets or book value of equity. We further drop 60 firms from countries with fewer than ten firms (we require ten firms for the cross-country analysis). Finally, we exclude 78 firms from two island countries ("Bermuda" and "Cayman Islands"). These data filters provides us with a final sample of 2,106 firms across 34 countries. The returns analysis relates annual CBF data for these firms to monthly returns between 2019 and 2022, resulting in a panel of 89,132 firm-month observations. As the variable is highly skewed, we use Ln(CBF) for most tests.[14] The majority of sample firms are members of the MSCI All Country World Index (MSCI ACWI), the universe that IDL seeks to cover.

Data on firm-level carbon emissions (CO_2 Emissions) is from Trucost and data on regulatory climate change exposure (CCExposure^{Reg}) from Sautner et al. (2023). We use the sum of scope 1, 2, and 3 emissions as the CBF includes corresponding scope 1, 2, and 3 components. Emissions data (CCExposure^{Reg} data) are available for 99% (59%) of the observations

14. For some sample firms, we fill forward missing CBF values, because CBF data is missing in some years (especially for 2021). This procedure increases the number of firm-month observations by 20%, from 66,890 to 89,132, but our results do not depend on this choice.

entering our returns analysis. The correlation between Ln(CO_2 Emissions) and Ln(CBF) in our sample is 0.60, and that between CCExposure^{Reg} and Ln(CBF) is 0.20. Accounting and stock price data is from Compustat, data on E scores from Refinitiv, and country-level data on biodiversity protection from Yale University. Appendix A defines all variables.

3.2 Descriptive statistics of the CBF

Table 1 reports summary statistics of the CBF metric for our sample. The mean (median) value of Ln(CBF) is 4.79 (5.28), indicating that the average (median) firm has a biodiversity impact corresponding to the complete loss of biodiversity over an area of 120.3km^2 (196.4km^2).

In Figure 1, Panel A, we decompose the CBF metric into its four subcomponents or sources: i) land use, ii) GHG emissions, iii) water pollution, and iv) air pollution. The greatest impact on biodiversity originates from land use (49% of the CBF), followed by GHG emissions (22.5%), water pollution (20%), and air pollution (8.5%). In Figure 1, Panel B, we decompose the biodiversity footprint into its scope 1, scope 2, and scope 3 dimensions.[15] Scope 3 contributes about 79% to the overall CBF value, while scope 1 and 2 account for, on average, 15% and 6%, respectively. Scope 3 is dominant in the overall CBF metric because most large firms either assemble and distribute products or provide services, implying that they usually do not have direct impacts on their environments (examples include retailers, banks, or tech firms); for such firms, the largest parts of the scope 3 footprints originate from upstream (e.g., providers of farming land or extracting raw materials) or downstream

15. Scope 1 reflects the direct pressures generated by a firm, that is, the loss of biodiversity directly caused by the establishments owned or controlled by the firm. Scope 2 footprint captures indirect effects, namely the loss of biodiversity caused by the generation of purchased heat, steam, and electricity consumed by the firm. Lastly, scope 3 measures biodiversity loss caused by the operations and products of the firm, but coming from sources that the firm does not own or control.

(e.g., usage of products by clients, financing activities by banks) activities.[16]

In Table 2, we present a ranking of industries and countries, using the overall as well as source- and scope-based measures.[17] In Panel A, the industries with the highest average CBF value are Retail & Wholesale, Paper & Forest, and Food, consistent either with their intensive land use (mostly indirectly through the supply chain in the case of, for example, food or fashion retailers) or their toxic emissions into air and water. These industries are followed by Asset Management, with scope 3 biodiversity harm (indirectly through financing) being the major component of the sector's overall footprint. Firms with large scope 1 footprints tend to operate in the Paper & Forest or in Metals & Mining, that is, with business models that have a large direct effect on the local biodiversity.

In IA Table A.2, we do not observe significant variation across countries in terms of the footprint decompositions. In Table A.3, there is more variation across industries. For instance, for the Waste industry, scope 1 accounts for 78.3% of the total CBF, whereas in Asset Management, scope 3 accounts for 99.9%. Chemicals and Metal & Mining impact biodiversity mainly via the release of toxic compounds and land use. Transportation is the sector for which the impact of air pollution is strongest. In Food, Beverages, Paper & Forest, and Tobacco, land use contributes about 90% or more to the overall footprint.

3.3 Sample selection concerns

Our sample departs from the MSCI ACWI for two reasons. First, IDL expanded its coverage to some U.S., European, and Chinese firms outside of the index. As mentioned, the initial IDL data includes 2,724 firms with a Compustat match. While 72% or 1,954 of these firms belong to the MSCI ACWI, 28% or 770 firms are from outside of the index. Second, the data

16. IA Table A.1 reports additional summary statistics on the decomposition of the CBF metric.
17. IDL's industry classification is similar to the Revere Business Industry Classification System (RBICS).

requirements described in Section 3.1 lead to further deviations from the MSCI ACWI. As a result, the final sample of 2,106 firms includes 70% or 1,477 firms from the MSCI ACWI and 30% or 631 firms from outside of the index. For comparison, the ACWI universe from 2017-2022 contains 2,642 firms. IA Section C analyzes determinants of IDL's data coverage. As we detect some observable differences between covered and non-covered MSCI firms, we verify below that our results hold if we restrict the sample to firms inside the MSCI ACWI.

4 Biodiversity footprint: Validation and determinants

4.1 Nature Action 100 targets and CBF

We conduct several validations of the CBF metric. As an outside validation, we test whether the CBF measure correlates with whether a firm is targeted by Nature Action 100 (NA100). Similar to ClimateAction100+, NA100 is an institutional investor initiative that has identified 100 firms across eight sectors to engage with in order to tackle biodiversity and nature loss.[18] To identify targets, NA100 used four principles: i) a firm operates in a sector deemed to be systemically important in reversing nature loss; ii) an analysis conducted by the Finance for Biodiversity Foundation indicates a firm has a high potential impact on nature; iii) a firm has a large market capitalization (within the sector); and iv) a firm is from a developed or emerging market. NA100, launched at the COP15, is supported by 200 institutions representing $27 trillion in assets under management or advice as of 2023.

We first calculate the correlation between being targeted by NA100 and the CBF metric.

18. The sectors are biotechnology and pharmaceuticals; chemicals; household and personal goods; consumer goods retail, including e-commerce and specialty retailers and distributors; food; food and beverage retail; forestry and packaging; and metals and mining. The target list, released on June 26, 2023, is provided here. It includes firms such as Bayer, Danone, Glencore, Home Depot, Nestlé, Procter & Gamble, or Rio Tinto.

Using the most recent 2021 CBF data, we observe a positive correlation of 27% (as our sample covers a broader scope of sectors, it is unsurprising that the correlation is not higher). We also calculate that mean value of Ln(CBF) is twice as large for the group of NA100 targets, compared to the non-targeted group (8.76 vs. 4.63, significantly different at the 1% level). If we use CBF/Total assets, then the difference is even bigger, with NA100 targets having more than four times larger CBF intensities. Further, the vast majority of NA100 targets are in the top percentiles of the CBF distribution: In Figure 2, more than 50% of the NA100 targets locate in the top-10% of the CBF distribution (Panel A), and 69% in the top-20% (Panel B).[19] We conclude that there is a correspondence between the CBF measure and the set of priority targets that institutional investors engage with to address biodiversity issues.

4.2 Textual analysis of corporate disclosures and CBF

4.2.1 Corporate annual reports and CBF

As a text-based validation, we examine how the CBF metric correlates with biodiversity mentions in 10-K filings of U.S. firms, borrowing GKSZ's text-based measure. GKSZ develop a biodiversity dictionary and use it to create an indicator that equals one if a 10-K contains at least two sentences related to terms that reflect biodiversity issues. Their dictionary contains words such as biodiversity, ecosystem(s), habitat(s), species, (rain)forest(s), deforestation, aquatic, desertification, or carbon. GKSZ's data indicate that only 3.8% of 10-K reports mention the biodiversity issues between 2015-2020 in their sample (this corresponds to 2.4% for our sample from 2018 to 2021). Numbers are even smaller when the topic is about

19. The fact that NA100 focuses on only eight sectors explains why some large-CFB firms in our sample are not on their target list. These firms come from Asset Management, Electrical Equipment, Financial Services, Oil & Gas, or Pharmaceutical. The two firms that locate in the third CBF decile in Panel A are Charoen Pokphand Indonesia, a poultry processer, and U.S. animals drug producer Zoetis Inc.

biodiversity regulatory risk. Using their data, we calculate that CBF exhibits a modest positive correlation of 8.2% with GKSZ's 10-K-level measure.[20] More importantly, Figure 3 shows the CBF distribution for firms with and without 10-K-based mentions of biodiversity risk. While, on average, firms mentioning biodiversity topics in their 10-Ks have higher CBF values, there is again significant overlap of the two distributions. Hence, many firms without risk disclosures have higher biodiversity footprints than firms with disclosures.[21] This being said, we emphasize again that our and GKSZ's measures have different objectives.

In IA Section D, we provide case study snippets on how biodiversity issues are discussed in corporate text corpus. We provide these snippets for Danone, which ranks among the sample firms with the largest CBF, is a target of NA100, and is used in IA Section B to illustrate the CBF calculation. Danone explains that food production and farming depends on biodiversity and that it is striving to protect and restore biodiversity. We add the cautionary note that Danone is rather an exception in terms of how extensively it discusses biodiversity issues.

4.2.2 Earnings conference calls and CBF

As a related validation, we perform a textual analysis of earnings calls, to explore whether firms may disclose more on biodiversity issues when interacting with analysts. Earnings calls are key corporate events in which financial analysts listen to management and ask questions about current and future developments material to the firm. We collect earnings call transcripts from Refinitiv Street Events between 2019-2022, and we identify text dis-

20. Consistent with 10-Ks emphasizing direct biodiversity impacts, the 10-K-based measures exhibit stronger correlations with the scope 1 CBF component than with the scope 2 and 3 ones (IA Table A.16).

21. This may be in parts due to investor demand for biodiversity information. Though evolving fast, demand for biodiversity footprint disclosure is less prevalent, and the quality of information is poor. According to the head of Schroders, reporting on biodiversity is where reporting on climate change was five to ten years ago (Agnew 2022). To the contrary, Ilhan et al. (2023) show that institutional investors value and demand climate risk disclosures.

cussing biodiversity issues by using GKSZ's biodiversity dictionary. A benefit of earnings call is that they are available for firms outside of the U.S.

We again find that biodiversity words occur only rarely: just 5.1% of the quarterly calls in our sample contain at least one biodiversity term during our sample period. Therefore, a text-based validation exercise is challenging also using earnings calls. The firm-level correlation between the CBF metric and the yearly average number of mentions of biodiversity terms in earnings calls is just 8.3%. The low correlation is useful by providing some insights into the challenges when using textual analysis for identifying biodiversity risks. Notably, as shown in Figure 4, the low correlation results from many large-CBF firms *not* discussing biodiversity-related issues in their earnings calls. In the figure, we report two distributions of the CBF metric: for firms with and without mentions of biodiversity terms. The significant overlap between the two distributions indicates that many firms without mentions of these terms have *higher* biodiversity footprints than firms with mentions.[22]

With these limitations in mind, IA Section D provides—as case studies—snippets from earnings calls that do discuss biodiversity issues. The examples come from Archer-Daniels-Midland, a food processing and commodities trading firm, and from Sysco Corp, a firm active in the marketing and distribution of food products (among others). Both firms score high in the CBF metric (top 1% of the sample) and are on the target list of NA100. Archer-Daniels-Midland explains how it has accelerated the deadline for a completely deforestation-free supply chain from 2030 to 2025, and Sysco emphasizes how it has improved sustainable grazing practices across 1 million acres of grassland.

22. We also calculate that, for 2021, in almost 94% of the earnings calls of NA100 targets, there is no mention of biodiversity terms.

4.2.3 Interpretation

That simple text-based biodiversity measures overlap poorly with the biodiversity footprint is remarkable from an investor or regulatory perspective. Many firms with a large negative impact on biodiversity appear to do not address the associated risks in their corporate reports and in earnings calls, and analysts also do not probe them on these risks. More advanced natural language techniques may be able to pick up more variation in biodiversity-related discussions among firms (Schimanski et al. 2023). Moreover, Over the next years, investor demand for biodiversity disclosure will likely grow; biodiversity topics, even when measured simply, should in turn become more prominent in earnings calls and 10-Ks.

4.3 Firm-level determinants

To assess which factors drive the variation in CBF values across firms, we examine firm-level determinants of the CBF metric by estimating for firm i in year t from 2018 to 2021:[23]

$$\text{Ln}(\text{CBF})_{i,t} = \beta_0 + \beta_1 \mathbf{X}_{i,t} + \gamma_t + \delta_c + \mu_j + \epsilon_{i,t}, \tag{1}$$

where $\text{Ln}(\text{CBF})_{i,t}$ is the natural logarithm of the CBF metric in km².MSA. The vector $\boldsymbol{X}_{i,t}$ contains various firm characteristics. We include different sets of fixed effects, capturing year (γ_t), country (δ_c), and industry (μ_j) dimensions. Some estimations also use fixed effects at the level of the country-by-year ($\gamma_t \times \delta_c$), industry-by-year ($\gamma_t \times \mu_j$), or country-by-industry-

23. We also conduct a variance decomposition in IA Table A.4 to assess the relative contributions of industry-, year-, country-, and firm-level variation in explaining the CBF. The CBF metric has sizeable industry components (41.2%). Time fixed effects explain little of the variation, yielding an incremental R^2 of only 0.1% for the raw and intensity measures. Country fixed effects only account for about 3 to 5% of the variation. Interactions between industry and time fixed effects or between country and time fixed effects provide little additional explanatory power. Large parts of the variation, 55%, are unexplained by these sets of fixed effects. This indicates that CBF variation mainly plays out at the firm level.

by-year ($\gamma_t \times \delta_c \times \mu_j$). Standard errors are clustered at the firm level.

Table 3 presents estimations of Equation (1). Firm size positively relates to the biodiversity footprint, which is plausible as the CBF metric reflects the loss of biodiversity caused by a firm's activities in km^2.MSA; larger firms typically have a larger spatial impact. Firms with greater asset tangibility (PPE over assets) also have a larger footprint, which is again intuitive given that the main CBF source is land use (firms with more tangible assets likely contribute more to the degradation of biodiversity). Consistent with Bolton and Kacperczyk (2021) for carbon emissions, the biodiversity impact is smaller for firms with higher capex. Firms with higher carbon emissions also have larger biodiversity footprints, in parts because emissions are one of the pressure considered in the CBF computation. Finally, firms with better Refinitiv E scores have worse biodiversity footprints.[24]

5 Cross-section of returns

5.1 Estimation design: Cross-sectional regressions

In this section, we rely on cross-sectional regressions relating individual firms' returns to their CBF values. As in Bolton and Kacperczyk (2023), we employ a characteristic-based approach, rather than a factor-based model, which is well suited given the rich cross-sectional variation in firm characteristics in our sample. With a characteristics-based approach, there is no need to make assumptions about the underlying asset pricing model.[25] We link the

24. This indicates that it may be misleading to rely on aggregate E scores to incorporate biodiversity into investment decisions, as a negative biodiversity impact does not translate into a lower E score. One reason is that most ESG raters, including Refinitiv, focus on aspects that are financially material to shareholder value, rather than impact materiality.

25. As explained by Bolton and Kacperczyk (2023), a conceptual difficulty with the choice of asset pricing model, in the context of a complex pricing problem such as climate risk, is that no such model has yet been formulated. The same argument applies in our setting, especially since biodiversity risk has received less

return of firm i in month m of year t to its corresponding biodiversity footprint in year *t-1*:

$$\text{Monthly return}_{i,m,t} = \beta_0 + \beta_1 \text{Ln(CBF)}_{i,t-1} + \beta_2 \mathbf{X}_{i,t-1} + \gamma_t + \delta_c + \mu_j + \epsilon_{i,m,t}, \tag{2}$$

where Monthly $\text{return}_{i,m,t}$ is the return of firm i in month m of year t and $\text{Ln(CBF)}_{i,t-1}$ is the natural logarithm of the biodiversity footprint of firm i in year *t-1*. We control for various firm characteristics, following prior studies on the asset pricing implications of environmental externalities (e.g., Bolton and Kacperczyk 2023; Hsu, Li, and Tsou 2023). Specifically, $\boldsymbol{X}_{i,t-1}$ includes Ln(Total assets) (annual), Ln(Market cap) (monthly), Book-to-market (monthly), Leverage, Capex/Total assets, PPE/Total assets, ROA, Asset growth, Sales growth (all annual), as well as Volatility and Momentum (both monthly). Annual (monthly) variables are lagged by one year (month). We control for year-month, industry, and country fixed effects, and double cluster standard errors at the year-month and firm level.

5.2 CBF and the cross-section of returns: Baseline results

Table 4 reports in Column 1 the results of estimating Equation (2) with time, country, and industry fixed effects across the full sample period using monthly returns between January 2019 and December 2022. While the coefficient on Ln(CBF) is positive, it is not statistically significant. Hence, on average, a larger biodiversity footprint is *not* associated with greater (or lower) returns. In Column 2, this average non-result holds when we account for time-varying unobserved heterogeneity at the industry level (industry-by-time fixed effects).

Investors may start considering the risks associated with a firm's biodiversity footprint in response to important policy-related news. Arguably particularly relevant is the Kunming

attention than climate risk.

Declaration, which—together with the subsequent Montreal Agreement—has been hailed as being the biodiversity equivalent of the climate-focused Paris Agreement. The Kunming Declaration was adopted at the 15$^{\text{th}}$ Conference of the Parties of the CBD (COP15) in October 2021.[26] More than 100 countries committed to developing, adopting, and implementing an effective post-2020 global framework to put biodiversity on a path to recovery by 2030. Analogous to the Paris Agreement, the Declaration stresses the need to align financial flows in support of the conservation and sustainable use of biodiversity (Article 13).

In Table 4, Columns 3–6, we split the sample period into monthly returns from January 2019 to September 2021 (pre-Kunming period) and from October 2021 to December 2022 (post-Kunming period). In Columns 3–4, we continue to find no significant effects in the period before the Kunming Declaration. By contrast, in Columns 5–6, a larger CBF value is associated with significantly greater returns in the post-Kunming period. In Column 5, a one-standard-deviation increase in Ln(CBF) is associated with an additional monthly return of 18.5 basis points, or a 2.2% annualized increase. In Wald tests of coefficient equality, the coefficients on Ln(CBF) are statistically significantly different across the pre- and post Kunming periods (with p-values of 0.019 and 0.036, respectively).

5.3 CBF and the cross-section of returns: Country heterogeneity

To shed light on the mechanism behind these results, we examine whether the cross-sectional return differ across countries depending on two measures of biodiversity protection: i) the Biodiversity & habitat index, which assesses countries' actions toward retaining natural ecosystems and protecting biodiversity within their borders; and ii) the Ecosystem vitality

26. The UN Convention on Biological Diversity (CBD) was opened for signature at the Earth Summit in Rio de Janeiro on June 5, 1992 and entered into force on December 29, 1993. Since then, 15 Conferences of the Parties to the CBD (COPs) have been held, though success has been limited until recently. IA Section E provides a historical overview of global and regional policy developments and initiatives.

index, which captures how well countries are preserving, protecting, and enhancing ecosystems and the services they provide. We create two dummy variables that each equal one if biodiversity protection in a country falls below the median ("Low protection"), and zero otherwise ("High protection"). Both variables are measured as of before the Kunming Declaration (end of 2020); values of the indexes by country are reported in IA Table A.5. We then estimate an augmented version of Equation (2) for the post-Kunming period:

$$\begin{aligned} \text{Monthly return}_{i,m,t} = \beta_0 + \beta_1 \text{Ln(CBF)}_{i,t-1} \times \text{Low protection}_c \\ + \beta_2 \text{Ln(CBF)}_{i,t-1} + \beta_3 \mathbf{X}_{i,t-1} + \gamma_t + \delta_c + \mu_j + \epsilon_{i,m,t}, \end{aligned} \tag{3}$$

where $\text{Monthly return}_{i,m,t}$ and $\text{Ln(CBF)}_{i,t-1}$ are defined as above, and Low protection_c in country c is constructed as just explained. We include the same control variables and fixed effects as in Equation (2). Low protection_c is absorbed by the country fixed effects.

Table 5 reports estimations of Equation (3). In Columns 1 and 4, we find for both biodiversity protection measures that the effects of high-CBF stocks on returns are significantly amplified in low-protection countries: the coefficients on $\text{Ln(CBF)}_{i,t-1} \times \text{Low protection}_c$ are positive and statistically significant in both columns. The standalone effects for Ln(CBF) are not significantly different from zero, implying that the returns for high-CBF stocks accrue entirely in low-protection countries. We find similar results in Columns 2–3 and 5–6 if we use sample splits into low- and high-protection countries instead of interaction terms.

5.4 CBF and the cross-section of returns: Robustness

Given the conceptual links and overlaps between biodiversity and climate change discussed in Section 2.5, a concern is that our results are driven by carbon emissions, rather than broader biodiversity impacts of firms. To address this concern, we test whether our main results hold when directly controlling for two measures of climate transition risk: carbon emissions and firm-level regulatory climate change exposure.[27]

The results that address robustness of Table 4 are reported in IA Table A.6. In Columns 1–4, we add Ln(CO_2 Emissions) and CCExposure^{Reg} as firm-level control variables. While the CBF metric continues to be unrelated to returns over the full sample period, a significant biodiversity footprint premium emerges in the post-Kunming period. While only significant at the 10% level, the magnitudes of the post-Kunming estimates are similar compared to the baseline (0.060 in Column 2 and 0.055 in Column 4, which compares to 0.061 in Table 4, Column 5). As a complementary robustness check, in Columns 5–6, we report estimates in which we compute the CBF metric considering only land use, air pollution, and water pollution (that is, we exclude the GHG component). We continue to find that the "emissions-free" biodiversity footprint is positively associated with returns in the post-Kunming period.

Results are even stronger even in IA Table A.7, in which we document the robustness of Table 5 after controlling for climate transition risk.

A further concern is that our results may be confounded by non-linear size effects. However, in IA Table A.8, we obtain positive and significant return effects also for intensity measures (CBF scaled by total assets or sales). This evidence is useful, as the TNFD focuses on scaled measures. Further, in IA Table A.9, our baseline results hold when implementing alternative standard error clusterings. In Columns 1–2, we cluster standard errors at

27. We verify that our sample firms earn a carbon premium using an estimation as in Bolton and Kacperczyk (2023) (same 2005-2018 sample period). For the 2019-2022 sample period in our paper, emissions remain positively associated with returns, but the estimate is more noisy (t-statistic of 1.24). This is possibly for three reasons: i) our period may be too short to estimate the carbon premium with precision; ii) the trend towards ESG investing during the past years may have led to unexpected shifts in climate concerns and investors' preferences, pushing up realized returns for low-emission stocks Pástor, Stambaugh, and Taylor (2022); and iii) in Bolton and Kacperczyk (2023), the rise in the carbon premium since the Paris Agreement originates mostly from Asian firms, which constitute a relatively smaller fraction in our sample compared to Bolton and Kacperczyk (2023).

firm-year level, in Columns 3–4 we cluster at the firm level, and in Columns 5–6 we double cluster at the firm and year level as in Bolton and Kacperczyk (2021, 2023). The choice of clustering by year-month (48 groups) instead of year (four groups) is motivated by the small number of clusters it would generate, which can be problematic econometrically.

We verify in IA Table A.10 that our results hold if we restrict the estimation to firms inside the MSCI ACWI universe. These results are reassuring as they suggest that IDL's coverage decision within the MSCI ACWI does not unduly bias our estimates.

A further concern is that realized returns, while providing unbiased estimates of expected returns, are notoriously noisy and lead to effects due to luck, especially in short samples (e.g., Elton 1999; Lundblad 2006). Pástor, Sinha, and Swaminathan (2008) show that expected return-risk tradeoffs can sometimes more easily be detected using the implied cost of capital (ICC), instead of realized returns. Similarly, Cenedese, Han, and Kacperczyk (2023) argue in the climate finance context that estimates for expected returns derived from valuation models can help corroborate that effects observed in realized returns indeed reflect required, expected returns rather than luck. The ICC is the discount rate (or internal rate of return) that equates a firm's market value to the present value of expected future cash flows. We therefore construct an ICC measure and relate it to the CBF metric. We derive the ICC measure as an average across four valuation models, following the approach by Lee, So, and Wang (2021).[28] In IA Table A.11 we re-estimate Equation (2) after replacing Monthly

28. We calculate the ICC measure as a mean value of the ICCs derived from the GLS model (Gebhardt, Lee, and Swaminathan 2001), the CAT model (Claus and Thomas 2001), the PEG model (Easton 2004), and the AGR model (Ohlson and Juettner-Nauroth 2005). The GLS and CAT models are based on variants of the residual-income model, and they differ in terms of their forecasting horizon and terminal value estimation. The PEG and AGR models are based on the abnormal-growth-in-earnings model, they differ in their formulation of the long-term growth in abnormal earnings. For details on the computations, see Lee, So, and Wang (2021)'s Appendix B.2. All four ICC measures are based on earnings forecasts derived from the cross-sectional mechanical forecast model of Hou, Van Dijk, and Zhang (2012), and do not have to rely on analyst forecasts, which facilitates the ICC computation for a large cross-section of international firms.

return with Monthly ICC.[29] While CBF is unrelated with ICC in the pre-Kunming period, we observe that CBF has a positive and significant association with ICC after Kunming. In the Post-Kunming period, a one-standard-deviation increase in Ln(CBF Value) is associated with a monthly ICC increase of 0.057% (0.94% annualized).

6 Event study evidence

6.1 Estimation design: Event study

A concern with Section 5.2 is that the returns after the Kunming Declaration are due to confounding factors correlated with a firm's CBF. To address this concern, we conduct an event study in which we examine daily returns of firms with large versus small biodiversity footprints around the date of the Kunming Declaration. We estimate the following regression at the firm-day level over a window of three days before to three days after the event:

$$\text{Daily return}_{i,t} = \beta_0 + \beta_1 \text{Large CBF}_i \times \text{Post}_t + \delta_i + \gamma_t + \epsilon_{i,t}, \tag{4}$$

where Daily $\text{return}_{i,t}$ is the return of firm i in day t, Large CBF_i equals one if the firm has a large biodiversity footprint (CBF is above the median), and Post_t equals one after the event. The event date is the last day of the Kunming conference (October 13, 2021), and it is the first day of the post-event window (denoted as t=0). We label the event window as [-3,2] days, reflecting the three days before the event date and three days following it (the event date plus two days). We control for firm (δ_i) and day (γ_t) fixed effects. The firm fixed effects control for firm characteristics or potential determinants of stock returns that

29. We match the ICC measure, computed at the end of month t, so that it corresponds to the realized return over the following month.

are fixed around the days of the event. The standalone variables Large CBF_i and Post_t are absorbed by, respectively, the firm and time fixed effects. Standard errors are clustered at the country level. The coefficient of interest β_1 captures the differential in daily returns for large-CBF stocks in the days following Kunming, relative to small-CBF stocks.

6.2 Event study of the Kunming Declaration

Table 6 reports the results of estimating Equation 4. In Columns 1–4, we report results for raw returns and in Columns 5–8 for abnormal returns (in excess of each firm's domestic market index). In Column 1, Large CBF × Post is negative and statistically significant at the 1% level, indicating that large-CBF firms experienced statistically lower returns than small-CBF firms. On average, in the three days following the October 13 announcement, the daily returns of large-CBF firms were 0.38% below those of small-CBF firms. These effects accumulate to a cumulative valuation decline of -1.14% over the three-day period. In Columns 2–3, results are similar if we control for country- or industry-wide reactions around the day of the Kunming Declaration, and in Columns 5–7, they are similar if we use abnormal returns. In Columns 4 and 8, we replace the Post variable with dummies capturing the individual days surrounding the Kunming Declaration. In this dynamic specification, we estimate effects relative to day t=-3. The negative price reaction for large-CBF firms mostly spans the day of the declaration and the following day (t=0 and t=+1), both in Column 4 and 8. Before the declaration, we observe no significant differences in the returns of large- versus small-CBF firms. An exception is t=-1 in Column 4 for raw returns, where we find a weakly significant effect; this effect disappears in Column 8 with abnormal returns.

To capture possible pre-trends and reversals, we expand the time window to [-5;5] days. Figure 5 reports the average difference in returns between large- and small-CBF stocks for a given day. While there are no significant return differences before the Kunming Declaration, there is a significant relative price drop for high-CBF firms on the day of the Kunming Declaration (t=0). There is no significant valuation reversal following the Declaration.

We document in IA Table A.12 that the event study results also hold when controlling for carbon emissions and regulatory climate change exposure. In IA Table A.13, we re-estimate variants of Table 6, Column 1, documenting negative and significant return reactions for three of the four sources of pressures. We also observe a negative reaction when we categorize stocks into large- versus small-CBF groups based on intensity measures. Results are also unchanged if we define as large-CBF firms those with a CBF value in the top quartile or top tercile, or use the continuous CBF measure instead of the Large CBF dummy. In IA Table A.14, the event study results hold if we restrict the sample to MSCI ACWI stocks. Results are also robust to clustering standard errors at the industry or firm levels (unreported).

6.3 Event study of the TNFD launch

The Kunming Declaration emerges as a key event due to which prices of large-CBF stocks were bid down. The bid-down prices in turn imply higher expected returns at high-CBF stocks, which we document in the cross-sectional tests when splitting the sample into a pre- and post-Kunming period. While these results closely align, we do not posit that the Kunming Declaration was the only relevant biodiversity policy event, uniquely triggering a regime shift and valuation declines. Instead, other recent events may have had similar effects. The launch of the TNFD, in particular, is likely a further salient event which may have contributed to changes in investors' perceptions of biodiversity risk. Similar to the TCFD, the TNFD seeks to develop and deliver a risk management and disclosure framework for organizations to report and act on evolving nature-related risks. While initially voluntary, it is widely expected that the TNFD recommendations eventually become mandatory. The formal launch of the TNFD, with endorsement by the G7 countries, took place on June 4, 2021, that is, just four months before the Kunming Declaration.[30] A first disclosure framework was released by the TNFD in early 2022, and the final one in September 2023.

We in turn examine whether and how investors revised their valuations of large- versus small CBF stocks around the TNFD launch. We re-estimate Equation (4) around June 4, 2021, the date of the TNFD launch, with results reported in Table 7. In Column 1, in the three days following the TNFD launch, relative to the three days before, large-CBF stocks experienced a significant decline of about -0.5% per day on average. The estimates are robust to alternative fixed effects in Columns 2–3, and we find no pre-trends in Column 4. In Columns 5–8, the conclusions are also unaffected when using abnormal returns. Motivated by this finding, we also re-estimate the cross-sectional regression from Equation 2 for the post-TNFD period, instead of the post-Kunming period. Unsurprisingly given the close proximity of the events, Ln(CBF) positively and significantly relates to returns post-TNFD. Overall, the general developments exemplified by the Kunming Declaration and the TNFD appear to have shifted the return dynamics.

7 Interpreting the overall evidence

Having established evidence on the cross-section of returns and more granular evidence from two biodiversity policy events, the question that emerges is what economic channels explain these patterns consistently. Three channels could create a link between the CBF metric and

30. A potentially confounding event to the TNFD launch was a proposed regulatory revisions to the Endangered Species Act (ESA) by the the U.S. Fish and Wildlife Service. In these revisions, changes made during the Trump Administration were rescinded. The release of the plan to improve and strengthen the implementation of the ESA was also on June 4, 2021, the TNFD event date.

returns: i) shifts in investor preferences; ii) unexpected cash flows shocks; or iii) a biodiversity transition risk premium. We evaluate each of these channels in turn.

According to the first channel, investor preferences change over time because of a heightening of biodiversity concerns. These changes imply gradual shifts in fund flows and equity investments towards low-CBF firms, away from high-CBF firms. While plausible in other ESG contexts, our overall evidence does not line up with this channel: it would predict that high-CBF firms have *lower* (not higher) returns in the months since the Kunming Declaration (Pástor, Stambaugh, and Taylor 2021, 2022).[31] Our results are also hard to reconcile with unexpectedly high cash flows of high-CBF stocks, the second channel. The valuation declines in the event studies are inconsistent with such cash flow surprises, and it is conceptually unclear why any such unexpectedly higher cash flows would materialize only in the months after Kunming and not before.

Instead, the positive cross-sectional link between CBF and returns is consistent with a risk premium channel. According to this interpretation, the CBF metric proxies for exposure to biodiversity transition risk, and our results reflect the pricing of such risk. This channel aligns with the pricing of carbon transition risk, proxied using the corporate carbon footprint (Bolton and Kacperczyk 2021, 2023). The cross-country results support the risk premium interpretation because, in countries with low biodiversity protection, the uncertainty about, and expected stringency of, future regulation should be the highest. The risk premium channel in turn implies that the premium should be larger in countries with low biodiversity protection. By the same token, firms should have lower exposure to biodiversity transition risks if located in countries that have already taken ambitious actions to protect biodiversity (there is much less uncertainty on the expected future path). The event study results also

31. Pástor, Stambaugh, and Taylor (2022) document that a strengthening of climate concerns are responsible for the outperformance of "green" stocks relative to "brown" stocks from 2012 to 2020.

line up with the risk premium channel. The evidence that we obtain indicates that the Kunming Declaration was one key event around which the prices of high-CBF stocks were bid down in response to changes in investor beliefs about biodiversity risks. The bid-down stock prices in turn imply higher expected returns at high-CBF stocks.

A biodiversity risk premium can operate through cash flow uncertainty related to biodiversity transition risk: investors may worry about how future biodiversity regulation or litigation affect investments, stranded assets, and the operating performance of firms, all of which increases cash flows uncertainty. Another source relates to changes in a firm's discount rates, that is, changes in how investors perceive the biodiversity transition risks of firms (e.g., there may be changes to the model used to price these risks).

This prompts the question of how to interpret the TNFD results within the risk premium channel. While primarily about biodiversity-related disclosure, the TNFD launch have also raised awareness of biodiversity issues, signifying the importance of future transition risks. If this is the case, then investors should also have revised downward after the TNFD launch their valuation of large-CBF stocks. More disclosure can also increase the odds of firms being targeted by litigation. Hence, like Kunming, the TNFD launch may have contributed to changing investors' awareness of biodiversity transition risk.

A transition risk premium provides investors with a compensation for future losses related to the realization of transition risks. This raises the question of whether there have been examples to date where such risks materialized. In a recent report, BloombergNEF (2023) provide case studies where transition risks materialized through the impacts of firms on nature. One case in point is chemicals producer 3M, who entered in June 2023 into a $10.5 billion settlement with U.S. water authorities because it introduced substances known as PFAS into water (PFAS are harmful to the environment and hundreds of species risk harm from it). The case was associated with a large share price decline of 3M.

8 Comparison with MSCI and Refinitiv measures

We compare the CBF metric to two measures provided by commercial data vendors: i) MSCI's biodiversity & land use exposure score, and ii) Refinitiv's biodiversity impact reduction indicator. These measures are also available for a longer time-series, but not based on the biodiversity impact metrics discussed in Section 2. Hence, they differ conceptually from the CBF measure, which uses MSA to quantify a firm's biodiversity impact.[32]

MSCI scores a firm's biodiversity and land use exposure on a 0-10 scale, with 10 corresponding to the highest and 0 to the lowest risk. The score aims to capture three risks for firms: i) loss of license to operate; ii) litigation by landowners and other affected parties; and iii) increased costs of land protection and reclamation. The CBF value and MSCI score both seek to measure firms' impact on biodiversity, though—as score name suggests—MSCI mostly considers land use. That said, the CBF metric provides a more complete measure of the biodiversity impact. First, the MSCI score is not a quantitative measure of the impact on biodiversity, and it is in turn also not considered in the review of biodiversity metrics by Finance for Biodiversity (2022). Second, MSCI focuses on the direct operations of a firm, rather than the overall life cycle of its products.[33] By contrast, the life cycle assessment in the CBF calculation captures the potential environmental impacts associated with the production of a good or service. It takes into account all or part of the production stages, from the supply chains of raw materials to the end of the product's life. IA Table A.15 sum-

32. As explained, MSCI plans on introducing an MSA-based measure in 2024, initially without a time-series. Hoepner et al. (2023) employ another measure of a firm's biodiversity impact, which was constructed by Eiris (now majority owned by Moody's). However, Eiris stopped providing the measure in January 2018.

33. Consistent with this observation, the MSCI score has a correlation of 0.56 with the Scope 1 component of the CBF, but only a 0.01 (0.31) correlation with the scope 2 (scope 3) components (IA Table A.16).

marizes the comparison between CBF and MSCI and Refinitiv's measure, and we explain how both vendors construct their scores in IA Section F.[34]

Refinitiv's measure is a dummy variable indicating whether a firm reports its impact on biodiversity or on activities to reduce this impact. This indicator positively correlates with Ln(CBF) (correlation of 0.32), suggesting that firms with larger biodiversity footprints disclose more on the topic (IA Table A.16). IA Figure A.3 reports the distributions of CBF values for disclosing and non-disclosing firms according to the Refinitiv measure. While firms disclosing more on biodiversity tend to have higher CBF values, there are also many cases where non-disclosing firms have much larger biodiversity footprints than disclosing firms.

Beyond the comparison, we replicate our returns results after replacing the CBF metric with MSCI's score. IA Table A.17, Panel A, reports that a positive impact of the MSCI's score on returns emerges in the post-Kunming period, whereas there is no effect before.[35] For MSCI's measure, the post-Kunming results are so strong that even in the overall sample, the MSCI score is positive and statistically significant. In Panel B, we find a negative and significant reaction for firms with above-median MSCI scores, but this effect disappears once we control for industry shocks occurring on days of the event window.

9 Conclusion

Biodiversity loss and climate change are two of the major crises of our era. Research on climate finance has grown rapidly over the past years, thereby improving our understanding of the potential consequences of climate change for financial markets. By stark contrast,

34. MSCI also provides a biodiversity & land use *management* score, which evaluates a firm's ability to manage its exposure. The score is available for a small sample. Xin et al. (2023) utilize this score.

35. The MSCI score is also available for years before 2019. We do not find a significant relation with returns even when we include additional years in the pre-Kunming period.

there has been very little research on biodiversity finance. Although the two crises are related, biodiversity preservation can clash with actions taken to address climate change. For example, renewable energy and electric cars require lithium, cobalt, magnesium, and nickel, the mining of which comes with severe impacts on biodiversity (and on the human communities that rely on biodiversity). Therefore, it is important to separately analyze finance's role in the loss of biodiversity. Our paper offers a first step toward understanding the interplay between finance and biodiversity by introducing a measure of the corporate biodiversity footprint and exploring whether it is priced by investors.

Examining a large sample of international stocks, we find that over our sample period, investors did not care about the impact of firms on biodiversity, on average. However, things appear to be changing, as we document the emergence of a biodiversity footprint premium following the Kunming Declaration (the first part of the COP15) and the launch of the TNFD. Consistent with this effect, we document negative stock price reactions for firms with large biodiversity footprints in the days following the Kunming Declaration and the launch of the TNFD. Our results indicate that investors start to ask for a return premium in light of the uncertainty associated with future biodiversity regulation.

Appendix A. Variable definitions

Variables	Definitions	Sources
CBF	Biodiversity loss caused by the firm's annual activities. It results from four environmental pressures: land use transformation, emission of greenhouse gases, emission of nitrogen oxides, and release of toxic compounds into the environment. It is expressed in km^2.MSA, which is equivalent to the pristine natural area destroyed by the firm's annual activities. MSA (Mean Species Abundance) is a metric characterizing the level of biodiversity in an ecosystem. The original CBF metric is a negative number, corresponding to the degradation of biodiversity caused by the firm. We multiply this variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
Large CBF	Dummy variable that equals one if the firm has a large biodiversity footprint (CBF is above the median) as of the beginning of the year, and zero otherwise. Annual data.	Iceberg Data Lab
CBF GHG	Biodiversity loss due the firm's greenhouse gas (GHG) emissions. In addition to direct GHG emissions due to the firm's energy consumption, GHG emissions resulting from the electricity consumption and emissions of products purchased in the firm's upstream supply chain are taken into account. We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF land use	Biodiversity loss due the firm's due to transformation of pristine land into agricultural land or artificialized areas. The firm's direct pressures on land use, such as its physical assets, buildings, or plantations, are factored in. The land use impact of the firm's upstream supply chain (i.e., purchased products) is also taken into account. We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF water pollution	Biodiversity loss due the firm's due to the release of toxic compounds into the water. Release of substances due to the firm's direct activity (e.g., processing food or fertilizing crops) are taken into account, as well as those of the firm's upstream supply chain. We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF air pollution	Biodiversity loss due the firm's release of nitrogen oxides (NOx) into the air. Direct pressures coming from the firm, such as NOx emissions arising from its fuel consumption, are taken into account, as are NOx emissions arising from the electricity consumption and emissions of products purchased in the firm's upstream supply chain. We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF scope 1	Biodiversity loss due the firm's direct activities (i.e., surface artificialized or occupied). We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF scope 2	Biodiversity loss due the firm's purchase of electricity, heat, and cooling. We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF scope 3	Biodiversity loss due the firm's firm's indirect activities (such as its products sold or investments made, or products purchased by the firm). We multiply the original variable by -1 so that higher values indicate a more negative impact on biodiversity. Annual data.	Iceberg Data Lab
CBF/Total assets	CBF value scaled by total assets in $. Winsorized at the 2.5% and 97.5% levels. Annual data.	Iceberg Data Lab
CBF/Sales	CBF value scaled by revenue in$. Winsorized at the 2.5% and 97.5% levels. Annual data.	Iceberg Data Lab

Monthly return (%)	Monthly stock return. We build total return using stock prices expressed in $ (prccd), adjustment factors (ajexdi), exchange rates (exratd), and total return factors (trfd). Winsorized at the 1% and 99% levels. Monthly data.	Compustat
Monthly ICC (%)	Monthly implied cost of capital (ICC). Following Lee, So, and Wang (2021), we construct the variable as the mean value across four ICC values of the following valuation models: GLS (Gebhardt, Lee, and Swaminathan 2001), CAT(Claus and Thomas 2001), PEG (Easton 2004), and AGR (Ohlson and Juettner-Nauroth 2005). The GLS and CAT models are based on variants of the residual-income model, they differ in terms of their forecasting horizon and terminal value estimation. The PEG and AGR models are based on the abnormal-growth-in-earnings model, they differ in their formulation of the long-term growth in abnormal earnings. We trim the ICC values below zero or above one for the the four models. We compute the mean across the four ICC measures, requiring a non-missing value for PEG.	Compustat
Daily return (%)	Daily stock return. We build total return using stock prices (prccd) expressed in $, adjustment factors (ajexdi), exchange rates (exratd), and total return factors (trfd). Winsorized at the 1% and 99% levels. Monthly data.	Compustat
Volatility (%)	Standard deviation of the monthly returns over the 36 preceding months. Winsorized at the 1% and 99% levels. Monthly data.	Compustat
Momentum (%)	Average monthly return over the twelve preceding months. Winsorized at the 1% and 99% levels. Monthly data.	Compustat
Total assets	Total assets. Winsorized at the 1% and 99% levels. Annual data.	Compustat
Market cap	Market Capitalisation. Winsorized at the 1% and 99% levels. Monthly data.	Compustat
Book-to-market	Ratio of book equity to market capitalization. Winsorized at the 1% and 99% levels. Monthly data.	Compustat
Leverage	Total debt, divided by total assets. Winsorized at the 1% and 99% levels. Annual data.	Compustat
Capex/Total assets	Capital expenditures divided by total assets.Winsorized at the 1% and 99% levels. Annual data.	Compustat
ROA	Income before extraordinary items divided by total assets. Winsorized at the 1% and 99% levels. Annual data.	Compustat
PPE/Total assets	Net property, plant, and equipment, divided by total assets. Winsorized at the 1% and 99% levels. Annual data.	Compustat
Asset growth	Percentage change in total assets. Winsorized at the 1% and 99% levels. Annual data.	Compustat
Sales growth	Percentage change in sales. Winsorized at the 1% and 99% levels. Annual data.	Compustat
E score	Score that reflects how a firm uses best management practices to avoid environmental risks and to capitalize on environmental opportunities to generate long-term shareholder value. Higher numbers indicate better environmental performance. Winsorized at the 1% and 99% levels. Annual data.	Refinitiv
Trucost estimated emissions	Dummy variable that is equal to one if data on a firm's carbon emissions is estimated, and zero if data on a firm's carbon emissions is disclosed.	Trucost
Biodiversity impact reduction	Dummy variable that is equal to one if a firm reports on its impact on biodiversity or on activities to reduce its impact, and zero otherwise. Annual data.	Refinitiv
CO_2 Emissions	Natural total CO_2 and CO_2 equivalent emissions, in tonnes. It encompasses the sum of scope 1, scope 2, and scope 3 emissions. Winsorized at the 1% and 99% levels. Annual data.	Trucost
High emissions	Dummy variable that is equal to one if CO_2 Emissions is above the median value, and zero otherwise. Calculated as of end of 2020. Annual data.	Trucost

CCExposure^{Reg}	Regulatory climate change exposure measure from Sautner et al. (2023). Reflects the relative frequency with which bigrams that capture regulatory shocks related to climate change occur in the transcripts of earnings conference calls. The measure uses the average over the last four quarters. Annual data.	Sautner et al. (2023)
High CCExposure^{Reg}	Dummy variable that is equal to one if CCExposure^{Reg} is above the median value, and zero otherwise. Calculated as of end 2020. Annual data.	Sautner et al. (2023)
10-K Biodiversity count score	Dummy variable that is equal to one if a firm's 10-K statement contains at least two sentences related to biodiversity, and zero otherwise. Annual data.	Giglio et al. (2023)
Biodiversity & habitat index	This measure assesses countries' actions toward retaining natural ecosystems and protecting the full range of biodiversity within their borders. It consists of seven indicators, some of which are based on separate indexes: Terrestrial biome protection, Marine protected areas, Protected Areas Representativeness Index, Species Habitat Index, Species Protection Index, and Biodiversity Habitat Index. Measured as of 2020.	Yale Center for Environmental Law & Policy
Ecosystem vitality index	This measure captures how well countries are preserving, protecting, and enhancing ecosystems and the services they provide. It comprises 42% of the total EPI score and is made up of six issue categories: Biodiversity & Habitat, Ecosystem Services, Fisheries, Acid Rain, Agriculture, and Water Resources. Measured as of 2020.	Yale Center for Environmental Law & Policy
Low protection	Dummy variable that is equal to one if a country is below the median value of the Biodiversity & habitat index (Ecosystem vitality index) as of end 2020, and zero otherwise.	Self-constructed
Biodiversity & land use exposure score	Score from 0 to 10 indicating the extent to which a firm's business is exposed to the issue of biodiversity and land use based on its unique mix of business and geographic segments. Examples of criteria assessed include: the products and services a firm provides; location of firm operations; and the nature of those operations. Higher scores indicate greater risk. Annual data.	MSCI

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Figure 1: Decomposition of the corporate biodiversity footprint

Panel A decomposes the CBF into its constituent topical subcomponents (or sources). Panel B decomposes the CBF into its scope 1, scope 2, and scope 3 dimensions. Scope 1 measures the environmental pressure of the firm's direct activities, scope 2 measures the pressures induced by the firm's purchase of electricity, heat, and cooling, and scope 3 measures all indirect pressures. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.

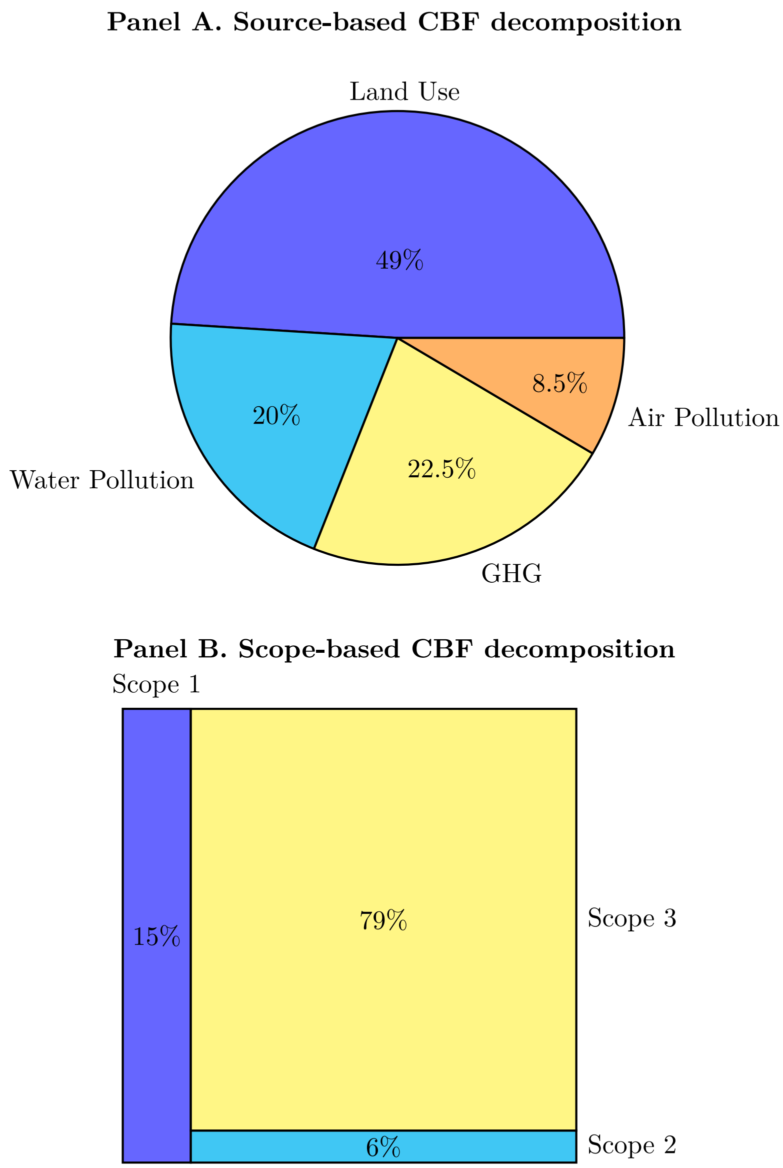
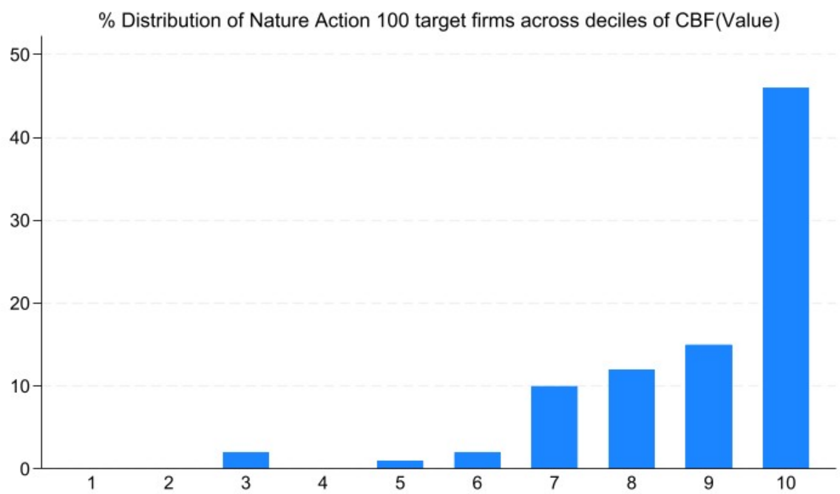


Figure 2: Nature Action 100 Targets and corporate biodiversity footprint

This figure reports the presence of Nature Action 100 target firms across deciles (Panel A) and quintiles (Panel B) of the Ln(CBF) distribution. For each firm, we consider the latest observation in our sample to construct the distribution. We restrict our sample in the figures to industries covered by Nature Action 100. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.

Panel A. Deciles of the Ln(CBF) distribution



Panel B. Quintiles of the Ln(CBF) distribution

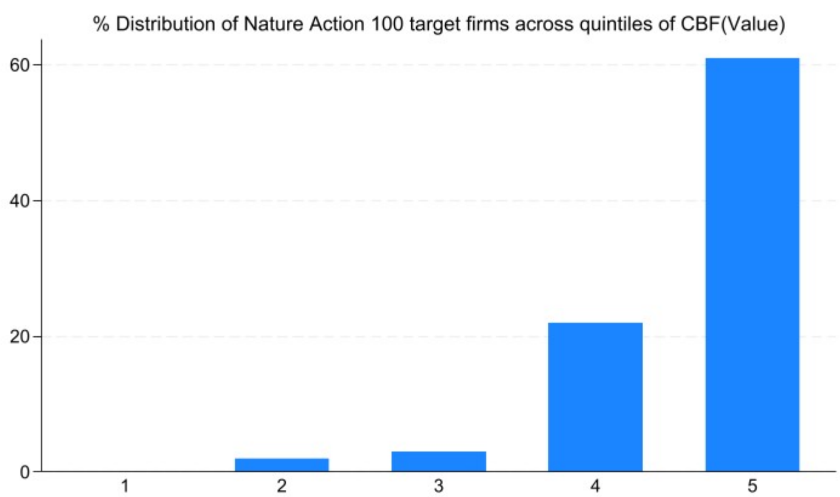


Figure 3: Biodiversity footprint and biodiversity terms in 10-Ks

This figure displays the CBF distribution for firms with and without disclosure of biodiversity terms in their 10-K reports. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The measure of biodiversity disclosure is based on Giglio et al. (2023)'s variable "10-K Biodiversity Count Score."

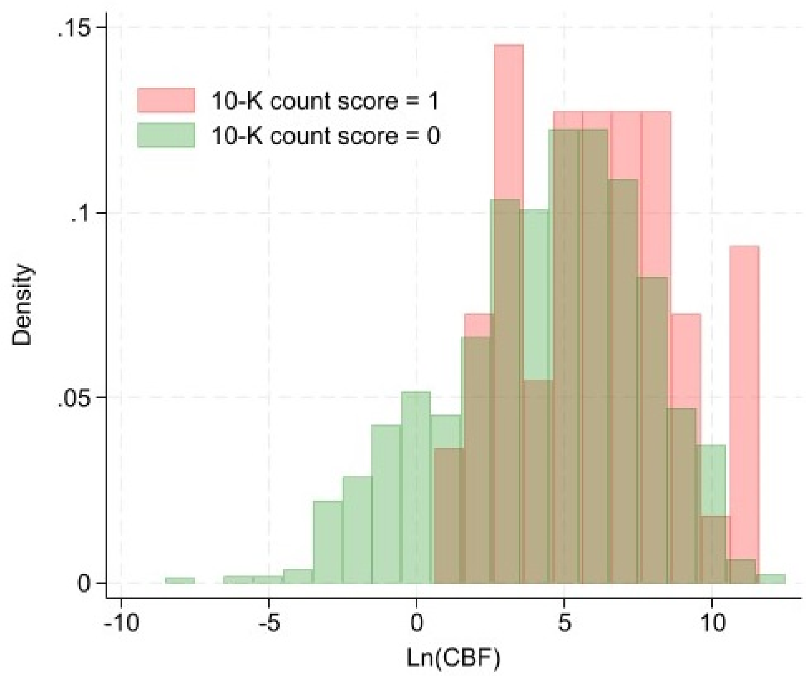


Figure 4: Corporate biodiversity footprint and biodiversity terms in earnings calls

This figure displays the CBF distribution for firms with and without mentions of biodiversity terms in their earnings calls. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.

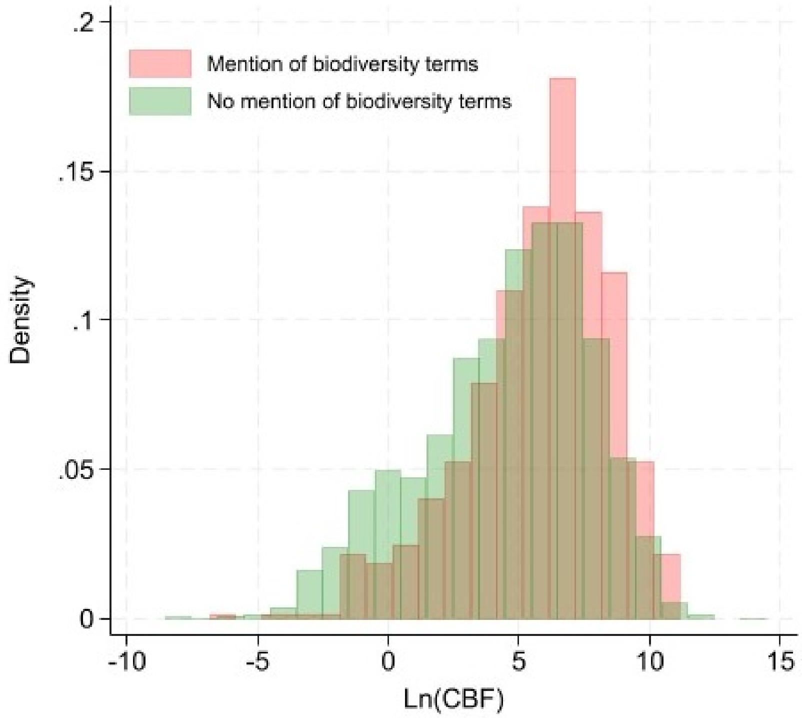


Figure 5: Kunming Declaration: Return differences between large- and small-CBF firms

This figure reports daily mean stock return differences around the Kunming Declaration between large- and small-CBF firms. It covers the event window [-5,+5]. The day of the Kunming Declaration (event date) is t=0. Returns are adjusted for the mean daily return of the country and the mean daily return of the industry. Large-CBF (small-CBF) firms have a CBF value that is above (below) the median as of end 2020. We also report 95% confidence interval. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.

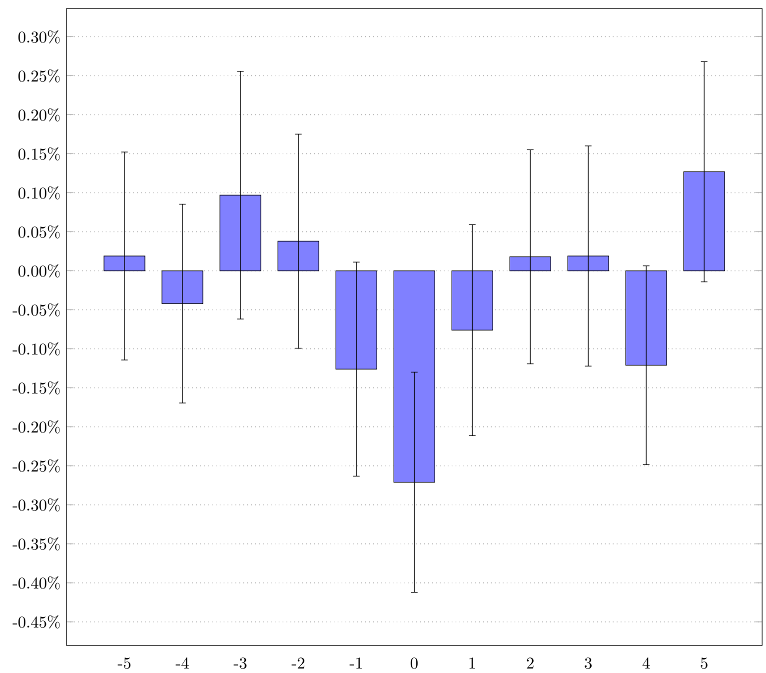


Table 1. Summary statistics

This table presents summary statistics at the firm-month level of the variables used in the returns analysis. The sample period uses returns between 2019-2022. The CBF, accounting, ESG, and CO_2 Emission variables are measured at the annual frequency and lagged by one year. Market capitalization, volatility, and momentum are measured at the monthly frequency and lagged by one month. Appendix A provides variable definitions.

Variables	#Obs.	Mean	S.D.	Min	25%	50%	75%	Max
Ln(CBF)	89,132	4.79	3.11	-9.25	3.17	5.28	7.01	13.78
Ln(CBF GHG)	89,132	2.27	2.97	-12.33	0.24	2.51	4.42	10.08
Ln(CBF land use)	88,820	3.60	3.56	-15.88	1.75	4.10	6.06	13.77
Ln(CBF water pollution)	89,132	1.37	4.27	-15.53	-1.15	2.21	4.40	11.34
Ln(CBF air pollution)	89,132	1.47	3.29	-13.47	-0.39	1.96	3.71	9.12
Ln(CBF scope 1)	89,012	0.88	3.82	-12.69	-2.03	0.98	3.81	13.77
Ln(CBF scope 2)	88,856	-4.54	5.51	-30.77	-8.70	-3.18	-0.15	6.57
Ln(CBF scope 3)	89,120	4.36	3.45	-11.26	2.78	5.01	6.78	12.11
Ln(CBF/Total assets)	89,132	-4.34	2.73	-11.28	-5.50	-3.86	-2.45	0.10
Ln(CBF/Sales)	89,108	-3.75	2.61	-10.21	-4.88	-3.17	-1.90	0.30
Monthly return (%)	89,132	1.18	10.53	-25.63	-5.28	0.81	7.02	34.40
Monthly ICC (%)	48,814	0.67	0.86	0.00	0.02	0.46	0.84	4.97
Volatility (%)	89,132	0.10	0.04	0.04	0.07	0.09	0.12	0.24
Momentum (%)	89,132	0.01	0.04	-0.05	-0.01	0.01	0.03	0.19
Ln(Total assets)	89,132	9.15	1.47	5.83	8.13	9.10	10.09	12.93
Ln(Market cap)	89,132	23.46	1.40	20.19	22.51	23.33	24.33	27.25
Book-to-market	89,132	0.42	0.57	0.01	0.12	0.24	0.49	3.87
Leverage	89,132	0.26	0.17	0.00	0.13	0.26	0.38	0.69
Capex/Total assets	89,132	0.04	0.03	0.00	0.01	0.03	0.05	0.18
ROA	89,132	0.06	0.06	-0.14	0.02	0.05	0.09	0.27
PPE/Total assets	89,132	0.28	0.22	0.00	0.10	0.23	0.43	0.86
Asset growth	89,132	0.13	0.25	-0.19	0.00	0.07	0.16	1.56
Sales growth	89,132	0.10	0.23	-0.45	-0.02	0.06	0.17	1.14
E score	84,074	53.09	26.98	0.00	33.48	57.45	75.32	99.09
Ln(CO_2 Emissions)	88,113	14.08	1.93	9.48	12.75	14.04	15.44	18.48
CCExposure^{Reg}	45,266	0.16	0.39	0.00	0.00	0.00	0.13	5.93

Table 2. Corporate biodiversity footprint: Rankings by industry and country

This table reports different rankings of the CBF across industries (Panel A) and countries (Panel B) (reported vertically). The different footprint measures are reported horizontally. Lower rank values indicate larger biodiversity footprints. The rankings are based on mean values across all firms in an industry or country, whereby the most recent value per firm is considered. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Appendix A provides variable definitions.

Panel A. Rankings by industry

	Ln(CBF)	Ln(CBF/TA)	Ln(CBF/Sales)	Ln(CBF air poll.)	Ln(CBF GHG)	Ln(CBF land use)	Ln(CBF water poll.)	Ln(CBF scope 1)	Ln(CBF scope 2)	Ln(CBF scope 3)
Asset Management	4	30	35	11	7	5	6	33	34	4
Automotive & Logistics	18	21	18	6	4	16	21	19	14	17
Beverages	15	27	29	25	27	10	25	24	22	15
Building Products	26	18	17	23	22	26	20	17	17	26
Chemicals	9	29	27	16	18	13	3	14	7	9
Construction & Real Estate	20	13	15	4	17	17	17	6	21	22
Defense	13	14	12	9	6	27	4	30	29	13
Education	35	8	7	35	35	35	35	34	35	35
Electrical Equipment	8	31	32	2	2	20	5	18	23	7
Electronics	24	12	10	20	15	23	19	23	18	24
Financial Services	7	6	9	14	11	6	7	35	24	6
Food	3	35	33	13	16	4	10	10	15	3
Healthcare	25	16	16	26	29	21	14	26	26	25
Hotel and Accommodation	21	22	28	19	20	15	18	20	6	19
Household Goods	17	19	14	10	14	1	16	4	16	18
Industrial Equipment	22	20	19	15	9	28	9	22	32	20
Insurance	14	7	6	17	13	11	8	8	27	14
Internet & Data	31	4	5	28	21	29	28	27	13	29
Leisure	27	10	11	30	31	24	29	21	31	28
Materials	16	26	26	12	8	12	30	7	4	16
Media	33	5	4	32	32	34	26	32	20	31
Metals & Mining	6	32	30	3	3	14	1	3	3	8
Oil & Gas	5	24	24	1	1	9	11	2	5	5
Paper and Forest	2	34	34	22	24	3	23	1	11	2
Pharmaceutical	10	23	22	21	23	18	2	16	33	10
Power	19	15	21	8	5	19	12	5	2	23
Retail and Wholesale	1	33	31	5	10	2	22	11	1	1
Services	34	3	3	34	33	33	32	28	25	32
Software	28	2	1	27	34	32	13	31	30	27
Telecommunications	32	1	2	33	30	31	31	29	9	30
Textiles	12	28	23	18	25	8	27	9	28	12
Tobacco	11	25	25	31	26	7	24	25	19	11
Transportation	23	17	20	7	12	22	15	15	8	21
Waste	30	9	8	29	19	30	33	13	10	34
Water	29	11	13	24	28	25	34	12	12	33

Table 2 (cont.)

Panel B. Rankings by country

	Ln(CBF)	Ln(CBF/TA)	Ln(CBF/Sales)	Ln(CBF air poll.)	Ln(CBF GHG)	Ln(CBF land use)	Ln(CBF water poll.)	Ln(CBF scope 1)	Ln(CBF scope 2)	Ln(CBF scope 3)
Australia	26	15	18	21	20	25	19	18	11	27
Belgium	15	16	17	33	32	11	15	26	23	15
Brazil	1	32	31	12	19	2	30	1	18	3
Canada	5	14	21	6	8	7	4	8	21	5
China	12	23	24	4	6	13	11	14	6	11
Denmark	31	28	27	14	33	1	24	32	8	30
Finland	2	29	26	22	3	3	27	3	27	1
France	13	8	7	3	9	15	14	11	3	14
Germany	4	12	11	17	4	14	1	20	7	4
Hong Kong	29	7	10	16	10	30	25	22	1	29
India	24	26	23	5	12	27	9	13	26	25
Indonesia	19	30	29	13	15	17	21	21	24	19
Ireland	28	10	5	27	18	24	26	29	31	26
Israel	34	2	2	34	34	33	34	34	34	34
Italy	27	4	6	15	5	28	29	16	30	28
Japan	20	18	13	19	14	23	6	23	9	18
Korea	22	21	19	7	11	22	16	12	13	21
Malaysia	30	25	28	10	28	26	33	15	12	31
Mexico	18	22	22	26	24	20	8	5	5	23
Netherlands	17	3	1	9	23	16	17	30	29	17
Norway	33	6	8	23	22	32	22	24	28	33
Philippines	9	31	34	24	25	5	31	27	20	7
Poland	7	24	20	2	2	12	18	4	25	10
Saudi Arabia	3	19	25	1	1	4	13	2	2	2
Singapore	14	1	4	28	30	10	32	33	17	12
South Africa	21	34	33	8	21	21	12	6	4	24
Spain	11	11	15	18	13	29	2	10	19	13
Sweden	25	20	16	31	31	18	20	19	32	22
Switzerland	16	13	12	30	27	19	5	28	16	16
Taiwan	23	5	3	32	26	34	3	31	22	20
Thailand	10	27	32	11	7	9	28	9	15	9
Turkey	32	33	30	29	29	31	23	25	33	32
United Kingdom	8	17	14	25	17	8	10	7	14	8
United States	6	9	9	20	16	6	7	17	10	6

Table 3. Determinants of the corporate biodiversity footprint

This table reports regressions relating annual values of Ln(CBF) to firm characteristics. The data frequency is yearly. Ln(CBF) is measured in year *t* and firm characteristics in year *t*. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Standard errors are clustered at the firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Ln(CBF)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln(Total assets)	0.851***	0.629***	-0.033	0.663***	0.661***	0.662***	0.658***
	(0.045)	(0.052)	(0.066)	(0.063)	(0.063)	(0.063)	(0.077)
Book-to-market	-0.106	-0.046	-0.164*	-0.058	-0.064	-0.063	-0.017
	(0.099)	(0.095)	(0.089)	(0.073)	(0.074)	(0.074)	(0.076)
Leverage	-1.045***	-1.425***	-1.652***	-1.245***	-1.264***	-1.262***	-1.309***
	(0.402)	(0.389)	(0.364)	(0.299)	(0.302)	(0.302)	(0.375)
Capex/Total assets	-9.027***	-9.692***	-10.274***	-4.162***	-4.196***	-4.077***	-4.337***
	(2.059)	(2.064)	(1.795)	(1.331)	(1.353)	(1.342)	(1.495)
PPE/Total assets	3.983***	3.807***	1.256***	-0.025	-0.023	-0.041	0.022
	(0.317)	(0.312)	(0.313)	(0.270)	(0.274)	(0.273)	(0.309)
ROA	1.835*	0.901	-1.335	-0.527	-0.522	-0.587	-0.356
	(0.938)	(0.949)	(0.861)	(0.671)	(0.687)	(0.682)	(0.819)
Asset growth	-0.784***	-0.589***	-0.069	-0.324***	-0.319***	-0.326***	-0.357***
	(0.168)	(0.165)	(0.148)	(0.107)	(0.109)	(0.108)	(0.131)
Sales growth	-0.011	0.133	0.001	-0.086	-0.089	-0.077	-0.176
	(0.186)	(0.172)	(0.157)	(0.116)	(0.129)	(0.122)	(0.163)
E score		0.027***	0.011***	0.004*	0.004*	0.004**	0.003
		(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Ln(CO_2 Emissions)			0.933***	0.352***	0.354***	0.354***	0.337***
			(0.048)	(0.048)	(0.048)	(0.048)	(0.056)
Year fixed effects	Yes	Yes	Yes	Yes	No	No	No
Country fixed effects	Yes	Yes	Yes	Yes	Yes	No	No
Industry fixed effects	No	No	No	Yes	No	Yes	No
Country×year fixed effects	No	No	No	No	No	Yes	No
Industry×year fixed effects	No	No	No	No	Yes	No	No
Country×industry×year fixed effects	No	No	No	No	No	No	Yes
#Obs.	7,489	7,059	6,996	6,996	6,996	6,996	6,179
R^2	0.243	0.278	0.403	0.630	0.633	0.632	0.688

Table 4. Corporate biodiversity footprint and stock returns

This table reports regressions relating monthly stock returns to Ln(CBF). The sample period in Columns 1–2 includes monthly returns over the full sample period from January 2019 to December 2022. The sample period in Columns 3–4 includes monthly returns from January 2019 to September 2021 (the COP15 in Kunming started in October 2021) and in Columns 5–6 monthly returns from October 2021 to December 2022. Ln(CBF) is measured as of the end of the previous year. The accounting-based right-hand variables are measured as of the last fiscal year. Market capitalization, volatility, and momentum are measured as of the end of the previous month. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (%)					
	Whole period		Pre-Kunming period		Post-Kunming period	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(CBF)	0.003	-0.000	-0.036	-0.036	0.061**	0.057**
	(0.019)	(0.018)	(0.022)	(0.022)	(0.026)	(0.026)
Ln(Total assets)	0.211	0.158	0.143	0.112	0.336	0.290
	(0.171)	(0.164)	(0.192)	(0.187)	(0.329)	(0.313)
Ln(Market cap)	-0.468***	-0.393***	-0.426**	-0.382**	-0.372	-0.305
	(0.153)	(0.143)	(0.187)	(0.178)	(0.252)	(0.238)
Book-to-market	-0.086	-0.043	-0.072	-0.047	-0.057	-0.043
	(0.159)	(0.158)	(0.196)	(0.189)	(0.285)	(0.289)
Leverage	0.353	0.372	0.630	0.701	-0.524	-0.496
	(0.351)	(0.347)	(0.438)	(0.435)	(0.562)	(0.576)
Capex/Total assets	1.933	2.265	6.695***	6.459***	-6.763*	-5.955
	(2.200)	(2.089)	(2.100)	(2.070)	(3.518)	(3.411)
PPE/Total assets	0.327	0.353	-0.319	-0.270	1.624*	1.569*
	(0.401)	(0.414)	(0.425)	(0.427)	(0.760)	(0.747)
ROA	2.216	2.014	0.979	0.969	5.534	5.109
	(1.864)	(1.724)	(1.712)	(1.584)	(3.493)	(3.457)
Asset growth	-0.408	-0.300	0.221	0.167	-1.491**	-1.343**
	(0.336)	(0.316)	(0.334)	(0.320)	(0.566)	(0.552)
Sales growth	-0.038	-0.218	0.047	0.398	0.101	-0.403
	(0.480)	(0.374)	(0.676)	(0.509)	(0.476)	(0.340)
Volatility	5.433	5.012	14.644**	13.513*	-2.692	-2.214
	(5.096)	(5.077)	(7.126)	(7.115)	(6.226)	(6.473)
Momentum	4.407	3.134	-1.459	-0.438	-3.682	-1.515
	(5.382)	(4.770)	(6.418)	(5.913)	(8.548)	(7.804)
Wald test (p-value): Column 3 vs. 5			0.019			
Wald test (p-value): Column 4 vs. 6					0.036	
Year-month fixed effects	Yes	No	Yes	No	Yes	No
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	No	Yes	No	Yes	No
Industry×year-month fixed effects	No	Yes	No	Yes	No	Yes
#Obs.	89,132	89,132	58,218	58,218	30,914	30,914
R^2	0.251	0.320	0.245	0.309	0.255	0.324

Table 5. Heterogeneity in country biodiversity protection and stock returns

This table reports regressions of monthly stock returns on Ln(CBF) after the Kunming Declaration for firms in countries with high or low biodiversity protection. The sample period includes monthly returns from October 2021 to December 2022. Ln(CBF) is measured as of the end of the previous year. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Low protection is a dummy variable that equals one if a country is below the median value of the Biodiversity & habitat index (or below the median value of the Ecosystem vitality index) as of end 2020, and zero otherwise. We also report regressions using interaction terms of Ln(CBF) × Low protection. The regressions use the same control variables as Table 4 (not reported). Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (%)					
	Biodiversity & habitat index			Ecosystem viability index		
		Low	High		Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(CBF)	-0.021	0.091***	-0.046	-0.002	0.086***	-0.018
	(-0.03)	(-0.027)	(-0.048)	(-0.027)	(-0.028)	(-0.048)
Ln(CBF) × Low protection	0.111**			0.085**		
	(-0.04)			(0.038)		
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
#Obs.	30,899	20,714	10,185	30,899	20,691	10,208
R^2	0.255	0.225	0.346	0.255	0.22	0.363

Table 6. Stock price reactions to Kunming Declaration

This table reports regressions documenting the stock price reactions to the Kunming Declaration, with the focal date of the event being October 13, 2021. We report results for firms with large versus small CBF values. The event window consists of the [-3,2]-day window around the focal date. The market reaction is computed as the within-firm difference in daily returns between the three trading days before versus after the event. Large CBF equals one for firms with a CBF value above the median (as of the beginning of the year), and zero otherwise. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Post equals one in the three days after the event (days t=0 to t=+2), with day t=0 being the event date. Abnormal returns are returns in excess of their domestic stock market index returns (using MSCI domestic indices). Standard errors are clustered at the country level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Daily return (%)				Abnormal daily return (%)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Large CBF × Post	-0.381***	-0.372***	-0.189**		-0.295***	-0.380***	-0.209**	
	(0.064)	(0.057)	(0.084)		(0.073)	(0.055)	(0.078)	
Large CBF × t = -2				0.040				-0.043
				(0.213)				(0.204)
Large CBF × t = -1				-0.504*				-0.361
				(0.278)				(0.277)
Large CBF × t = 0				-0.671***				-0.590**
				(0.218)				(0.226)
Large CBF × t = +1				-0.642***				-0.461**
				(0.193)				(0.196)
Large CBF × t = +2				-0.301*				-0.241
				(0.164)				(0.166)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day fixed effects	Yes	No	No	Yes	Yes	No	No	Yes
Country×day fixed effects	No	Yes	No	No	No	Yes	No	No
Industry×day fixed effects	No	No	Yes	No	No	No	Yes	No
#Obs.	12,301	12,301	12,301	12,301	12,301	12,301	12,301	12,301
R^2	0.240	0.332	0.298	0.243	0.192	0.256	0.245	0.194

Table 7. Stock price reactions to TNFD launch

his table reports regressions documenting the stock price reactions to Taskforce on Nature-related Financial Disclosure (TNFD) launch, with the focal date of the event being June 4, 2021. We report results for firms with large versus small CBF values. The event window consists of the [-3,2]-day window around the focal date. The market reaction is computed as the within-firm difference in daily returns between the three trading days before versus after the event. Large CBF equals one for firms with a CBF value above the median (as of the beginning of the year), and zero otherwise. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Post equals one in the three days after the event (days t=0 to t=+2), with day t=0 being the event date. Abnormal returns are returns in excess of their domestic stock market index returns (using MSCI domestic indices). Standard errors are clustered at the country level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Daily return (%)				Abnormal daily return (%)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Large CBF × Post	-0.502***	-0.479***	-0.212**		-0.423***	-0.479***	-0.195**	
	(0.108)	(0.108)	(0.098)		(0.103)	(0.107)	(0.093)	
Large CBF × t=-2				0.133				0.220
				(0.172)				(0.143)
Large CBF × t=-1				-0.143				-0.038
				(0.122)				(0.113)
Large CBF × t=0				-0.516**				-0.336*
				(0.227)				(0.172)
Large CBF × t=+1				-0.431**				-0.317**
				(0.162)				(0.130)
Large CBF × t=+2				-0.569***				-0.435***
				(0.155)				(0.144)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day fixed effects	Yes	No	No	Yes	Yes	No	No	Yes
Country×day fixed effects	No	Yes	No	No	No	Yes	No	No
Industry×day fixed effects	No	No	Yes	No	No	No	Yes	No
#Obs.	12,392	12,392	12,392	12,392	12,392	12,392	12,392	12,392
R^2	0.208	0.279	0.255	0.208	0.164	0.229	0.210	0.165

Internet Appendix

for

Do Investors Care About Biodiversity?

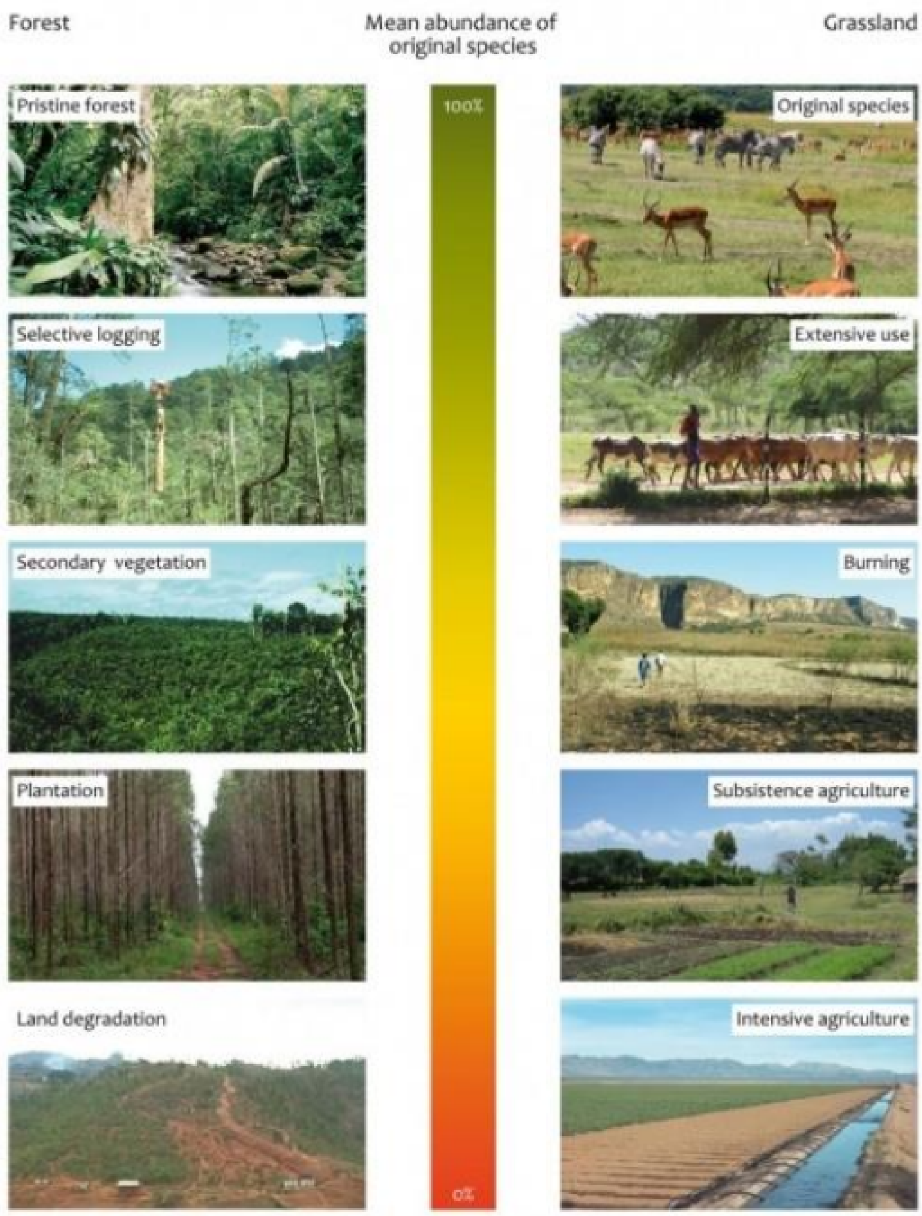
This Internet Appendix provides additional material supporting the main text. Section A provides additional tables and figures, Section B provides details on the construction of the CBF metric, Section C discusses determinants of data coverage by IDL, Section D provides case study examples on how firms disclose on biodiversity issues in earnings conference calls and annual reports, Section E discusses key biodiversity-related policy developments, and Section F provides details on how MSCI and Refinitiv construct their biodiversity risk measures.

A Supplemental Analysis and Robustness Checks

This section of the Internet Appendix provides supplemental analysis and robustness checks to support the main results in the paper.

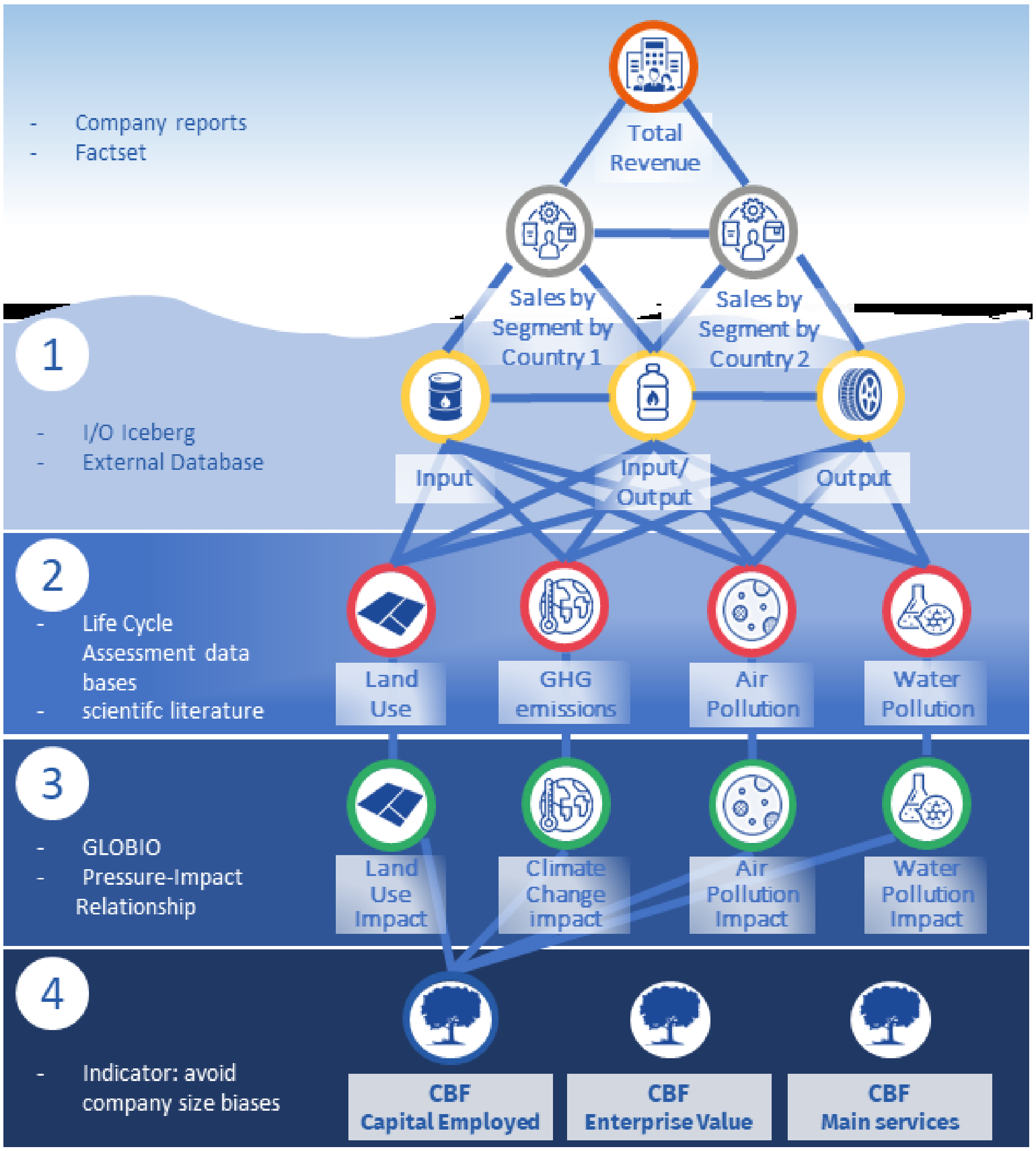
IA Figure A.1. Illustration of MSA variation

This figure illustrates the variation in Mean Species Abundance (MSA) for forest and grassland ecosystems. Source: Iceberg Data Lab (2023).



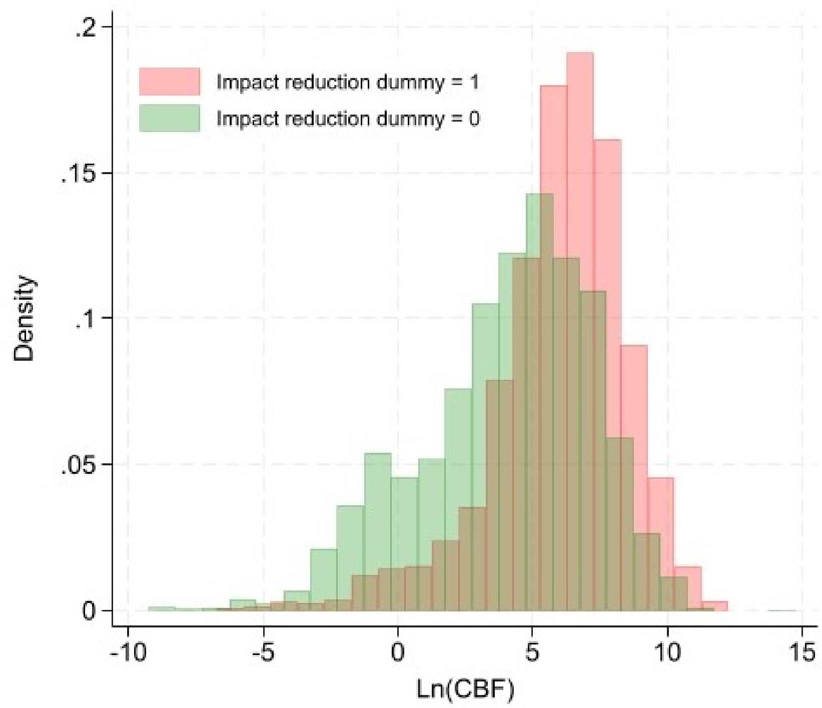
IA Figure A.2. Calculation of the biodiversity footprint

This figure illustrates the methodological steps used to calculate the CBF. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Source: Iceberg Data Lab (2023).



IA Figure A.3. Biodiversity footprint and biodiversity risk measure by Refinitiv

This figure displays the CBF distribution of the biodiversity footprint for firms with and without disclosure of biodiversity risk according to Refinitiv's Biodiversity impact reduction indicator. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.



IA Table A.1. Decomposition of the corporate biodiversity footprint: Summary statistics

This table reports the average proportion of each biodiversity footprint subcomponent (land use, air pollution, water pollution, and GHG emissions) and the average proportion of scope 1, scope 2, and scope 3 in the CBF measure. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Appendix A provides variable definitions.

Variable	#Obs.	Mean	S.D.	Min	25%	50%	75%	Max
CBF air pollution (%)	89,132	8.51	10.40	0.00	1.64	4.86	12.17	94.07
CBF GHG (%)	89,132	22.67	24.34	0.00	1.94	12.53	37.49	100.00
CBF land use (%)	89,132	48.95	33.51	-2.20	18.09	45.69	81.53	99.97
CBF water pollution (%)	89,132	20.02	27.33	0.00	0.86	6.04	28.20	99.61
CBF scope 1 (%)	89,132	14.79	23.30	-29.47	0.39	3.12	19.49	100.00
CBF scope 2 (%)	89,132	5.77	17.38	-0.03	0.00	0.02	0.48	103.10
CBF scope 3 (%)	89,132	79.55	28.74	-2.53	67.90	95.58	99.45	129.47

IA Table A.2. Decomposition of the corporate biodiversity footprint by country

This table reports the average proportion, by country, of each CBF subcomponent or source (land use, air pollution, water pollution, and GHG emissions) and the average proportion of scope 1, scope 2, and scope 3 in the CFB measure. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Appendix A provides variable definitions.

	CBF air pol. (%)	CBF GHG (%)	CBF land use (%)	CBF water pol. (%)	CBF scope 1 (%)	CBF scope 2 (%)	CBF scope 3 (%)
Australia	13.34	26.92	41.04	18.70	24.01	6.88	69.11
Belgium	6.30	15.86	53.37	24.47	9.79	2.50	87.72
Brazil	9.49	22.94	63.29	4.28	35.19	0.81	64.00
Canada	8.08	26.17	46.29	19.47	26.37	3.68	69.95
China	9.12	19.96	46.18	24.74	16.41	3.67	79.93
Denmark	3.17	16.56	65.19	21.73	10.84	1.46	87.70
Finland	5.45	19.01	61.35	14.19	7.32	2.98	89.70
France	11.58	26.55	46.84	15.03	14.39	6.44	79.18
Germany	7.59	26.10	44.32	21.99	12.54	6.15	81.31
Hong Kong	11.99	36.62	39.70	11.71	15.52	20.34	64.14
India	10.13	23.64	45.14	21.09	14.90	2.36	82.74
Indonesia	5.30	15.65	67.07	11.97	10.85	0.49	88.70
Ireland	6.49	24.11	56.45	12.94	11.17	3.43	85.40
Israel	15.95	16.99	54.22	12.84	7.45	3.13	89.42
Italy	11.63	35.50	41.41	11.46	13.58	8.73	77.69
Japan	7.93	22.38	47.37	22.57	10.72	4.29	85.26
Korea	11.16	24.77	43.63	20.72	20.82	5.00	74.18
Malaysia	14.49	23.14	57.46	4.91	27.15	5.49	67.36
Mexico	7.36	31.69	46.59	17.33	32.98	6.31	63.76
Netherlands	10.80	24.57	48.51	16.22	11.34	14.48	74.18
Norway	13.32	31.57	34.20	20.91	19.39	0.85	79.76
Philippines	12.84	13.49	70.75	2.92	3.80	11.16	85.03
Poland	10.07	25.28	53.96	10.70	25.07	11.83	63.10
Saudi Arabia	8.92	24.01	35.10	31.98	21.46	6.20	72.34
Singapore	11.48	37.11	35.81	15.62	22.64	13.53	63.83
South Africa	6.60	13.74	46.75	32.91	30.21	1.78	68.01
Spain	11.18	27.73	33.02	28.07	33.14	7.00	59.87
Sweden	7.13	17.71	52.00	23.16	7.80	3.13	89.07
Switzerland	6.50	20.90	43.73	28.87	7.53	7.80	84.67
Taiwan	7.74	42.80	32.32	19.26	18.89	12.66	68.60
Thailand	7.13	26.89	59.98	6.70	17.24	2.45	80.30
Turkey	9.62	19.00	48.24	23.14	19.86	6.68	73.46
United Kingdom	5.44	19.02	57.07	18.47	19.47	2.39	78.15
United States	7.63	21.36	52.52	18.65	11.96	8.02	80.05

IA Table A.3. Decomposition of the corporate biodiversity footprint by industry

This table reports the average proportion, by industry, of each biodiversity footprint subcomponent (land use, air pollution, water pollution, and GHG emissions) and the average proportion of scope 1, scope 2, and scope 3 in the CBF measure. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.. Appendix A provides variable definitions.

	CBF air pol. (%)	CBF GHG (%)	CBF land use (%)	CBF water pol. (%)	CBF scope 1 (%)	CBF scope 2 (%)	CBF scope 3 (%)
Asset Management	2.34	6.96	68.76	21.95	0.01	0.01	99.98
Automotive & Logistics	14.12	31.66	44.17	10.05	5.95	0.75	93.30
Beverages	0.98	2.93	95.06	1.03	1.47	0.18	98.35
Building Products	7.12	15.09	55.87	21.92	20.28	0.78	78.93
Chemicals	6.18	9.63	51.57	33.28	8.19	1.06	91.43
Construction & Real Estate	15.47	15.73	62.74	6.07	23.88	1.77	74.35
Defense	8.38	15.21	28.20	48.21	0.67	0.34	98.99
Education	3.12	5.06	80.00	11.82	3.15	0.27	96.58
Electrical Equipment	11.21	29.33	11.34	48.13	1.38	0.03	98.59
Electronics	5.46	45.29	28.91	21.22	10.99	15.88	73.19
Financial Services	10.71	32.70	46.09	10.67	3.45	32.91	63.64
Food	2.09	3.28	93.59	1.64	3.50	0.26	96.24
Healthcare	1.28	1.63	68.61	28.49	0.98	0.37	98.65
Hotel and Accommodation	3.26	3.30	85.24	8.20	3.07	0.72	96.21
Household Goods	9.10	16.78	51.49	25.57	14.56	1.05	84.39
Industrial Equipment	7.94	25.05	25.28	41.73	2.04	0.09	97.87
Insurance	8.64	25.05	51.50	14.81	7.54	19.88	72.59
Internet & Data	10.45	42.21	41.71	5.64	3.55	8.65	87.79
Leisure	6.47	17.94	61.92	13.67	17.19	6.22	76.60
Materials	9.58	22.14	66.27	2.01	27.13	0.99	71.87
Media	8.65	24.15	35.01	32.19	2.70	14.30	83.00
Metals & Mining	7.63	15.50	27.54	49.33	42.26	0.41	57.33
Oil & Gas	10.40	39.93	44.32	5.35	26.56	0.22	73.22
Paper and Forest	1.59	4.56	88.63	5.22	21.91	0.34	77.75
Pharmaceutical	0.82	1.67	22.55	74.96	2.61	0.04	97.35
Power	16.01	44.56	22.05	17.39	47.08	3.03	49.89
Retail and Wholesale	2.46	5.33	91.03	1.18	4.43	0.26	95.30
Services	14.18	37.11	41.72	6.99	12.38	32.06	55.56
Software	9.16	31.55	53.34	5.94	8.24	9.78	81.98
Telecommunications	9.59	48.24	37.12	5.05	10.56	34.69	54.75
Textiles	3.50	4.65	90.36	1.49	12.81	4.42	82.77
Tobacco	0.27	0.76	96.44	2.54	1.08	0.10	98.84
Transportation	24.20	37.34	25.63	12.83	38.47	4.16	57.46
Waste	6.63	62.92	22.21	8.24	78.28	1.53	20.19
Water	12.47	9.60	76.47	1.46	87.41	3.15	9.43

IA Table A.4. Variance decomposition

This table provides a variance decomposition of the CBF measures. Regressions are estimated at the firm-year level. We report the Incremental R^2. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Intercepts are not reported. Appendix A provides variable definitions.

	Ln(CBF)
Year fixed effects	0.10%
Country fixed effects	3.20%
Industry fixed effects	41.20%
Industry×year fixed effects	0.10%
Country×year fixed effects	0.40%
"Firm level"	55.00%
Sum	100.00%

IA Table A.5. Biodiversity protection indexes by country/region

This table reports values per country/region of the Biodiversity & habitat index and the Ecosystems viability index. Values are as of 2020. We list countries/regions alphabetically.

Country/region	Biodiversity & habitat index	Country/region	Ecosystem viability index
Australia	83.7	Australia	63.8
Belgium	87.4	Belgium	64.8
Brazil	78.1	Brazil	52.2
Canada	60.5	Canada	57.3
China	19	China	34.4
Denmark	81.7	Denmark	76.4
Finland	75.5	Finland	65.3
France	88.3	France	72.3
Germany	88.8	Germany	68.9
Hong Kong	19	Hong Kong	34.4
India	33.7	India	35.2
Indonesia	56.3	Indonesia	43.7
Ireland	65.8	Ireland	58.6
Israel	47.6	Israel	54
Italy	75.6	Italy	61.3
Japan	76.6	Japan	65.1
Korea	62.6	Korea	56.6
Malaysia	55.1	Malaysia	42.9
Mexico	72.9	Mexico	55.9
Netherlands	83.7	Netherlands	64.8
Norway	71.5	Norway	63.8
Philippines	56.6	Philippines	41.4
Poland	89	Poland	62.3
Saudi Arabia	38.8	Saudi Arabia	41.8
Singapore	20.9	Singapore	40.2
South Africa	63.2	South Africa	51
Spain	87.6	Spain	66
Sweden	72.5	Sweden	65.6
Switzerland	63	Switzerland	72.5
Taiwan	65	Taiwan	55.8
Thailand	53	Thailand	43.5
Turkey	15.1	Turkey	36.9
United Kingdom	88	United Kingdom	74.3
United States	67.5	United States	60.3

IA Table A.6. Cross-section of returns: Controlling for climate transition risk

This table reports regressions relating monthly stock returns to Ln(CBF) after controlling for measure of climate transition risk. Ln(CO_2 Emissions) is the natural logarithm of Scope 1, 2, and 3 carbon emissions from Trucost. CCExposure^{Reg} is the regulatory climate change exposure measure from Sautner et al. (2023). CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The regressions use the same control variables as Table 4 (not reported). Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (%)					
	Whole period	Post-Kunming	Whole period	Post-Kunming	Whole period	Post-Kunming
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(CBF)	0.003	0.060*	0.030	0.063*		
	(0.019)	(0.028)	(0.022)	(0.030)		
Ln(CO_2 Emissions)	-0.007	-0.047				
	(0.067)	(0.124)				
CCExposure^{Reg}			0.404*	0.304		
			(0.230)	(0.231)		
Ln(CBF without GHG)					0.005	0.037*
					(0.017)	(0.020)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
#Obs.	88,113	30,663	45,266	15,660	89,132	30,914
R^2	0.252	0.256	0.316	0.329	0.251	0.255

IA Table A.7. Heterogeneity in country biodiversity protection: Controlling for climate transition risk

This table reports regressions relating monthly stock returns to Ln(CBF) after the Kunming Declaration for firms in countries with high and low biodiversity protection after controlling for measures of climate transition risk. Ln(CO_2 Emissions) is the natural logarithm of Scope 1, 2, and 3 carbon emissions from Trucost. CCExposure^{Reg} is the regulatory climate change exposure measure from Sautner et al. (2023). CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The regressions use the same control variables as Table 5 (not reported). Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (\%)					
	Biodiversity & habitat index			Ecosystem viability index		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(CBF) × Low protection	0.109**	0.151**		0.083**	0.123**	
	(0.040)	(0.052)		(0.038)	(0.056)	
Ln(CBF without GHG) × Low protection			0.092**			0.069**
			(0.031)			(0.030)
Ln(CBF)	-0.020	-0.056		-0.001	-0.035	
	(0.034)	(0.047)		(0.031)	(0.046)	
Ln(CBF without GHG)			-0.032			-0.015
			(0.028)			(0.026)
Ln(CO_2 Emissions)	-0.042			-0.044		
	(0.124)			(0.124)		
CCExposure^{Reg}		0.309			0.294	
		(0.231)			(0.232)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
# Obs.	30,648	15,645	30,899	30,648	15,645	30,899
R^2	0.256	0.329	0.255	0.256	0.329	0.255

IA Table A.8. Cross-section of returns: CBF intensity measures

This table reports regressions relating monthly stock returns to Ln(CBF) after replacing Ln(CBF) by Ln(CBF/Total assets) and Ln(CBF/sales). CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The regressions use the same control variables as Table 4 (not reported). Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (%)			
	Whole period	Post-Kunming	Whole period	Post-Kunming
	(1)	(2)	(3)	(4)
Ln(CBF/Total assets)	0.005	0.058*		
	(0.021)	(0.028)		
Ln(CBF/Sales)			0.012	0.071**
			(0.022)	(0.030)
Controls	Yes	Yes	Yes	Yes
Year-month fixed effects	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
#Obs.	89,132	30,914	89,108	30,899
R^2	0.25	0.255	0.252	0.255

IA Table A.9. Cross-section of returns: Alternative clustering of standard errors

This table reports regressions relating monthly stock returns to Ln(CBF) after clustering standard errors differently (indicated below, Columns 7–8 correspond to Table 5, Columns 3 abd 5). CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The regressions use the same control variables as Table 4 (not reported). Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (%)					
	Whole period	Post-Kunming	Whole period	Post-Kunming	Whole period	Post-Kunming
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(CBF)	0.003	0.061**	0.003	0.061**	0.003	0.061**
	(0.015)	(0.025)	(0.014)	(0.024)	(0.037)	(0.004)
SE clustering	Firm-year		Firm		Firm and year	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-month fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
#Obs.	89,132	30,914	89,132	30,914	89,132	30,914
R^2	0.251	0.255	0.251	0.255	0.251	0.255

IA Table A.10. Cross-section of returns: Sample selection

This table reports regressions relating monthly stock returns to Ln(CBF) after restricting the sample to firms inside the MSCI ACWI universe. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The regressions use the same control variables as Table 4 (not reported). Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly return (%)	
	Whole period	Post-Kunming
	(1)	(2)
Ln(CBF)	0.008	0.054*
	(0.020)	(0.026)
Controls	Yes	Yes
Year-month Fixed Effect	Yes	Yes
Country Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
#Obs.	62,947	22,016
R^2	0.283	0.287

IA Table A.11. Cross-section of returns: Implied cost of capital

This table reports regressions relating monthly implied cost of capital (ICC) estimates to Ln(CBF) after restricting the sample to firms inside the MSCI ACWI universe. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. The regressions use the same control variables as Table 4 (not reported). Standard errors are clustered at the year-month and firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Monthly ICC (in %)		
	Whole period	Pre-Kunming	Post-Kunming
	(1)	(2)	(3)
Ln(CBF)	0.013**	0.010	0.019**
	(0.006)	(0.007)	(0.008)
Controls	Yes	Yes	Yes
Year-month Fixed Effect	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
#Obs.	48,813	31,595	17,218
R^2	0.177	0.179	0.205

IA Table A.12. Market reaction to Kunming Declaration: Controlling for climate transition risk

This table reports regressions documenting the stock price reactions to the Kunming Declaration after controlling for climate transition risk, with the focal date of the event being October 13, 2021. We report results for firms with large versus small CBF values. The event window consists of the [-3,2]-day window around the focal date. The market reaction is computed as the within-firm difference in daily returns between the three trading days before versus after the event. Large CBF equals one for firms with a CBF value above the median (as of the beginning of the year), and zero otherwise. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Post equals one in the three days after the event (days t=0 to t=+2), with day t=0 being the event date. High Emissions is a dummy variable that equals one if firm has an above-median level of carbon emissions (Scope 1, 2, and 3) as of end 2020. High CCExposure^{Reg} is a dummy variable that equals one if a firms has an above-median value of CCExposure^{Reg} as of end 2020, and zero otherwise. Standard errors are clustered at the country level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Daily returns (%)			
	(1)	(2)	(3)	(4)
Large CBF × Post		-0.349***		-0.395***
		(0.097)		(0.073)
High Emissions × Post	-0.234**	-0.064		
	(0.100)	(0.137)		
High CCExposure^{Reg} × Post			-0.158**	-0.057
			(0.066)	(0.071)
Firm fixed effects	Yes	Yes	Yes	Yes
Day fixed effects	Yes	Yes	Yes	Yes
#Obs.	12,182	12,182	5,490	5,490
R^2	0.240	0.242	0.259	0.262

IA Table A.13. Market reaction to Kunming Declaration: Additional results

This table reports regressions documenting the stock price reactions to the Kunming Declaration, with the focal date of the event being October 13, 2021. We report results for firms with large versus small CBF values, using either the subcomponents of CBF (Columns 1–4), intensity measures (Columns 5–6), or alternative percentiles to identify large and small CBF firms (Columns 7–8). We also report continuous values of Ln(CBF) instead of indicators (Column 9). The event window consists of the [-3,2]-day window around the focal date. The market reaction is computed as the within-firm difference in daily returns between the three trading days before versus after the event. In Columns 1–4, Large CBF for a subcomponent equals one for firms with a CBF value above the median (as of the beginning of the year), and zero otherwise. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Post equals one in the three days after the event (days t=0 to t=+2), with day t=0 being the event date. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Daily returns (%)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Large CBF air pollution x Post	-0.268**								
	(0.107)								
Large CBF land use × Post		-0.368***							
		(0.072)							
Large CBF GHG × Post			-0.316***						
			(0.110)						
Large CBF water pollution × Post				-0.205					
				(0.184)					
Ln(CBF/Total assets) × Post					-0.377***				
					(0.094)				
Ln(CBF/Sales) × Post						-0.384***			
						(0.137)			
Top quartile CBF × Post							-0.394***		
							(0.083)		
Top tercile CBF × Post								-0.379***	
								(0.093)	
Ln(CBF) × Post									-0.073***
									(0.010)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
#Obs.	12,301	12,223	12,301	12,301	12,301	12,295	12,301	12,301	12,301
R^2	0.238	0.24	0.239	0.238	0.24	0.24	0.239	0.239	0.241

IA Table A.14. Market reaction to Kunming Declaration: Sample selection

This table reports regressions documenting the stock price reactions to the Kunming Declaration after restricting the sample to firms inside the MSCI universe, with the focal date of the event being October 13, 2021. We report results for firms with large versus small CBF values. The event window consists of the [-3,2]-day window around the focal date. The market reaction is computed as the within-firm difference in daily returns between the three trading days before versus after the event. Large CBF equals one for firms with a CBF value above the median (as of the beginning of the year), and zero otherwise. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities. Post equals one in the three days after the event (days t=0 to t=+2), with day t=0 being the event date. Standard errors are clustered at the country level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

	Daily return (%)		
	(1)	(2)	(3)
Large CBF x Post	-0.555***	-0.547***	-0.315***
	(0.063)	(0.060)	(0.103)
Firm fixed effects	Yes	Yes	Yes
Day fixed effects	Yes	No	No
Country×day fixed effects	No	Yes	No
Industry×day fixed effects	No	No	Yes
#Obs.	8,761	8,761	8,755 5
R^2	0.253	0.358	0.325

IA Table A.15. Comparison of firm-level biodiversity measures

Measure	**Source**	**Type**	**Definition**	**Coverage**
Corporate biodiversity footprint (CBF)	Iceberg Data Lab	Impact	Measure of the absolute biodiversity loss caused by the firm's annual activities. It is expressed in km^2.MSA, which is equivalent to the pristine natural area destroyed by the firm's annual activities. For details, see Section 2.	International
Biodiversity & land use exposure score	MSCI	Impact	Score from 0 to 10 indicating the extent to which a firm's business is exposed to the issue of biodiversity and land use based on its unique mix of business and geographic segments. Examples of criteria assessed include: the products and services a firm provides; location of firm operations; and the nature of those operations. Higher scores indicate greater risk. For details, see Section 8.	International
Biodiversity impact reduction	Refinitiv	Disclosure	Dummy variable that is equal to one if a firm reports on its impact on biodiversity on on activities to reduce its impact. For details, see Section 8.	International

IA Table A.16. Correlation matrix for biodiversity risk measures

This table presents correlations for the different firm-level biodiversity measures. Appendix A provides variable definitions.

	1	2	3	4	5	6	7
1. Ln(CBF)	1.00						
2. Ln(CBF scope 1)	0.68	1.00					
3. Ln(CBF scope 2)	0.20	0.19	1.00				
4. Ln(CBF scope 3)	0.96	0.57	0.14	1.00			
5. 10-K Biodiversity count score	0.08	0.18	0.02	0.07	1.00		
6. Refinitiv biodiversity impact reduction	0.31	0.41	0.18	0.26	0.17	1.00	
7. MSCI Biodiversity & land use exposure	0.37	0.56	0.00	0.31	0.27	0.39	1.00

IA Table A.18. MSCI biodiversity & land use exposure and stock returns

Panel A of this table reports regressions relating monthly stock returns to the MSCI biodiversity & land use exposure. The sample period in Columns 1–2 includes monthly returns over the full sample period from January 2019 to December 2022. The sample period in Columns 3–4 includes monthly returns from January 2019 to September 2021 (the COP15 in Kunming started in October 2021), and in Columns 5–6 monthly stock returns from October 2021 to December 2022. Panel B reports the Kunming stock price reactions analysis. Standard errors are double clustered at the year-month and firm level in Panel A, and at the country level in Panel B. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions.

Panel A. Cross-section of stock returns

	Monthly return (%)					
	Whole Period		Pre-Kunming period		Post-Kunming period	
	(1)	(2)	(3)	(4)	(5)	(6)
MSCI biodiversity & land use exposure	0.119**	0.097*	0.016	0.009	0.220**	0.203**
	(0.054)	(0.049)	(0.050)	(0.048)	(0.082)	(0.080)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-month fixed effects	Yes	No	Yes	No	Yes	No
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	No	Yes	No	Yes	No
Industry×year-month fixed effects	No	Yes	No	Yes	No	Yes
#Obs.	82,085	82,085	52,943	52,943	29,142	29,142
R^2	0.261	0.332	0.254	0.321	0.265	0.337

Panel B. Market reaction to COP15 - Kunming

	Daily return (%)		
	(1)	(2)	(3)
Large MSCI score × Post	-0.315***	-0.261***	-0.078
	(0.083)	(0.092)	(0.099)
Firm fixed effects	Yes	Yes	Yes
Day fixed effects	Yes	No	No
Country×day fixed effects	No	Yes	No
Industry×day fixed effects	No	No	Yes
R^2	0.239	0.342	0.300
#Obs.	11,296	11,296	11,296

B Step-by-step construction of the CBF metric

This section of the Internet Appendix provides additional information on how the corporate biodiversity footprint (CBF) is constructed. Our measure of a firm's impact on biodiversity is the corporate biodiversity footprint (CBF) constructed by IDL. The data provider has developed the measure to provide a science-based indicator that helps financial institutions measure and manage their investments' impact on biodiversity. The CBF metric is calculated in three steps. The following subsections comment on each of these steps, drawing on an example, Danone, the dairy manufacturer (which in the U.S. is called Dannon). IA Figure B.1 summarizes the calculations of the 2021 biodiversity footprint for Danone (it has a CBF value of -10,486 km^2.MSA), and IA Figure B.2 provides for Danone more details on the steps in the calculation of the CBF. A general, publicly available introduction into IDL's methodology is provided in Iceberg Data Lab (2023).

B.1 Step 1: From business activities to used commodities

For each firm, IDL first collects data on the activities (business segments) per country at the NACE4 (and sometimes NACE5) level. Based on these Revenue x Segment x Country data, IDL's input/output model, Wunderpus, translates these data into quantities consumed (or produced) of a set of commodities. In this analysis, IDL depends on the granularity of disclosure by each firm. For example, in the U.S., Danone has substantial activities in fresh dairy products (NACE4 Code: 1051 - Manufacture of fresh dairy products), beverages (NACE4 Code: 1107 - Manufacture of soft drinks; production of mineral waters and other bottled waters), and biscuits (NACE4 Code: 1072 - Manufacture of rusks and biscuits; manufacture of preserved pastry goods and cakes), among others. Based on its research, IDL concludes that roughly €2 billion of Danone's 2021 revenue (out of a total of €18.76 billion) stem from its operations of dairy and cheese making in the U.S.

IDL's version of the EXIOBASE input/output model turns each of these segment-country-revenue combinations into a use of commodities, such as tons of milk, sugar, or oil. The model covers 216 countries, 2,130 products and services, and 1,219 NACE sectors. For example, the revenue from Danone's operations of dairy and cheese making in the U.S. are turned into an estimated consumption of milk by Danone. The IDL analyst that covers a firm can adjust the commodities' quantities estimated by the model when the firm directly reports these commodities' quantities. In the case of Danone, their 2021 sustainability report states that they collected 5.6 million tons of fresh milk in 2021. The report also states that 29% of this occurred in North America. Combining the model and disclosed information, IDL concludes that 1.6 million tons of milk used in the production process come from the U.S.

B.2 Step 2: From commodities to environmental pressures

Once IDL has computed, for a given firm, the list of all the commodities and the associated quantities for each commodity, they turn them into environmental pressures. To do so, they use various databases on life cycle analysis (LCA). These include, for example, data from EcoInvent, but also from the Food and Agriculture Organization (FAO) and the academic literature. The general idea of LCA is to link one unit of a given commodity to an increase of x units in the respective pressure dimension, that is, pressure from land use, air pollution, water pollution, and CO_2 emissions.

First, in terms of pressure from land use, based on LCA databases, IDL works with the assumption that 1,000 tons of cow milk are associated with an impact through land use pressure of 13km^2. Conceptionally, impact is counted as maintaining due to ongoing operations in an area with a different biodiversity level than originally (i.e., preventing its return to a pristine state). This type of impact is labeled as occupational land use. If a firm expands operations, there may additionally be transformational land use.[1]

Second, air pollution pressure aggregates terrestrial acidification and terrestrial eutrophication. IDL's LCA model focuses on the impact of nitrogen and of sulphur. Third, IDL's model estimates the increase in toxic substances in fresh water (water pollution pressure). For air and water pollution, there is no distinction between maintained and additional impact. Plastic entanglement is considered to be part of water pollution. Finally, IDL collects or estimates data on greenhouse gas emissions (measured in tons of CO_2 equivalent).

1. Some transformational land use also happens to maintain the same level, for example, to grow additional soy as food for cows. IDL distinguishes three sub-pressures resulting in transformational land use: Incremental land use corresponds to the additional surface that a firm occupies compared to the previous year. Fragmentation emphasizes the impact of human activities through the splitting of natural landscape. Encroachment corresponds to the perturbation induced through lights and noises that can lead to biodiversity loss.

B.3 Step 3: From environmental pressures to impact on MSA

To turn the four environmental pressures from air pollution, water pollution, land use, and GHG emissions into an impact on km^2.MSA, IDL requires an estimate of the damage. In general, the framework is to compute:

$$\text{Impact} = \text{Pressure} \times (\text{Final MSA} - \text{Initial MSA})$$

where Impact is a negative number whenever MSA is reduced through a firm's activities. For estimates of the damage, IDL mostly relies on the GLOBIO model (Schipper et al. 2020). GLOBIO has compiled many research articles to create damage functions (or pressure-impact functions) that turn an environmental pressure into a biodiversity impact (some of them are simple linear functions).

B.3.1 Land use

In the case of Danone, intuitively, large parts of Danone's footprint originate from the land use needed to breed and feed dairy cattle. There are various types of land use, which have a higher or lower impact on biodiversity. In particular, as seen in Figure 2C of Schipper et al. (2020), intensive land use, for example, has a far greater negative impact on MSA than minimal use. The damage is computed relative to a reference point. IDL posits an initial MSA of 65% (not 100%) in general, which is the average MSA for land use worldwide in the baseline year 2015 (for wood commodities, the initial MSA is 85%). They argue that this baseline is more appropriate than assuming an initial MSA of 100%, as such a baseline may overestimate the impact of firm activities on biodiversity. The final MSA depends on the actual use. Specifically, according to an example provided by IDL, for cow milk the final MSA is posited to be 60%. Therefore, the land use impact of 1000 tons of cow milk is computed as

$$13\text{km}^2 \times (60\% - 65\%) = -\ 0.65\ \text{km}^2.\text{MSA}$$

It is interesting to see how a different activity of Danone plays out in this computation. Danone also sells soy milk products. Significantly less land is required to produce 1,000 tons of soy beverage (IDL estimates the corresponding pressure to be 0.5km², which compares to 13km² for cow milk). However, the damage is far greater: Soy agriculture is estimated to almost completely wipe out biodiversity in the areas where it is conducted, resulting in a final MSA of only 20%. Therefore, the impact of 1,000 tons of soy beverage is

$$0.5\text{km}^2 \times (20\% - 65\%) = - 0.23 \text{ km}^2.\text{MSA}$$

Hence, the impact of soy beverages per ton is still smaller than that of cow milk, but the difference is far less pronounced than it would appear based on the land amount needed.

Returning to the MSA impact of cow milk, a firm that sources 1 million tons of cow milk would have a CBF component of 1,000 × -0.65 km².MSA = -650 km².MSA. Using such computations, IDL estimates the overall CBF of Danone to be equal to -10,846 km².MSA.

Country by country, and activity by activity, IDL aggregates up all these land uses into a total land use CBF of Danone. We do not have the exact data that IDL uses for these computations so we cannot completely derive the full land use CBF for Danone.

B.3.2 GHG emissions

GHG emissions affect biodiversity because climate change causes changes in species distribution, often associated with population declines of local species (Alkemade, Bakkenes, and Eickhout 2011). Considering the damage function for GHG emissions, the basic idea is to use an estimate of what the impact of a certain amount of tons of CO_2 is on temperature increases, and then estimate the impact of an increase of the temperature by x units on MSA per km² (worldwide).

To perform this computation, IDL first draws on Joos et al. (2013), who estimate that the integrated absolute global mean temperature potential of one kg of CO_2 for the 100-year time horizon is 4.76.10-14$°C.yr.kgCO_2^{-1}$. Moreover, IDL draws on literature that estimates impacts on biodiversity expressed in MSA, for example the meta-analysis of Arets, Verwer, and Alkemade (2014). They propose a damage function linking the impact of each degree of Global Mean Temperature Increase (GMTI) to a relative loss of biodiversity expressed in MSA for 14 different biomes. Knowing the respective surface area of each of these 14 biomes, it is then possible to calculate their respective absolute MSA loss expressed in km²$.$MSA (Wilting et al. 2017). Danone discloses that it emitted 978kt CO_2 (scope 1 and 2) in 2021. IDL states that they always use modeled scope 3 data. Combining these data, IDL computes a contribution to a temperature increase. Then, applying estimates from the GLOBIO model, which simulates the impact of this temperature on each of the 14 terrestrial biomes (biogeographical unit) on Earth and their respective surface areas, IDL arrives at an MSA reduction (and thus a CBF) of -59.3km^2 due to Danone's GHG emissions.

B.3.3 Air and water pollution

For air pollution and water pollution, IDL proceeds similarly. Based on the estimate of tons of NOx emissions, and given the damage functions in the GLOBIO model for different biomes, IDL aggregates up the total impact of a firm's Nitrogent deposition worldwide as the sum of the impacts on each biome. They also convert Sox into NOx equivalents using acidification potentials and thus also allocate the impact of SOx emissions. Finally, IDL's model quantifies the biodiversity loss in freshwater ecosystems by drawing on data from UNEP and SETAC to characterize the ecotoxicological impacts of chemical emissions.

B.4 Changes in CBF over time

From this process, it is also apparent how the CBF for a firm changes over time. First, there may be changes in revenues per segment-country, either modelled or because reported inputs are replacing modelled ones. For instance, over time, Danone has produced more granular information in recent documents regarding its activities and its uses of commodities. For Danone it means for instance that if more cows are needed to produce milk, it will require extra soy to feed the cow which adds to Scope land use if it means new lands to be cultivated (deforestation). All the existing cattle will produce an additional yearly impact on climate change (it adds to the stock of CO_2 and contributes to climate change). Finally, some firms engage in restorative actions such as maintaining forest.

B.5 Numerical example for MSA

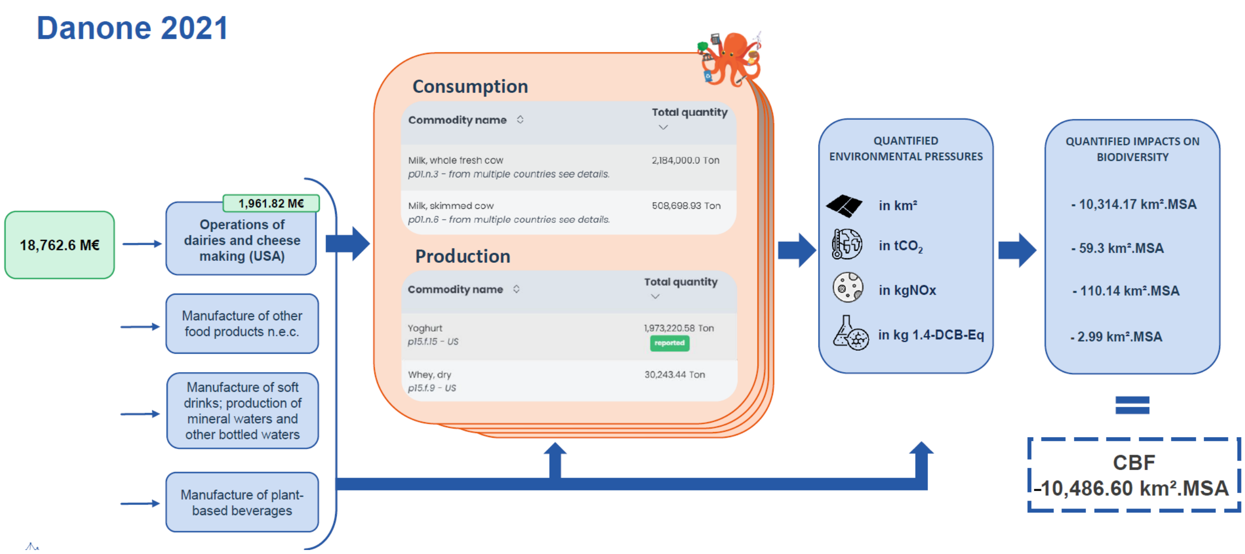
The MSA metric is an indicator of local biodiversity intactness. MSA ranges from 0 to 1, where 1 means that the species assemblage is fully intact, and 0 means that all original species are extirpated (locally extinct). MSA is calculated based on the abundance of individual species under influence of a given pressure, compared to their abundance in an undisturbed situation (natural situation/reference).

Notice that only species present in the undisturbed situation are included, and increases in individual species abundance from the reference to the impacted situation are ignored. This is done to avoid the indicator being inflated by opportunistic or generalist species that benefit from habitat disturbance.

For example, in IA Figure B.3, three species decrease in abundance (tree, deer, and owl) and two show an increase (frog, rodent). As new species and abundance increases do not count, the MSA is calculated as the mean of the abundance ratios of the four species in the reference situation, whereby the increase in frog abundance is ignored.

IA Figure B.1. CBF calculation for Danone: Overview

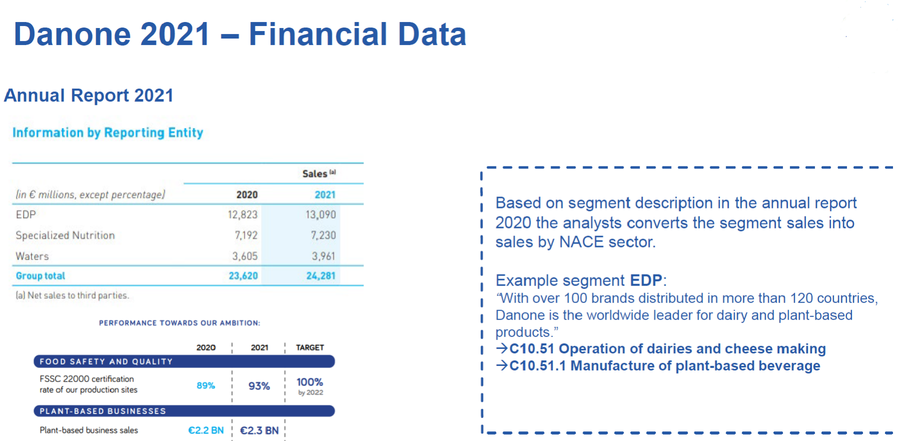
This figure illustrates the calculation of the CBF for food producer Danone for the year 2021. CBF is the corporate biodiversity footprint and reflects the biodiversity loss caused by the firm's annual activities.



IA Figure B.2.CBF calculation for Danone: Details

Panel A illustrates how data from Danone's annual report are used to determine its sales by NACE sector, which constitutes one step in calculating the firm's biodiversity footprint for the year 2021. Panel B illustrates how Danone's raw milk consumption, per geographical area, is used to calculate the firm's biodiversity footprint for the year 2021. Panel C illustrates how the data on carbon emissions are used to calculate Danone's biodiversity footprint for the year 2021. Panel D illustrates the contribution to biodiversity footprint by products and by sources of environmental pressures for Danone for the year 2021. Source: Iceberg Data Lab.

Panel A. Annual report data



Panel B. Raw milk consumption data

Panel C. Reported emissions data

Reported emissions used

GHG Data Scope 1 & 2

	Year ended December 31	
Scope 1 and 2 emissions, market-based *(in $ktCO_2$)* [a]	**2020**	**2021**
Scope 1	668	683
Scope 2	479	295
Total Scopes 1 & 2	**1,147**	**978**
Absolute emissions reduction, scopes 1 and 2, market-based since 2015	**38.1%**	**48.3%**

(a) Greenhouse Gas scope, see Methodology Note.

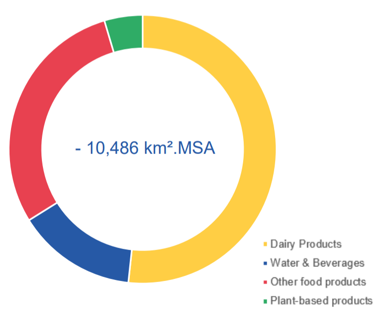
When the company reports on its CO2eq emissions, we integrate those values in the platform and replace the modelled data.

We use reported scope 1 & 2 emissions but we always model the scope 3.

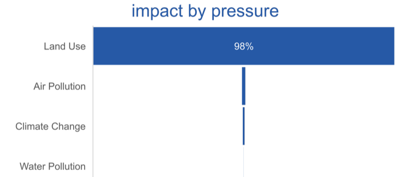
Panel D. Biodiversity impact by product

Corporate Biodiversity Footprint

Absolute contribution to CBF impact by products



Distribution of absolute contribution to CBF impact by pressure



Danone specializes in the worldwide manufacture and sale of fresh dairy products, nutrition food, and beverages. Like most Agri-food companies, its biodiversity footprint is driven by its supply chain through the land needed for the raw materials used to manufacture its products. The commodities which have the most material impact on biodiversity are the dairy products (land needed to breed and feed the dairy cattle) which require a higher land use occupation than other non-animal-related products. This results in a higher biodiversity ratio compared to industry peers.

IA Figure B.3. Computation of MSA

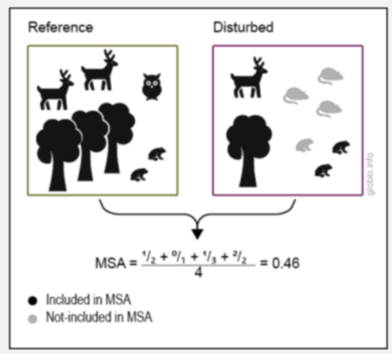
This figure illustrates the computation of the MSA metric. In the example, three species decrease in abundance (tree, deer and owl) and two show an increase (frog, rodent). As new species and abundance increases do not count, the MSA is calculated as the mean of the abundance ratios of the four species in the reference situation, whereby the increase in frog abundance is ignored. Source: https://www.globio.info/what-is-globio.

Species abundance ratio: $\frac{A_{i,disturbed}}{A_{i,reference}} = \frac{Nb\ individuals\ species\ i\ in\ \textbf{disturbed}\ state}{Nb\ individualsspecies\ i\ in\ \textbf{reference}\ state}$

Mean: $MSA = \sum_{i\ species} \frac{1}{N_{species}} \times \frac{A_{i,disturbed}}{A_{i,reference}}$

Example:

Species	Taxa	Indigenous / Invasive	Nb of individuals in reference state	Nb of individuals in disturbed state	Abundance Ratio A_i
Deer	Mammal	Indigenous	2	1	$\frac{1}{2}$
Tree	Plants	Indigenous	3	1	$\frac{1}{3}$
Owl	Bird	Indigenous	1	0	$\frac{0}{1}$
Frog	Amphibian	Indigenous	2	3	$\frac{2}{2}$
Rat	Mammal	Invasive	0	3	0
Total					**0.46**



C Determinants of sample coverage

This section of the Internet Appendix discusses determinants of data coverage by IDL.

A concern is that firms covered by IDL may be systematically different from non-covered firms, and these differences may bias any estimated biodiversity risk premium. For example, IDL may cover firms where investors worry about biodiversity issues, and our sample may in turn be biased towards firms with a biodiversity risk premium. A related concern is that the covered MSCI ACWI may be systematically different from the non-covered one. This is important to explore given that the MSCI ACWI is global market index followed by many investors ($4.3 trillion in assets are benchmarked to the index as of June 30, 2023). Sample selection effects may in turn suggest that biodiversity is priced in global equity markets, while in fact it is only priced among the select index subset covered by IDL.

We perform two tests in IA Table C.1 to understand potential biases. First, in Column 1, we condition on the MSCI ACWI universe and compare characteristics of covered and non-covered firms. To this end, we create a first dummy variable, IDL coverage, which equals one if an MSCI ACWI firm is covered by IDL, and zero if an MSCI ACWI firm is not covered. We then relate this variable to firm characteristics and proxies for a firm's transparency of environmental information (E score, Trucost estimated emissions, Biodiversity impact reduction). The latter variables help us understand whether some MSCI ACWI members are covered as they are more transparent. We find that MSCI ACWI firms covered by IDL are larger and invest more, but none of the information environment proxies emerges as a predictor of IDL coverage. Second, in Column 2, we condition on the universe covered by IDL and contrast firms inside and outside of the MSCI ACWI. We now create a second dummy, MSCI ACWI member, which is one if a firm covered by IDL is in the MSCI ACWI, and zero if it is not. We find that non-MSCI ACWI firms covered by IDL are relatively smaller and less environmentally transparent (as indicated by Trucost estimated emissions). In light of these observable differences, we verify below that our results hold if we restrict the sample to firms inside the MSCI ACWI universe.

IA Table C.1. Firm-level determinants of data coverage

This table reports reports regressions relating whether an MSCI ACWI firm is covered by IDL (whether a firm covered by IDL is a member of the MSCI ACWI) to firm characteristics. IDL coverage equals one if an MSCI ACWI firm is covered by IDL, and zero if an MSCI ACWI firm is not covered by IDL. MSCI ACWI member equals one if firm covered by IDL is included in the MSCI ACWI, and zero if firm covered by IDL is not included in the MSCI ACWI. Standard errors are clustered at the firm level. Intercepts are not reported. *, **, and *** represent significance levels of 0.10, 0.05, and 0.01, respectively. Appendix A provides variable definitions..

	IDL coverage	MSCI ACWI member
	MSCI ACWI firms	IDL firms
	(1)	(2)
Ln(Total assets)	-0.012	0.072***
	(0.014)	(0.012)
Ln(Market cap)	0.087***	0.111***
	(0.011)	(0.009)
Leverage	0.005	0.063
	(0.065)	(0.058)
Capex/Total assets	0.638*	-0.118
	(0.380)	(0.344)
PPE/Total assets	-0.069	0.018
	(0.080)	(0.069)
ROA	0.216	0.092
	(0.140)	(0.119)
Asset growth	0.056**	0.007
	(0.022)	(0.018)
Sales growth	0.037	0.035
	(0.027)	(0.023)
Ln(CO_2 Emissions)	-0.003	-0.008
	(0.009)	(0.007)
E score	-0.000	-0.001
	(0.001)	(0.000)
Trucost estimated emissions	-0.015	-0.088***
	(0.028)	(0.025)
Biodiversity impact reduction	0.018	-0.015
	(0.025)	(0.021)
Institutional ownership (Lagged)	0.000	0.001
	(0.001)	(0.001)
Year-month fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
# Obs.	5,338	5,490
R^2	0.224	0.438

D CBF and corporate disclosures: Case studies

This section of the Internet Appendix provides examples of how firms disclose biodiversity issues.

D.1 Examples from annual reports

Danone, Integrated Annual Report, 2019

“Together with partners, we launched two business-led coalitions ‘One Planet Business for Biodiversity’ (OP2B) and ‘Business for Inclusive Growth’ (B4IG), to transform farming and promote inclusive growth. These pioneering initiatives will help accelerate the food revolution and impact at scale.”

“...for food, just nine account for 66% of total crop production (*), while 60% of biodiversity has been lost. Business must promote a more diverse, resilient agriculture system. In line with our Goals to protect natural resources and serve the food revolution with partners, we co-built with the World Business Council for Sustainable Development the ‘One Planet Business for Biodiversity’ (OP2B) business coalition. Launched by Emmanuel Faber at the UN General Assembly in September 2019, OP2B unites 19 leading companies in a collective effort to promote biodiversity - by scaling up regenerative farming practices, diversifying crop production, eliminating deforestation and conserving ecosystems - and will report transparently on progress and impact. (*) UN Food & Agriculture Organization, 2019.”

“Producing food for future generations and farming responsibly depends on biodiversity - from soil regeneration to water filtration, pest control and pollination. Together with partners, we are striving to both protect and restore biodiversity and transform people’s relationship with nature, helping to create a healthy, resilient food system.”

“To promote biodiversity in the U.S., we have expanded our portfolio of yogurts to include non-GMO Project Verified options since 2016, in line with people’s preferences. In particular, we have supported farmers in cultivating non-genetically modified feed for their cows. We have also launched a multi-year, $6 million research program to help improve soil health and productivity. Importantly, we display the non-GMO Project Verified logo on packs and highlight any GM ingredients in our portfolio to help people make informed purchasing decisions."

D.2 Examples from earnings conference calls

Archer-Daniels-Midland, Earnings Conference Call, April 26, 2022

"We are advancing sustainability commitments in other parts of our business as well. Last year, we unveiled new goals to reduce Scope 3 emissions and eliminate deforestation from our supply chain. This is critical work. We do not make these kinds of commitments without an achievable plan to meet them, and once we move forward, we constantly challenge ourselves to do it faster. That is why last week, we announced that we've accelerated our deadline for a completely deforestation-free supply chain by 5 years from 2030 to 2025."

Sysco Corp, Earnings Conference Call, May 4, 2021

"Lastly, our corporate social responsibility initiatives in 2025 goals are progressing well. Our industry-leading CSR efforts are setting the standard for care and progress across 3 pillars of people, product and planet. We are making great strides on this very important work, as evidenced by our recent announcement with Cargill, which is a critical partnership, along with the National Fish and Wildlife Foundation to improve sustainable grazing practices across 1 million acres of grassland. This effort helps to improve soil health, promote biodiversity and increase carbon storage and safeguard the livelihoods of ranchers and the communities in which we serve."

E Biodiversity policy developments

This section of the Internet Appendix provides a summary of key biodiversity policy developments.

E.1 Pre-COP15 developments

The international biodiversity conservation agenda dates back to the 1980 "World Conservation Strategy" commissioned by the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN). The United Nation (UN) Convention on Biological Diversity (CBD) was opened for signature at the Earth Summit in Rio de Janeiro on June 5, 1992 and entered into force on December 29, 1993. Since then, 15 Conferences of the Parties to the CBD (COPs) have been held, though success has been limited. None of the 20 targets set at COP 10, for the period 2011-2020 (Aichi targets), have been fully reached (CBD Secretariat 2020).

While the UN CBD entered into force in 1993 and several Conferences of the Parties (COPs) to the CBD have adopted various plans to protect biodiversity, most goals have not been achieved (CBD Secretariat 2020); notably, the U.S. has signed but not ratified the CBD. Recent globally coordinated steps toward protecting biodiversity include the Kunming Declaration of 2021 and the Montreal Agreement of 2022, which we discuss in the next subsection.

While we focus on global developments, important region- and country-specific policy developments have also taken place, motivated in part by the local economic and financial consequences of biodiversity loss. For example, in the European Union (EU), the 2018 Action Plan on Financing Sustainable Growth has led to the establishment of a taxonomy of sustainable activities (which mostly concerns non-financial firms) and the consequent obligations of financial firms to disclose the "sustainable" part of their activities. The EU has also recently adopted regulatory technical standards for disclosures under the Sustainable Finance Disclosure Regulation (SFDR). In the U.S., following his executive order on protecting public health and the environment issued in January 2021, president Biden asked Fish and Wildlife Services (FWS) and National Marine Fisheries Service (NMFS) to review the changes made to the Endangered Species Act (ESA) during Trump mandate. On June

4, 2021, the two agencies released a plan to improve and strengthen the implementation of the ESA. In particular, they announced that the Trump administration's ESA rules which were making it easier to remove species from the endangered list or to exclude areas from critical habitat designation will be rescinded.

E.2 COP15: Kunming and Montreal summits

Major progress on biodiversity protection was made at the two parts of the UN Biodiversity Conference (COP15), which took place in October 2021 (Kunming) and December 2022 (Montreal). Reflecting a major breakthrough to protect biodiversity, the Kunming Declaration calls for countries to act urgently to protect biodiversity through their decision-making and to recognize the importance of conservation in protecting human health. In particular, it emphasizes the need to eliminate, phase out or reform subsidies and other incentives that are harmful to biodiversity. Analogous to the Paris Agreement for climate change, the landmark Kunming Declaration stresses the need to align financial flows to support the conservation and sustainable use of biodiversity (Article 13) (Kunming Declaration 2021). The second part of the COP15, in Montreal, ended with an agreement including 23 targets for achievement by 2030. The most prominent one, known as 30×30, places at least 30% of the world's land and ocean areas under protection. The Montreal Agreement also reaffirms that all relevant public and private activities as well as fiscal and financial flows should progressively be aligned with biodiversity protection (Target 14). Another target adopted in the Montreal Agreement includes requirements for large and transnational firms and financial institutions to monitor, assess, and transparently disclose their risks, dependencies, and impacts on biodiversity through their operations, supply and value chains, and portfolios (Target 15) (Montreal Agreement 2022).

E.3 Post-COP 15 developments

Since the COP15, central banks and financial market supervisors are increasingly paying attention to the topic (see, e.g., NGFS and INSPIRE 2022). Specifically, in March 2022, the Network for Greening the Financial System (NGFS), which regroups over 125 central banks and financial supervisors, published a statement acknowledging that nature-related risks could have important implications for financial stability and should therefore be considered as part of central banks' mandate. Partially as a result, various initiatives at the intersection of corporations and the public sector have emerged.

The Taskforce on Nature-related Financial Disclosures (TNFD), co-launched by the Financial Stability Board, proposes a framework for financial institutions and firms, analogous to the Task Force on Climate-related Financial Disclosures (TCFD). Specifically, the final recommendations, published in September 2023 and designed to be consistent with Target 15 of the Montreal Agreement, include 14 recommendations covering nature-related dependencies, impacts, risks and opportunities. These recommendations are regrouped in four pillars: i) *governance* (i.e., disclosure of the organisation's governance of nature-related dependencies, impacts, risks and opportunities), ii) *strategy* (i.e., disclosure of the effects of nature-related dependencies, impacts, risks and opportunities on the organisation's business model, strategy, and financial planning), iii) *risk and impact management* (i.e., description of the processes used by the organisation to identify, assess, prioritise and monitor nature-related dependencies, impacts, risks and opportunities), and iv) *metrics and targets* (i.e., disclosure of the metrics and targets used to assess and manage material nature-related dependencies, impacts, risks and opportunities).

Some countries or regions have developed additional disclosure guidelines. In France, a decree implementing the Article 29 of the Law on Energy and Climate requires financial institutions to disclose biodiversity-related risk (next to climate-related risks). In the EU, the SFDR contains Principle Adverse Impact (PAI) indicators, and one of these (PAI 7) requires information on activities negatively affecting biodiversity sensitive areas. Further, the EU Taxonomy's Environmental Objective 6 includes the protection and restoration of biodiversity and ecosystems. Last but not least, the Taxonomy's Do No Significant Harm (DNSH) principle requires that corporate activities are not detrimental to the ecosystem and status of protected habitats and species.

Important are also recent initiatives by institutional investor coalitions and NGOs, such as Nature Action 100, a global investor engagement initiative to tackle nature loss and biodiversity degradation. In September 2023, Nature Action 100 unveiled a list of 100 firms that the 190 institutional investor participants (representing $23.6 trillion assets under management) will engage with. Moreover, "Business for Nature" has called for nature assessment and disclosure to be mandatory. French SIF and Iceberg Data Lab (2022) provide an overview of these more recent policy developments and initiatives.

Finally, the High Seas Treaty (also referred to as the Biodiversity Beyond National Jurisdiction Treaty), adopted at the UN in June 2023, represents a landmark agreement for the safeguard of oceans and for the protection of marine biological diversity beyond national jurisdictions. The treaty was adopted in response to a blaring gap in ocean protection as only about 1% of the high seas areas was protected. It contains provisions based on the polluter-pays principle as well as mechanisms for disputes. As part of its 2030 biodiversity strategy, the EU has taken several actions to protect biodiversity including the adoption of a proposal for a nature restoration law (June 2022), the publication of sets of guidelines on forests (March 2023), the adoption of a proposal for a soil health law (July 2023), and the adoption of a proposal for a regulation establishing an EU forest monitoring framework (November 2023).

F Biodiversity measures by MSCI and Refinitiv: Score construction

This section of the Internet Appendix provides details on how MSCI and Refinitiv construct their biodiversity risk measures.

To compute the MSCI biodiversity & land use exposure measure, MSCI aims to capture three risks for firms: i) loss of license to operate; ii) litigation by landowners and other affected parties; and iii) increased costs of land protection and reclamation. It assesses firms based on their business segment and geographic exposures, for which it generates separate subscores that are then combined into an overall score. For the segment exposure, MSCI considers the percentage of each segment's operations with high/moderate/low impact on biodiversity, drawing on information from the World Resources Institute, Refinitiv, and firm disclosures. The overall Business Segment Exposure Score is a weighted average of the biodiversity and land use risk exposure scores of a firm's business segments (weighted by segment assets). Similarly, the Geographic Exposure Score is a weighted average of the biodiversity and land use risk scores of the countries and regions in which a firm operates (weighted by the assets in each geographic segment). MSCI states that it incorporates information from Global Forest Watch, the World Resources Institute, the UNDP Human Development Report, Refinitiv, and firm disclosures. The two subscores are then combined into an overall score, but the score can be further altered by other firm-specific factors, if applicable (e.g., size of workforce, percentage outsourced, etc.). MSCI scores a firm's biodiversity and land use exposure on a 0-10 scale, with 10 corresponding to the highest and 0 to the lowest risk.

In comparison, Refinitiv biodiversity impact reduction measure is not a score ranging from 0 to 10, but instead a dummy variable indicating whether a firm reports its impact on biodiversity or on activities to reduce this impact. Refinitiv constructs the indicator for a global sample

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