Nature and Biodiversity Loss: A Research Agenda for Financial Economics

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Abstract

We outline a research agenda to better understand the economic and financial consequences of nature and biodiversity loss. Our starting point is a simple model in which ecosystem services—such as pollination, water filtration, and carbon sequestration—enter economic production, and where nature degradation and climate change reinforce one another through a "Twin-Crises Multiplier." We then extend this framework to allow for heterogeneity across firms, industries, and geographies in how they depend on, and in turn affect, nature. This broader perspective provides a foundation for empirical analyses of how biodiversity loss influences aggregate output, firm productivity, and financial risk. We conclude by identifying opportunities for asset pricing and corporate finance research to systematically incorporate nature and biodiversity into financial economics.

The ongoing global acceleration of nature degradation poses significant economic and financial risks. Since these nature and biodiversity risks are conceptually distinct from—and yet interconnected with—the economic risks from climate change, they are becoming an important focus of firms, investors, and regulators. For example, in its 2025 update to its monetary policy strategy, the European Central Bank mentioned, for the first time, the relevance of such risks, announcing that *"within its mandate, the Governing Council is committed to ensuring that the Eurosystem fully takes into account, in line with the EU's goals and objectives, the implications of climate change and nature degradation for monetary policy and central banking."*[1]

And yet, while there has been much research on the financial implications of climate change (see Giglio, Kelly and Stroebel, 2021; Hong, Karolyi and Scheinkman, 2020; Stroebel and Wurgler, 2021, and the articles in this symposium for a review), nature and biodiversity risks are comparatively less well understood. This is quickly changing. This article synthesizes some of the emerging research on the economic and financial implications of nature and biodiversity loss, and proposes a research agenda to improve our understanding of these critical issues. We believe that such work constitutes a promising research endeavor, the importance of which is destined to grow over the coming years.

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[1] In a July 2025 speech, Frank Elderson, Member of the Executive Board and Vice-Chair of the Supervisory Board of the ECB, explained the significance of this strategy update as follows: *"Adding the three words 'and nature degradation' to our monetary strategy statement is an important step forward. Climate refers to the statistical patterns of weather over time—a pattern that is visibly changing, with major implications for our economy. Nature, on the other hand, encompasses the entirety of Earth's physical environment, including all living organisms. It is everything not made by humans. So, by adding "nature degradation" we have now committed to considering a vastly more complex set of factors in setting our monetary policy.*

Before we begin, a note on terminology. While the terms biodiversity and nature are often used interchangeably, they are somewhat distinct. Nature is a broad term that encompasses all natural elements, including landscapes, ecosystems, water, and living organisms. Biodiversity specifically refers to the variety of life within nature—covering the diversity of species, genes, and ecosystems. Biodiversity interacts with the non-animate parts of nature to produce the ecosystem services that enter economic production. In that sense, biodiversity loss is one of the most important examples of nature loss.[2]

We structure our discussion around a simple conceptual framework inspired by the model in Giglio et al. (2025*b*). The model incorporates the insight that ecosystem services provided by nature—including both *provisioning services* such as agricultural goods, timber, and genetic resources used in pharmaceutical production and R&D; and *regulating and supporting services* such as pollination, water purification, and air filtration—are direct inputs to economic production (see Heal, 2000; Dasgupta, 2021; Giglio et al., 2024). Our framework explicitly describes the interactions between climate change and nature loss. It also distinguishes the channels through which each translates into economic and financial impacts, underscoring the importance of dedicated research on both processes.

While this simple model focuses on the aggregate effects of climate change and nature loss, these losses percolate through the economy in heterogeneous ways that are key to understanding the full economic consequence of nature-related risks. Recent work has started exploring empirically the financial implications of these risks in reduced form (Giglio et al., 2023; Garel et al., 2024), but it has done so without the guidance of an explicit theoretical framework. This paper aims to fill this gap by providing theoretical foundations for future research via expansions and generalizations of the aggregate model that can account for (i) firm- and industry-level heterogeneity in the dependence of the production processes on nature, and thus in *physical nature risk exposures*; and (ii) firm- and industry-level heterogeneity in impacts on nature, and thus *transition nature risk exposures*. We also discuss research questions that arise from explicitly considering the geographic heterogeneity in the health of nature and from technological innovations that might increase our ability to substitute for declining provision of ecosystem services with other capital sources. We conclude by discussing a range of newly emerging financial instruments aimed at helping to finance nature conservation activities.

1 The Economics of Climate Change & Nature Loss: Distinct & Intertwined

Consider a two-period model with a representative agent who discounts the future at rate β. Output is produced using the function $F(K_t, E_t)$. The first input is physical capital, K_t; the second is ecosystem services derived from nature, E_t, highlighting nature's important role in the economic production process that was previewed above. Time-0 state variables are initial capital, K_0, and ecosystem services, E_0. The agent chooses K_1 to maximize total discounted utility,

$$W = U(C_0) + \beta U(C_1), \tag{1}$$

[2] We want to highlight the role of biodiversity loss not only because it is a crucial channel of nature loss, but also because the recent literature has made advances in both the theory and measurement specifically of biodiversity loss.

s.t.

$$C_0 = F(K_0, E_0) - K_1, \tag{2}$$

$$C_1 = (1 - D(Z_1, E_1))F(K_1, E_1). \tag{3}$$

$$Z_1 = \theta^K K_1 + \theta^E E_1, \tag{4}$$

$$E_1 = E_0 - \delta K_1 - \gamma Z_1. \tag{5}$$

Equation (2) shows that consumption in the first period, C_0, is the total output produced, F, minus investments in physical capital to be used in period 1, K_1.

Equation (3) describes consumption at time 1, when the agent produces with the pre-determined factors K_1 and E_1. We follow Nordhaus and Boyer (2003) and others, and capture the damages to output due to climate change through a damage function $D(Z_1, E_1)$. These damages are increasing in climate change, Z_1, but can be reduced by nature, E_1, capturing 'nature-based climate adaptation' such as the ability of mangrove forests to reduce damages from coastal flooding (Liu et al., 2025).

Equation (4) describes the determinants of period-1 climate change, Z_1. Climate-changing greenhouse gases are emitted through production using physical capital, K_1, with the coefficient $\theta^K > 0$ capturing the carbon intensity of capital. The parameter θ^E captures the net carbon emissions of nature, E_1. Since carbon sequestration by forests, oceans, and soils makes nature a net carbon sink, we let $\theta^E < 0$.

Equation (5) describes the evolution of ecosystem services. Period-1 ecosystem services will be reduced by higher period-1 capital use ($\delta > 0$), as highlighted by IPBES (2019). Nature's ability to provide services is also reduced by period-1 climate change ($\gamma > 0$), as described in Urban (2024).

Figure 1: Nature Loss, Climate Change, and Economic Activity

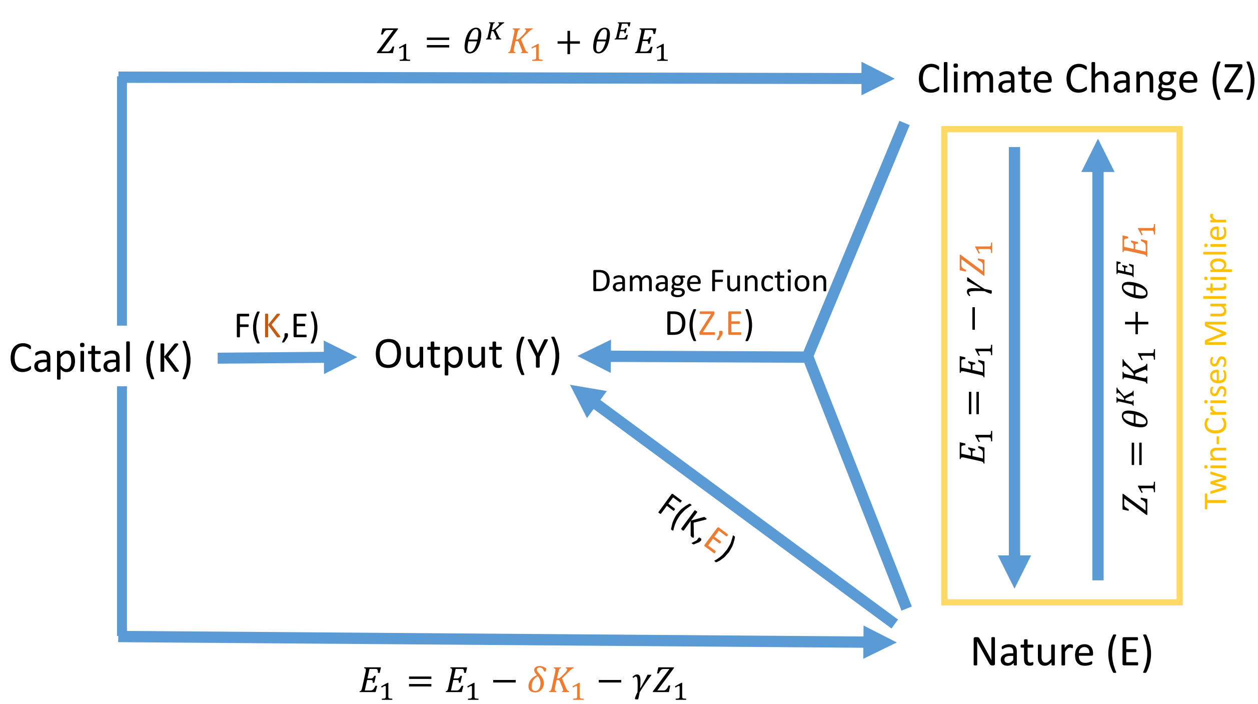


Figure 1 shows a schematic of the different forces captured by the model, which highlights several aspects of the climate-nature relationship. First, unlike physical capital, nature appears not just as another factor of production, but as a *clean* factor that can add to economic output while having *negative* net carbon emissions. This implies that even if the direct effects of nature loss on economic output can be compensated for by increases in physical capital—a big *if*, as we discuss below—this will come at the cost of increased carbon emissions and ultimately higher climate damages.

Second, the two-way feedback between climate and nature means that the benefits from improvements in one dimension (climate mitigation, nature conservation) are amplified by indirect effects in the other dimension. Conversely, the degradation of one is amplified by its effect on the other. Destroying nature therefore does not only reduce output directly, but also indirectly, since the destruction of carbon sinks leads to larger climate damages, which destroy output and further degrade nature. This "Twin-Crises Multiplier" is explored in more detail in Giglio et al. (2025*b*).

A recent concrete example of these interactions can be found in the Coral Triangle, a marine region spanning six countries in Southeast Asia that is home to 76% of the world's coral species. Coral reefs interact with climate change in various ways: they protect coastlines from storms and erosion (i.e., they reduce climate damages D) and also act as carbon sinks to absorb atmospheric carbon dioxide ($\theta_E < 0$); however, they are themselves damaged by climate change as increasing temperatures lead to coral bleaching ($\gamma > 0$). Together, these feedbacks have led to loss of marine biodiversity and the local provision of ecosystem services, which support the livelihoods of over 120 million people through fisheries and tourism (Coral Reef Alliance, 2023).

2 The Measurement and Pricing of Biodiversity Risk Exposures

A key research priority for financial economics is to understand how different assets are exposed to the risks associated with nature and biodiversity loss. Such measurement is central to managing these risks for both investors and corporate managers. It is also a necessary first step for exploring the asset pricing implications of biodiversity and nature risks: are assets that are more exposed to these risks trading at a discount, all else equal? And is the current pricing of these risks adequate, or should we worry about a potential sudden repricing of exposed assets as the risks become more widely appreciated?

Two types of risk exposures are of primary interest. *Physical risk exposures* capture the effects of nature degradation on asset values and tend to be larger for firms more dependent on ecosystem services. *Transition risk exposures* capture the effects of regulatory or other interventions to protect nature and are greater for firms with larger environmental footprints. In a recent survey of investors, academics, and regulators, over 70% of respondents judged such biodiversity risks to be at least moderately material for U.S. firms (Giglio et al., 2023). A complementary global survey found that 43% of firms already perceive material exposure to physical nature risks, while 27% report current financial materiality from transition risks (Gjerde et al., 2025).

In this section, we propose several ways to expand the aggregate model described above to incorporate heterogeneity in how much firms depend on and affect nature. This framework offers guidance to empirical research that seeks to measure and price various types of biodiversity or nature risk exposures.

2.1 Physical Biodiversity Risk Exposures

A common approach in the risk management literature is to describe physical risk exposures through the heuristic

$$Risk = Hazard \times Vulnerability,$$

which reflects the idea that risks arise from the probability and severity of dangerous events (hazards) combined with the extent of damage they can cause (vulnerability). Differences in physical risk exposures of firms can be driven both by variation in the hazards they face—which is largely driven by firm location—as well as variation in vulnerability. In the next section, we extend the model in Section 1 to account for this heterogeneity.

2.1.1 Heterogeneity in Hazards and Vulnerability Across Firms

Consider first the case in which a firm located in region ℓ uses a composite ecosystem service E_ℓ: the potential loss of this service represents the $Hazard_\ell$ from the firm's point of view. But even firms that are located in the same region, and that are therefore embedded in a common ecosystem, can have heterogeneous vulnerability due to different reliances on ecosystem services E_ℓ:

$$Y_{i,\ell} = F_i(K_{i,\ell}, \alpha_{i,\ell} E_\ell). \tag{6}$$

It follows that how Y_i depends on E will be a function of α_i: firms or industries with a higher α_i rely more on ecosystem services directly, in the sense that changes in E—all else equal—have larger effects on their output.[3] However, the coefficients α_i—which scale the marginal product of nature in the firm's production process—do not by themselves characterize the entire dependence of firm i's production on nature, and therefore its vulnerability. Instead, the long-run effects of nature degradation also depend on whether firms can substitute for declines in E using other factors of production. Specifically, in addition to the parameter α_i, the entire functional form of the production process F_i—and especially the substitutability between capital K_i and ecosystem services $\alpha_i E$—will be fundamental in determining a firm's reliance on nature.[4] For example, in agriculture, the negative effects of declining provision of ecosystem services such as soil recycling can be partially compensated for by increased use of synthetic fertilizers. On the other hand, ecotourism, another industry with significant nature dependencies, has few options to compensate for nature degradation, since the core product is the natural experience itself.

2.1.2 Disaggregation Across Ecosystem Services

So far, we have considered a "composite" ecosystem service used by the firm. In reality, different firms (even when located in the same place) will use different ecosystem services. As a result, the most advanced measurement approaches to calculating firm-level physical biodiversity risk exposures attempt to disaggregate the various ecosystem services a firm depends on:

$$Y_i = F(K_i, \alpha_{i1} E_1, \ldots, \alpha_{iG} E_G), \tag{7}$$

[3] To ease notation, we drop the dependence on location, but it is implicit that everything that follows varies with location.

[4] Furthermore, equation (6) only describes the *direct* role of ecosystem services in production. In reality, a full accounting of how a firm may be affected by nature declines needs to take into account *indirect* exposures via supply chains.

where E_1, E_2, ... represent different (but typically complementary) functions performed by the ecosystem where the firm operates. For example, E_1 might be pollination; E_2 clean water provision; E_3 biological control services; and so on.

However, when using such a framework to measure hazard and vulnerability, it is important to understand that these ecosystem services are *complementary* with each other, and that ecosystems struggle to reliably provide *any* ecosystem services when key ecosystem functions are missing (Szyrmer and Ulanowicz, 1987; Rapport, Costanza and McMichael, 1998; Williams et al., 2002; Felipe-Lucia, Comín and Bennett, 2014; OECD, 2023; Fricke et al., 2025). When a firm depends directly on only one function g but not others (that is, α_{ig} is high but α_{ih} is low for $h \neq g$), it may be tempting to assume that the firm's vulnerability arises from g alone, and an analyst assessing that function g is abundantly provided might conclude that the firm is not highly exposed to nature-related risks. But the complementarity across functions implies that firms are still indirectly exposed to shocks to *all other* ecosystem services. Intuitively, a firm may only rely directly on water; but water provisioning by the ecosystem may be disrupted when other ecosystem services—e.g., flow regulation function by forests—are degraded. We can model these interdependencies in reduced form as:

$$E_g = H^g(E_{-g}),$$

where E_{-g} denotes ecosystem functions other than g. Therefore, a firm depending directly on ecosystem function g can be affected indirectly by nature loss in seemingly unrelated ecosystem functions, through their indirect effect on the health of function g. This can be captured by contrasting the partial and total derivatives:

$$\frac{dF_i}{dE_g} = \frac{\partial F_i}{\partial E_g} + \sum_{j \neq g} \frac{\partial F_i}{\partial E_j} \frac{\partial H^j}{\partial E_g}.$$

2.1.3 Biodiversity Loss as a Source of Ecosystem Service Losses

The analysis so far has described firms' exposures to declines in ecosystem service provision at a given location ℓ and for a specific function g: $\partial E_{\ell,g}$. What remains is to identify the drivers of these declines, since understanding the underlying sources is essential for assessing both their likelihood and severity.

As reviewed by Giglio et al. (2024), ecosystem functions are typically performed by the interaction of multiple species, which may be partially substitutable. In species-rich ecosystems, local extinctions often have limited initial effects on service provision due to functional redundancy. For example, declines in bee populations can be partly offset by increases in other pollinators such as butterflies, though the positive biodiversity–productivity relationship documented in ecology suggests that such substitutions are rarely complete (Hooper et al., 2005; Tilman, Isbell and Cowles, 2014; Naeem et al., 1995; Tilman, Wedin and Knops, 1996; Hector et al., 1999; Liang et al., 2016). By contrast, degraded ecosystems with low species richness may depend heavily on a few keystone species, whose loss can generate severe disruptions in ecosystem functioning.

Building on these insights, it is possible to further enrich the model by "opening up" the function-level losses $\partial E_{\ell,g}$ and characterizing them as a function of the losses occurring at the species level, either due to naturally occurring stochastic events or due to human activity such as land use. Specifically, Giglio et al. (2024) model the provision of each function $E_{\ell,g}$ as arising from the interaction of species. They map species losses to losses in ecosystem services $\partial E_{\ell,g}$ and introduce the concept of *ecosystem fragility*, which measures the expected loss in ecosystem services from a random species decline in a given location. This fragility depends not only on the average level of past species loss but also on how these losses are distributed across ecological functions. They illustrate how to operationalize the ecosystem fragility measure empirically, using species-level habitat data from ecological surveys.

2.1.4 Current Measures of Physical Biodiversity Risk Exposures

Despite challenges in measuring physical biodiversity risk exposures, several approaches have been developed to capture the dependencies of firms and industries on nature.

The most widely used methodology is provided by the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) initiative, launched in 2018 by the Natural Capital Finance Alliance to help financial institutions and businesses understand their dependencies and impacts on nature. ENCORE maps 167 economic sectors and 271 economic activities to 25 ecosystem services, assigning each potential dependency a materiality score based on quantitative and qualitative indicators, including expert assessments that can reflect the substitutability of ecosystem services with produced capital discussed above. Several data vendors now aggregate these activity-level dependencies to the firm and industry level to produce nature dependency scores (S&P Global, 2025).

Giglio et al. (2023) propose two complementary approaches for measuring firm-level exposures to biodiversity risks (with data publicly available at www.biodiversityrisk.org). The first relies on expert surveys explicitly designed to assess a firm's total dependence on biodiversity: for example, financial market participants were asked to rank industries by exposure to physical and transition biodiversity risks (see Panel A of Figure 2). Such surveys can capture overall exposures—including indirect ones—provided experts are aware of the relevant dependencies. The second approach draws on firms' own disclosures, such as 10-K filings or earnings calls. This leverages firms' internal knowledge of both direct and supply-chain exposures, and Giglio et al. (2023) document numerous cases of firms explicitly reporting physical biodiversity risks. The drawback, however, is that such measures depend on firms' awareness and willingness to disclose their dependencies.

More generally, Table 1 provides an overview of some popular data sets that are helpful to researchers hoping to estimate asset-level nature and biodiversity risk exposures.

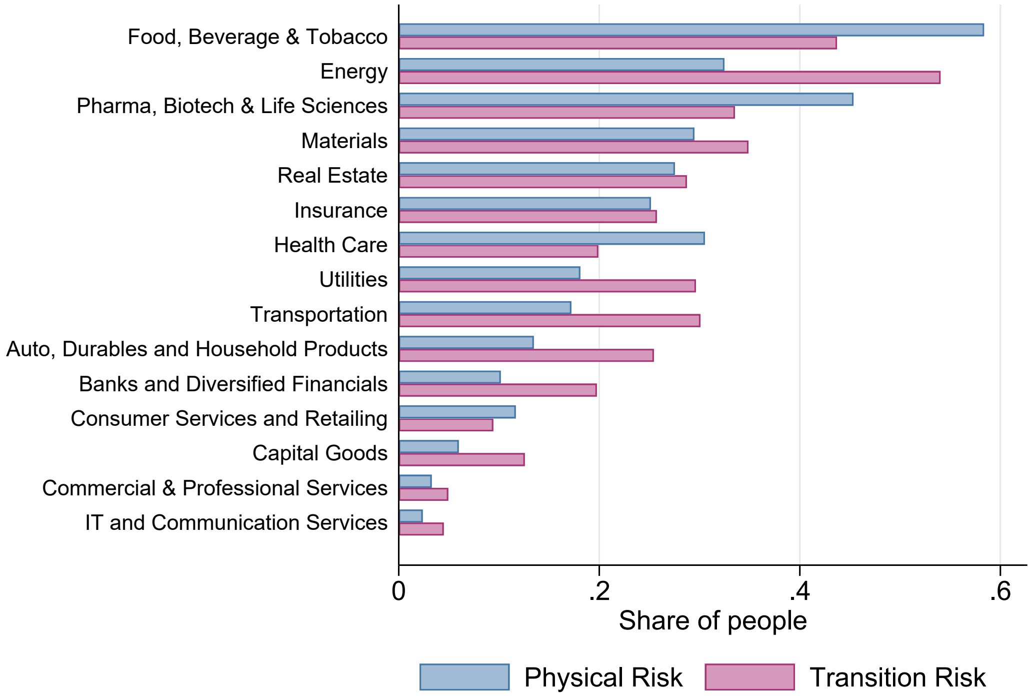
2.1.5 The Pricing of Physical Nature and Biodiversity Risk Exposures

The measurement of firms' dependency on nature and biodiversity is important for policymakers, who can use them to design taxes and regulations, as well as for financial market participants, who can use this information to allocate capital and potentially create incentives for firms to better manage these risks. For financial markets to have a material effect on firm behavior, however, a necessary condition is that biodiversity risks are reflected in the prices of financial assets. In this section, we review emerging research exploring this question, though we caution that the challenges with measuring firm-level physical biodiversity risk exposures complicate any such analysis.

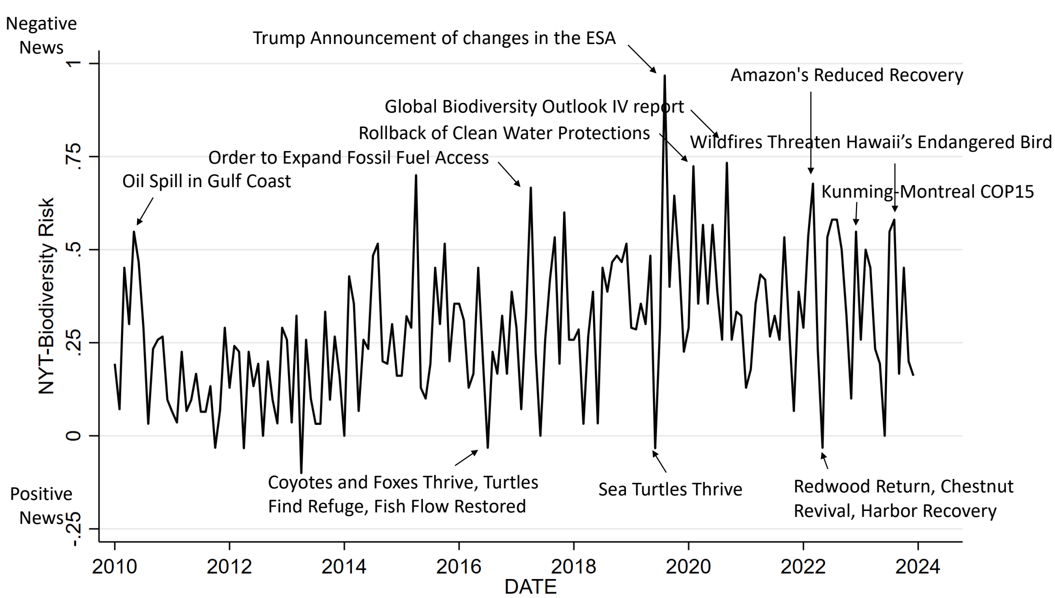
The empirical asset pricing literature has developed several tools that can be applied to study two aspects of how nature and biodiversity risks are priced. A first question is whether asset prices respond to the realization of such risks—that is, whether they exhibit a "beta" with respect to them. A second

Figure 2: Measures of Biodiversity Risk

(a) Industry-Level Biodiversity Risk Exposures



(b) NYT-Biodiversity News Index



Note: Panel (a) presents physical and transition risk exposures measured by experts, as reported in Giglio et al. (2023). The blue bars represent survey-based physical risk, while the red bars indicate survey-based transition risk. Industries are sorted by the average of these two survey-based measures. Panel (b) shows the Monthly NYT-Biodiversity News Index from 2010 to 2023, annotated with biodiversity-relevant news announcements. ESA: Endangered Species Act. Higher values correspond to more negative news. See Giglio et al. (2023) for details.

Table 1: Biodiversity Data Sources

Dataset	Description	Source
Map of Life	Global distribution maps, range data, and richness indices for vertebrates and select invertebrates and plants, integrating data from GBIF, eBird, and other sources, by Jetz, McPherson and Guralnick (2012)	Map of Life webpage
IUCN Red List	Conservation status, geographic ranges, and population trends covering 163,040 animal, plant and fungal species	IUCN Red List webpage
Global Forest Watch	Platform providing global annual tree cover loss data alongside near-real-time forest disturbance alerts, using methodology by Hansen et al. (2013)	Global Forest Watch webpage
Global Biodiversity Information Facility (GBIF)	Species occurrence records (point observations) from 116,617 datasets	GBIF webpage
Human Footprint Index	Global composite index of anthropogenic pressure on ecosystems from population, land use, and infrastructure, using methodology by Sanderson et al. (2002)	Mu et al. (2022) data and Gassert et al. (2023) data
InVEST Models	Spatially explicit models estimating the economic value of ecosystem services (e.g. carbon storage, pollination, water purification)	InVEST webpage
Ecosystem Services Valuation Database (ESVD)	Global database of over 10,000 monetary value estimates of ecosystem services across biomes and countries, collected by Brander et al. (2024)	ESVD webpage (request access)
ENCORE	Framework linking economic sectors to their dependencies on ecosystem services and their impacts on biodiversity, enabling assessment of nature-related risks	ENCORE webpage
World Bank Natural Capital Accounts	Country-level ecosystem and natural capital accounts developed using the SEEA framework, covering forests, water, land, and ecosystem services	World Bank Natural Capital Data Hub
Corporate Biodiversity Footprint	Aggregated indicators of biodiversity pressure at sector and geographic levels, derived from Iceberg Labs' corporate biodiversity footprint data by Garel et al. (2024)	UZH webpage (partial release; full dataset proprietary)
Biodiversity Risk	Indices of biodiversity-related financial risk, including a news-based aggregate risk index and firm- or industry-level exposures, by Giglio et al. (2023)	Biodiversity Risk webpage

Note: Table provides descriptions and sources of key datasets relevant for biodiversity research.

question is whether investors demand a risk premium for bearing exposures linked to a firm's dependence on nature, though the data requirements for addressing this second question are substantially more demanding.

To examine firms' betas with respect to nature risk realizations, one must first identify such shocks and then test whether the prices of more exposed firms decline upon their occurrence. For example, Giglio et al. (2023) sort companies by various measures of exposure to physical biodiversity risks and study their returns when aggregate negative biodiversity events are reported in the New York Times (see Panel B of Figure 2 for their aggregate risk series). They find that firms in industries more exposed to physical biodiversity risk experience weaker returns following negative biodiversity news, though the effects are small and not always statistically significant—perhaps reflecting the challenges of measuring physical biodiversity risk exposures at the firm level.

Another promising direction is to examine how biodiversity risks affect asset values through aggregate (country-level) exposure to ecosystems of varying health and resilience. Giglio et al. (2024), for instance, measure ecosystem fragility within each country based on the average biodiversity loss and its dispersion across ecological functions. They show that CDS spreads of countries with more fragile ecosystems increase more strongly following negative news about biodiversity loss.

Because nature and biodiversity exposures are inherently location-specific, it is particularly useful to study their effect on the pricing of assets whose cash flows can be tied clearly to a place, such as municipal bonds or real estate. Frank et al. (2025) document that defoliation outbreaks reduce nearby residential property values by roughly 3% on average. Similarly, Kovacs et al. (2011) analyze the impact of "Sudden Oak Death" (SOD), a virulent forest disease, and find that properties within three-tenths of a mile of SOD-infested oak woodlands lose 3–6% of their value, with discounts as large as 8–15% in areas where dying oaks are widespread throughout neighborhoods and wetlands.

2.2 Transition Biodiversity Risk Exposures

In the previous section, we focused on modeling how different firms depend on ecosystem services for their production, and how this dependence might lead to *physical* risks arising from nature and biodiversity loss. In this section, we instead consider the exposures of firms that arise because their economic activity *affects* nature and biodiversity, which makes those firms exposed to potential regulatory costs that we refer to as *transition risks*. Our model can accommodate heterogeneous exposure to transition risks by allowing firms to differ in how their production affects the evolution of ecosystem services (δ_i):

$$E_1 = E_0 - \sum_i \delta_i K_{1i} - \gamma Z_1. \tag{8}$$

However, the model in Section 1 highlighted that δ_i does not capture the full negative effects of firm i on nature. Firms also differ in how much carbon they emit (θ_i^K):

$$Z_1 = \sum_i \theta_i^K K_{1i} + \theta^E E_1, \tag{9}$$

and this has the indirect effect of further affecting nature (through γ). Equations (8) and (9) are linked through the two-way feedback loop between nature loss and climate change. Solving this system, we can map the cross-sectional distribution of economic activity (K_i) to aggregate ecosystem services:

$$E_1 = \Phi \times \left(E_0 - \sum_i (\delta_i + \gamma \theta_i^K) K_{1i} \right),$$

where $\Phi = \frac{1}{1+\gamma\theta^E}$ is the Twin-Crises multiplier. This allows us to understand the *total* impact that a firm's activity has on the provision of ecosystem services, taking into account the feedback effects with climate change. Specifically, firm i has an effective impact on ecosystems $\Phi \left(\delta_i + \gamma \theta_i^K \right) K_{1i}$ where the second term in the parentheses captures the destructive effect of the firm's carbon emissions on nature.

The externality imposed by firm i on nature does not represent a direct cost to the firm. It does, however, create exposure to potential regulatory costs, since policies that force firms to internalize their environmental footprint would likely impose higher taxes on those with greater impacts on nature. While solving for the optimal regulation is beyond the scope of this paper, it is plausible that regulators may choose to price either a firm's direct impact on nature, δ_i, or its total impact, $\Phi\left(\delta_i + \gamma\theta_i^K\right)$. In the latter case, biodiversity transition risk could extend to firms with high carbon emissions (captured by θ_i^K), even if they have no direct impact on ecosystems. Similarly, impact investors aiming to reduce the negative footprint of their portfolios would place greater pressure on firms with large impacts on nature, whether through direct ecosystem destruction or carbon emissions.[5]

Finally, it is important to note that, just as firms' dependence on nature may change over time due to technological advances or managerial choices, their impact on nature can also be time-varying. A comprehensive assessment of biodiversity transition risk exposures must thus consider firms' nature-related strategies, including the credibility of any commitments to reduce negative impacts on ecosystems.

2.2.1 Current Measures of Transition Risk Exposures

As with physical biodiversity risk, measuring a firm's exposure to transition risk is challenging, as it requires assessing its impact on nature,[6] though several approaches have been proposed in the literature.

In addition to mapping ecological dependencies, the ENCORE initiative characterizes, for each economic activity, its main environmental impacts based on data and expert assessments. Similarly, the commercial provider Iceberg Labs constructs a Corporate Biodiversity Footprint (CBF) as a metric of a company's impact on biodiversity. Giglio et al. (2023) employ multiple strategies to measure transition risks: (i) eliciting industry-level rankings of exposure through surveys of financial market participants, and (ii) analyzing firm disclosures about transition risks in 10-K statements. Arlt et al. (2024) define transition risk based on the industries identified by the NGFS-Nature Action 100 as systemically important for reversing nature loss. Finally, Sacher and Singla (2025) measure spatial variation in transition risk by combining ecological data from NatureServe on species rarity and gaps in habitat protection to construct county-level proxies for latent regulatory risk—highlighting areas where future interventions are most likely to emerge.

2.2.2 The Pricing of Biodiversity and Nature Transition Risk Exposures

Several studies have examined how biodiversity transition risks are priced across asset classes. Garel et al. (2024), using Iceberg Labs' CBF data, show that firms with greater negative biodiversity impacts experienced valuation declines following two salient events: the Kunming Declaration in October 2021 (COP 15) and the launch of the Taskforce on Nature-related Financial Disclosures in June 2021 (see also Coqueret, Giroux and Zerbib, 2025). Similarly, Giglio et al. (2023) find that firms more exposed to transition biodiversity risk lose value when negative biodiversity news materializes. Soylemezgil and Uzmanoglu (2024) further document that increases in firms' regulatory biodiversity risk exposures are associated with higher yield spreads on long-term bonds, with these effects intensifying after COP 15.

Evidence of pricing effects extends beyond corporate securities. Chen et al. (2023) show that the

[5] In addition, climate regulation (or climate-focused impact investors) may penalize firms with low direct emissions (low θ_i^K) if their activities degrade ecosystems in ways that ultimately increase emissions, for example by reducing the capacity of ecosystems to absorb carbon dioxide.

[6] Exposures to biodiversity transition risks can substantially differ from exposures to climate transition risks. For example, a solar or wind energy developer may benefit from stricter climate policy while still facing transition risk if new biodiversity rules restrict land use in ecologically sensitive areas.

"Green Shield Action," a regulatory initiative in China to enforce biodiversity protections in National Nature Reserves, raised municipal bond yields for affected jurisdictions, reflecting both foregone economic activity and higher conservation costs. Prices in real estate markets also seem affected by biodiversity risks: Bahrami, Gustafson and Steiner (2024) report that vacant parcels located just inside U.S. biodiversity-protected areas trade at a 45% discount relative to comparable parcels just outside the boundary, reflecting restrictions on future development.

3 Finance and the Monetization of Nature Conservation

The previous sections have highlighted the diverse ways in which nature interacts with firms, industries, and entire economies. Of course, these interactions alone do not necessarily imply a misallocation of capital or inefficient use of natural resources. However, as with climate change, externalities play a central role in shaping individual choices regarding nature. In particular, the damages from exploiting natural resources are widely distributed and often occur in the future, while the benefits can be extracted immediately and are typically concentrated among a few firms. In this section, we discuss the economic and financial tools available to incentivize nature conservation under such conditions, as well as the conceptual and practical limits of these solutions. Further research on the development of such instruments is both of academic interest (Karolyi and Tobin-de la Puente, 2023) and of key policy importance.

In an ideal world, the first-best policy response to the overuse of natural resources would be a Pigouvian tax or a cap-and-trade system. For climate change, such a policy is feasible—at least technically, if politically difficult—because the externality is well-defined and measurable: it arises from greenhouse gas emissions, which provide a natural policy target. By contrast, for nature degradation, a fundamental challenge stems from the heterogeneity of natural resources, their roles in economic activity, and their relative value. For instance, the destruction of a mangrove forest (providing coastal erosion protection) and the degradation of water quality from industrial discharge both represent losses of natural capital, but their value—formally, the present discounted value of future welfare impacts—is context-dependent and difficult to quantify. Moreover, as highlighted in previous sections, the ecological (and thus economic) value of even the same species can vary substantially across ecosystems, depending on the availability of other species that perform similar functions.

Even with well-measured externalities, the complexity of implementing first-best policies raises the question of whether financial markets can provide complementary mechanisms to encourage firms to internalize the effects of their actions on nature. One option is to require firms to invest in biodiversity offsets and credits, which compensate for ecological damage from development projects and mirror climate instruments. Offsets generally require developers to protect, restore, or create equivalent habitat elsewhere to balance biodiversity loss from their projects. Credits are tradable financial assets, decoupled from specific projects, that reward conservation outcomes (Aronoff and Rafey, 2023). While these mechanisms may promote conservation, they face the same challenges noted above: heterogeneity in the value of natural resources complicates comparisons between what is gained and what is lost.

Another market-based instrument to encourage conservation is a debt-for-nature swap, in which sovereign creditors reduce a country's external debt burden in exchange for commitments to fund domestic conservation projects. For instance, Ecuador's 2023 deal lowered its outstanding sovereign debt at a discount, reallocating savings toward marine conservation in the Galápagos Islands. More recently, Indonesia signed a similar agreement with the United States in 2024, redirecting over $35 million of debt payments toward protecting the Coral Triangle. These examples illustrate how financial solutions can simultaneously address fiscal constraints and biodiversity loss, though their global scale remains severely limited relative to the challenge they aim to meet.

Similar innovation has occurred elsewhere in the fixed income space. Green bonds, whose proceeds are committed to environmental projects, may provide benefits to borrowers through lower yields, though there is disagreement about the size of this discount, or whether it exists at all (Baker et al., 2022). Such bonds are financed by investors willing to sacrifice some financial return in exchange for subsidizing conservation activities (see Giglio et al., 2025*a*, for evidence on the share of investors willing to forgo financial returns to achieve non-financial objectives). While most green bonds have financed climate-related projects, more specialized nature and biodiversity bonds have recently been issued, often with a targeted conservation focus (e.g., blue bonds devoted to maritime projects). Other proposed instruments include sustainability-linked bonds, which offer firms financial incentives tied to specific conservation objectives. Blended finance—the mixing of public and private capital—provides another pathway for sustainability-oriented capital to support conservation, albeit at the cost of lower returns (see Flammer, Giroux and Heal, 2025*a*,*b*). Finally, payments for ecosystem services (PES) offer direct incentives to landowners or communities in exchange for maintaining or enhancing ecosystem functions (see the discussion in Harstad and Storesletten, 2023). A prominent example is Costa Rica's national PES program, launched in the 1990s and financed partly by a fossil fuel tax, which pays landowners to preserve or reforest land and is widely credited with helping reverse deforestation trends in the country.

While growing in practical importance, these financial mechanisms and instruments have received little academic attention—a missed opportunity, in our view. Improvements in assessing their ultimate conservation success could substantially influence their adoption and scaling.

4 Conclusion and Other Directions for Research

The study of nature, climate, and their joint interactions with economic activity presents both challenges and high-reward opportunities for future research.

Many of the most promising opportunities come from advancing the measurement. Improvements in the measurement of asset-level *physical* biodiversity risk exposures depend on advances in our ability to assess the underlying hazards. This promising direction for research will benefit from interdisciplinary collaborations between financial economists and ecologists. A better understanding of the likelihood of different hazards will also be helpful in the design of nature and biodiversity stress tests, which, alongside climate stress tests, are increasingly being added to the toolkit of regulators interested in exploring risks to the financial system (Acharya et al., 2023; Arlt et al., 2024). Similarly, it is important to better understand the direct and indirect dependencies of different firms on nature and biodiversity. Indeed, many firms might historically have taken their use of natural inputs in production as given, and thus may not be fully aware of their nature dependencies. Given the importance of estimating the degree of substitutability between nature and other factors of production, tools from industrial organization might be usefully applied in this context. In addition, it seems valuable to explore how R&D might be targeted towards increasing firms' ability to substitute for ecosystem services in economic production with other factors of production. A related research agenda at the intersection of finance and accounting should focus on ways to incorporate dependencies on nature in the financial accounting process. Such attempts at "putting nature on the balance sheet" are also an important first step in using various financial market instruments to finance nature conservation. On the transition risk side, further work is needed to quantify the total effect of firm activities on nature loss, particularly through carbon emissions and the Twin-Crises multiplier. It is also important to study firms' ability to reduce their negative effects on nature, especially if regulation increasingly prices these externalities.

Better measures of exposures and vulnerabilities will facilitate research on the pricing of biodiversity risks and help design financial instruments that internalize and transfer these risks. While initial studies suggest some pricing of biodiversity risks—a necessary first step for markets to address these issues—evidence remains limited and fragmented across asset classes. A particularly promising topic is whether there are regional differences in pricing, perhaps reflecting variation in market attention to nature and biodiversity risks. Finally, the key question is not only whether these risks are priced, but whether they are priced correctly. Answering this requires high-quality measures as well as the development of new theoretical frameworks.

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