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FINANCIAL MARKETS AND SUSTAINABILITY

HOW BIODIVERSITY AFFECTS INVESTMENT

Biodiversity, widely recognized for its role in environmental sustainability, remains an understudied topic in the context of the stock market. Using a combination of fixed regression models and random forest techniques, the research shows that biodiversity is a significant determinant of stock returns. This finding underscores the financial importance of integrating biodiversity into corporate strategies and decisions by providing valuable insights for investors, regulators, and companies interested in aligning their financial strategies with environmental sustainability goals.

BIODIVERSITY//FINANCE//ESG//FINANCIAL PERFORMANCE//SUSTAINABILITY

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INTRODUCTION

Biodiversity in nature is rapidly declining, a trend which is posing a concrete threat to ecosystems and, consequently, to investors. The variety of living species on Earth is diminishing at an alarming rate due to human activity, ranging from habitat destruction to greenhouse gas emissions. In this regard, although the world's 7.6 billion people represent only 0.01% of all living beings in terms of weight, humanity has already caused the loss of 83% of all wild mammals and half of all plants (World Economic Forum, 2020). The current extinction rate is tens or hundreds of times higher than the average of the last 10 million years, and it is accelerating. Current modes of production and consumption, land use and urbanization, demographic dynamics, trade, industry, and

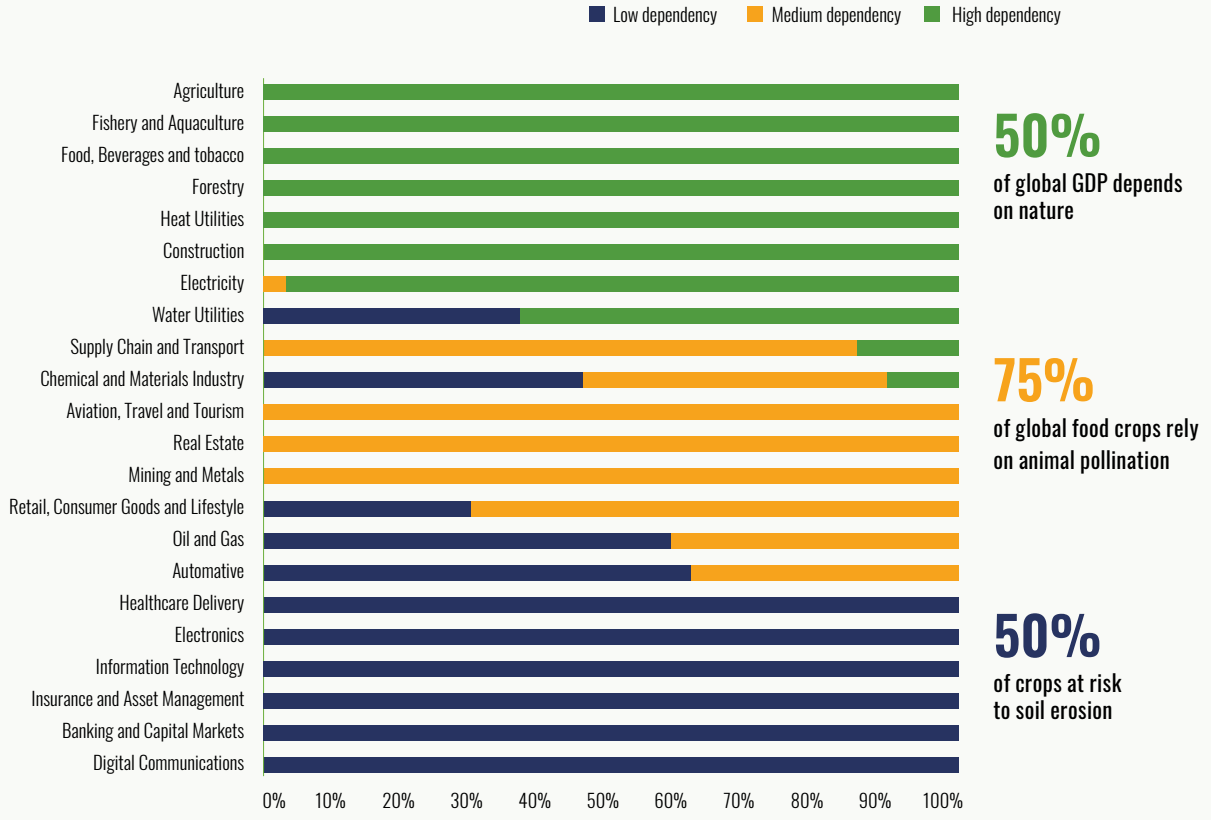
governance patterns are responsible for this loss, requiring a radical reset of humanity's relationship with nature.

It is not surprising, then, that in 2024 the World Economic Forum placed biodiversity loss and ecosystem collapse among the top three risks in terms of probability and impact over the next 10 years. This, according to the organization's Global Risks Report (GRR) based on its comprehensive risk perception survey. The basic premise here is that human societies and economic activities fundamentally depend on biodiversity. In fact, research shows that $44 trillion of economic value, more than half of the world's total GDP, is moderately or highly dependent on nature and its services, and therefore exposed to biodiversity loss.

Together, the three largest sectors heavily reliant on nature generate approximately $8 trillion of Gross Value Added (GVA): construction ($4 trillion); agriculture ($2.5 trillion); and food and beverages ($1.4 trillion) – taken together, that's roughly double the size of the German economy. While the risk to primary industries is easy to comprehend, the consequences for secondary and tertiary industries can be substantial too. For instance, six sectors - chemicals and materials; aviation, travel, and tourism; real estate; mining and metals; supply chain and transportation; retail, consumer goods, and lifestyle - with less than 15% of their direct GVA strongly dependent on nature, still have "hidden dependencies" throughout their supply chains. In fact, more than 50% of the GVA of their supply chains is highly or moderately dependent on nature (World Economic Forum, 2020).

Remarkable growth and prosperity have come

FIGURE 1 DEPENDENCE ON NATURAL CAPITAL (WORLD ECONOMIC FORUM, 2020)



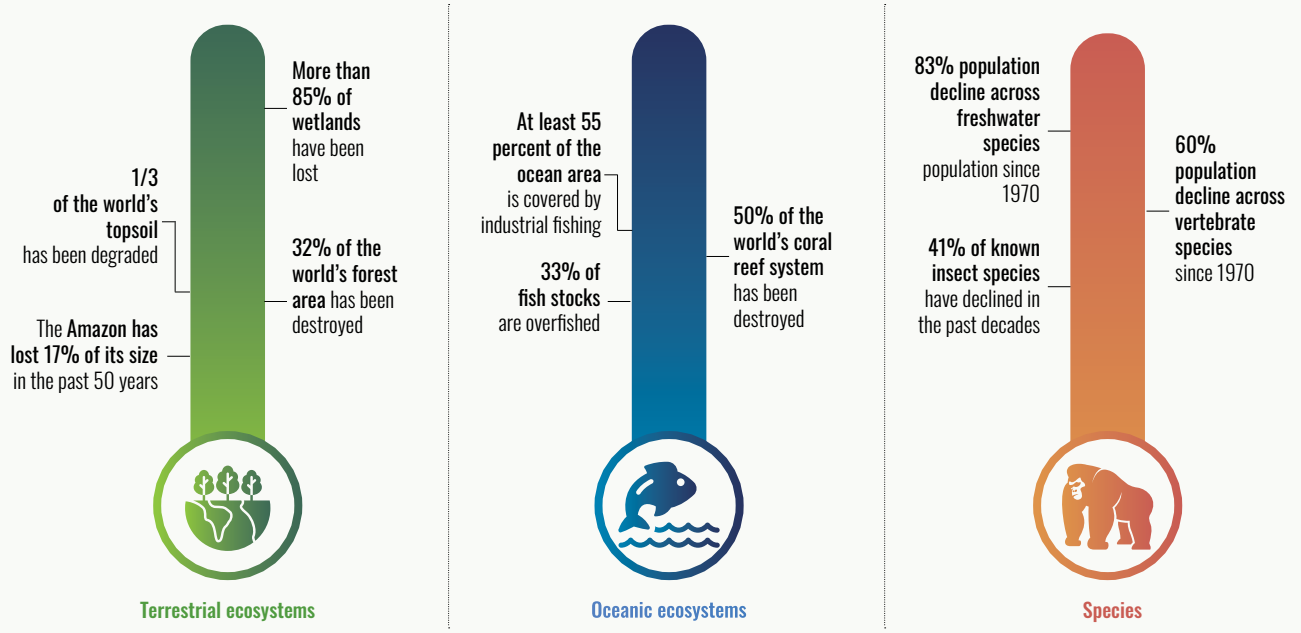
at a high cost to the natural systems that support life on Earth, and consequently, support these economic successes as well. Human activities have already severely altered 75% of the land and 66% of marine environments. About 25% of assessed plant and animal species are threatened by human actions, with one million species at risk of extinction.

Despite the growing awareness of biodiversity's financial relevance, and corporate policies that recognize this fact, there is still a gap in understanding its direct impact on stock performance. This paper seeks to bridge that gap by investigating the relationship between biodiversity and stock market outcomes. This issue is consequential because, unlike broader ESG factors, biodiversity has unique ecological and regulatory implications that could influence risk exposure, long-term sustainability, and market perception. Therefore, the significance of this study lies in its potential to provide actionable insights for businesses and investors. By empirically examining the relationship between biodiversity and financial returns, we aim to inform corporate strategies and investment decisions that align with sustainable development goals. This research not only advances our understanding of biodiversity's role in financial performance but also underscores the necessity for companies to integrate biodiversity considerations into their core business strategies.

Specifically, we explore whether listed companies that invest in biodiversity initiatives achieve superior stock performance compared to their peers. Using a comprehensive dataset across various industries and regions, this study examines the impact of biodiversity on corporate financial performance by analyzing firm-specific stock returns in an asset pricing framework, using the Fama-French five-factor model.

Our main results demonstrate a statistically significant, positive relationship between biodiversity investments and stock performance, confirming the hypothesis that firms that consider biodiversity tend to perform better financially. The study further identifies a market factor directly linked to biodiversity, underscoring its potential as a driver of stock returns. These findings suggest that biodiversity considerations could have

FIGURE 2 IMPACT OF HUMAN ACTIVITY (WORLD ECONOMIC FORUM, 2020)



meaningful implications for corporate financial outcomes in the broader market. Therefore, the main contribution of our research lies in the identification of biodiversity as a distinct factor influencing stock performance, providing empirical evidence of its potential financial relevance for both companies and investors.

In the subsequent sections, we review the relevant literature on biodiversity factors and financial performance. We then detail our research methodology, including data sources, variables, and our analytical approach. Following this, we present and discuss our empirical findings, concluding with a summary of key insights and suggestions for future research avenues.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

General ESG Framework

The degradation of the environment poses a major challenge potentially hindering the growth and expansion of companies worldwide. This issue primarily stems from the unsustainable utilization of resources in the pursuit of economic gains, leading to pollution with adverse social ramifications. Firms are increasingly recognizing the imperative of striking a balance across various aspects of ESG. This equilibrium is crucial for ensuring sustainable long-term growth while fostering trust and support from the community (Almeyda and Darmansya, 2019).

Existing literature has delved into the efficacy of ESG factors in influencing stock prices as safety assets, particularly by analyzing their performance during bear markets. However, findings do not uniformly support this hypothesis in the short term, suggesting a longer-term perspective instead (Rebonato, 2023). This outlook shows that ESG investments can potentially serve as an alternative for risk hedging purposes for global investors (Rubbaniy et al., 2021; Taylor and Neff, 2022) and may impact the risk premium of companies (Faccini et al., 2023). Therefore, it becomes essential to regard ESG as a risk management tool for corporations rather than merely a standalone driver of investment strategies. By integrating sustainability and social impact criteria, which also play a role in determining future financial performance, ESG factors can be effectively integrated into investment decision-making processes (Bradley, 2021).

Extensive research detailed in existing literature has focused on investigating the relationship between ESG activities and corporate financial performance over subsequent years. However, there remains a lack of consensus regarding the relevance and direction of the effects that ESG activities have on a firm's financial results (Martielli et al., 2022). The absence of a unified view on this topic is clearly observable in the data collected by Friede et al. (2015), underscoring the need for further exploration and a deeper understanding of the dynamics at play. In this sense, indeed, ESG is not a one-dimensional construct; its impact can vary appreciably based on the specific actions a firm undertakes. This highlights the importance of unpacking the various types of investments within the ESG framework, particularly as they relate to biodiversity. ESG initiatives are often characterized by unique environmental and social factors that can influence the returns they generate. Therefore, using a targeted approach will not only enhance our understanding of biodiversity's role in corporate financial performance but also provide valuable guidance for companies and investors looking to navigate the complexities of sustainable investing.

Biodiversity Loss: Definition and Causes

Biodiversity refers to the diverse array of life forms on Earth, including terrestrial, marine, and other aquatic ecosystems. It encompasses the genetic diversity within species, the variety among species, and the range of ecosystems they inhabit (United Nations, 2013). This comprehensive definition includes all life forms, even microorganisms like bacteria and viruses, which can sometimes pose risks to human health.

The majority of the world's biodiversity hotspots are located in the tropics, where fertile land supports a rich variety of life forms (Hanski, 2016).

However, biodiversity is unique to each country, with ecosystems that possess distinct characteristics and vulnerabilities (Dasgupta, 2021). Consequently, preserving biodiversity necessitates concerted efforts at global, national, and local levels. This requires the active participation of individuals, governments, nonprofit organizations, and critically, corporations and their supply chains (Salmi et al., 2023).

In the context of business and biodiversity, the literature frequently emphasizes land use change as a leading cause of biodiversity loss, implicating industries such as agriculture, forestry, and mining in particular. Other noteworthy drivers include pollution, the introduction of invasive species, overexploitation of natural resources, and climate change (Armenteras and Finlayson, 2012). Land use change involves converting natural areas into agricultural fields, orchards, tree farms, and residential or commercial developments (Turner et al., 1990). These transformations can lead to habitat destruction (Lambin et al., 2001) or habitat fragmentation (Winn and Pogutz, 2013), both of which are detrimental to biodiversity.

Pollution represents a critical but often underemphasized factor in biodiversity loss. It affects ecosystems by contaminating air, water, and soil. For example, emissions from power plants, including sulfur dioxide and nitrogen oxides, contribute to acid rain, which damages vegetation and aquatic systems (Grantz et al., 2003). Fertilizer runoff can lead to eutrophication, fostering algae blooms that severely disrupt aquatic ecosystems (Lyons et al., 2014). Furthermore, the pervasive use of pesticides and fertilizers modifies soil conditions, often making them inhospitable for various organisms and thereby diminishing soil biodiversity (Lyons et al., 2014).

Invasive species are a major driver of biodiversity loss (Butchart et al., 2010). These non-native species can be deliberately introduced by various industries, such as agriculture, forestry, aquaculture, and hunting, through the release of cultivated or bred plants and animals. Alternatively, they may be transported into a country or region unintentionally via the movement of goods, where invertebrates or pathogens hitch a ride in cargo holds (Essl et al., 2011). In regions where there are no natural predators or regulatory mechanisms to keep these invaders in check, and where environmental conditions are favorable, they can thrive and outcompete native species, leading to dramatic disruptions in local ecosystems (Butchart et al., 2010).

Finally, overexploitation of resources represents another major driver of biodiversity loss. The demand for wild animals and plants leads to excessive hunting and harvesting, often at rates that prevent populations from rebounding (Panwar et al., 2023).

Biodiversity Corporate Strategies

In today's rapidly evolving business landscape, integrating biodiversity considerations into corporate strategies has become increasingly critical (Salmi et al., 2023). Companies are recognizing that their operations do not occur in isolation but are deeply intertwined with the natural environment (Winn and Pogutz, 2013). As the impacts of human activity on ecosystems become more pronounced, businesses are compelled to address their role in biodiversity loss and adopt tactics to mitigate these effects. Corporate biodiversity strategies encompass a range of approaches designed to protect and enhance natural habitats, from implementing sustainable land use practices to investing in conservation initiatives. These strategies are not only essential for environmental stewardship but also hold meaningful implications for a company's financial performance, regulatory compliance, and public reputation (Panwar et al., 2023).

In this field, conservation is frequently employed as a broad term to describe efforts focused on protecting biodiversity proactively and on-site (Panwar et al., 2023). This approach is based on the premise that biodiversity loss can be prevented by designing business practices that avoid negative impacts on natural habitats. In essence, conservation represents a preventative strategy aimed at preserving the current state of

biodiversity before any harm occurs.

Restoration, while also implemented on-site like conservation, differs fundamentally in its approach. Unlike conservation, which aims to prevent biodiversity loss from occurring in the first place, restoration focuses on addressing biodiversity loss after it has happened. This strategy acknowledges the inevitability of some degree of biodiversity loss due to commercial activities and seeks to rehabilitate the affected areas once those activities have ended. The goal of restoration is often to revert an ecosystem to its condition prior to the disturbance in question (National Research Council, 1992). However, achieving this goal can be challenging due to the lack of comprehensive information about the original ecosystem and the complexities involved in recreating it, even when baseline conditions are known (Moerke & Lamberti, 2004).

Compensation is another preventative strategy, but it contrasts notably with conservation. Whereas conservation presumes that it is possible to conduct business in a way that avoids or minimizes biodiversity loss on-site, compensation, like restoration, concedes that the project site will see some degree of biodiversity loss. But instead of striving to prevent that loss, compensation focuses on offsetting the impact by developing or safeguarding biodiversity in a different location. This approach, known as spatial separation, enables companies and development planners to address the inherent conflicts between preserving biodiversity and pursuing economic development goals (Büscher & Dressler, 2007).

Finally, reparation functions as a post-impact form of compensation. It shares the fundamental goal of compensation—addressing biodiversity loss—but it is implemented after the damage has already occurred. This strategy is often driven by regulatory mandates as well as voluntary corporate commitments. In regulatory settings, reparation is commonly associated with in-lieu fee mitigation, where companies contribute financial resources to conservation efforts to compensate for their environmental impacts (Wilkinson, 2009).

Hypothesis Development

Companies can respond to biodiversity loss in various ways. Previous studies (e.g. Boiral et al., 2018) have examined numerous corporate biodiversity protection strategies, however their link with financial returns remains unclear (Salmi et al., 2023).

In this sense, we do believe that biodiversity is a critical factor for sustainability and we acknowledge global efforts are escalating to protect and conserve biodiversity (Winn and Pogutz, 2013). Specifically, investing in biodiversity can boost a firm's stock performance by enhancing regulatory compliance, improving brand reputation, and attracting ESG-focused investors. Such investments help mitigate risks associated with environmental regulations, strengthen public perception, and ensure operational sustainability. In this sense, the recent momentum in biodiversity conservation initiatives, such as the Kunming-Montreal Global Biodiversity Framework, underscores the growing importance of biodiversity considerations. Additionally, the potential positive impact of biodiversity investments on companies' long-term financial performance aligns with the broader understanding of sustainability as a driver of value creation. Moreover, governments and supervisory bodies are introducing stricter environmental regulations, like the new EU Nature Restoration Law, and companies that proactively invest in biodiversity are better positioned to comply with these new norms (Panwar et al., 2023). This reduces the risk of fines and sanctions, providing a more stable investment environment and positively impacting stock performance. Therefore, biodiversity investments help companies manage risks associated with ecosystem degradation, such as resource scarcity and supply chain disruptions. Companies that mitigate these risks through proactive biodiversity investments are likely to experience less volatility in their operations and stock performance (Bioral et al., 2018).

Furthermore, biodiversity investments can differentiate a company from its competitors (Salmi et al., 2023). Consumers are favoring products and services from environmentally

responsible companies more than ever (World Economic Forum, 2024). This preference can lead to higher sales, customer loyalty, and, consequently, improved financial outcomes. Investing in biodiversity can lead to long-term financial benefits as well. Healthy ecosystems support industries by ensuring the availability of resources, such as clean water and fertile soil, which are essential for agriculture, pharmaceuticals, and other sectors. Companies that contribute to maintaining these resources may enjoy lower operational costs and more sustainable supply chains, which translates into better financial performance.

Finally, while biodiversity investments are a subset of ESG investments, they are distinct in their specific focus on preserving the variety of life on Earth. Other ESG investments might address broader issues like carbon emissions, labor practices, or corporate governance. Biodiversity investments instead specifically enhance ecosystem services, which directly support various business operations and contribute to overall ecological stability. This unique contribution to sustaining the natural capital upon which many industries depend can provide additional, distinct financial benefits (World Economic Forum, 2024).

Therefore, based on these considerations, it is reasonable to propose the following hypothesis: **Companies that invest in biodiversity should obtain higher stock performances.**

MATERIALS AND METHODS

Data and Variables

This research utilized the Refinitiv Datastream database, incorporating both market and ESG information. The dataset comprised publicly listed companies in the US, Canada, Japan, the European Union, the UK, and Australia from 2018 to 2023. We focused exclusively on listed data given that sustainability reports are currently available mainly for public companies. To ensure investability, we applied the following criteria: i) market capitalization greater than €500 million; ii) free float exceeding €20 million; and iii) average daily traded value over the past 52 weeks of at least €5 million. Additionally, only companies with available biodiversity data were included, resulting in a final sample of 962 organizations. The dependent variable used in this study is total return, which account for both stock price returns and dividends.
Concerning the biodiversity variables, the following data points were retrieved from Refinitiv (Dyck et al., 2019): biodiversity score (ranging from 0 to 100) and dummy variables indicating that SDG 6, 14, or 15 is included in the company's sustainability plan.
The biodiversity score assesses a company's exposure to and management of risks related to biodiversity and land use. Combining several variables, this score: i) evaluates the company's involvement with external groups to address biodiversity impacts; ii) measures the proportion of operations with ecosystem protection programs certified or assured by external bodies; iii) checks if the company has committed to minimizing disturbances to biodiversity, following the mitigation hierarchy of avoid, minimize, restore, and offset; iv) assesses if the company has a policy to reclaim habitats on disturbed land; and v) reviews the extent of operations covered by the company's biodiversity and land reclamation policy, including supply chain and direct operations.

Another useful context for considering investments in biodiversity is provided by the United Nations Sustainable Development Goals (SDGs), which have emerged as a common language for understanding how companies and portfolios are positioned for environmental and social impact. Of the 17 SDGs, the three most directly associated with biodiversity are 6 (clean water and sanitation), 14 (life below water) and 15 (life on land). However, it's important to note that simply referencing a specific SDG does not necessarily mean that a company is actively investing in or implementing initiatives related to that goal. In other words, the mere mention of an SDG in a company's reports or statements may not reflect substantial or genuine efforts toward achieving the targets associated with that particular goal.

Following the recommendations in the literature (Fama and French, 1993), we enhanced the robustness of our results by incorporating control variables related to the Fama and French model. These variables were sourced from the Dartmouth Library.
The descriptive statistics of the variables we used can be found in the next table.
Results show that, on average, companies have a relatively moderate biodiversity score of approximately 60. This despite the fact that most organizations incorporate multiple biodiversity-related SDG into their targets.

TABLE 1 DESCRIPTIVE STATISTICS

Variables	Min	Median	Media	Max
BIODIVERSITY RATING	0.0	78.1	62.3	98.1
SG6	0.0	0.0	1.0	1.0
SDG14	0.0	0.0	1.0	1.0
SDG15	0.0	0.0	1.0	1.0
RI	-80.0	5.8	11.4	600.0
MKT-RF	-7.0	18.6	22.6	28.3
SMB	-6.2	-2.8	-3.4	3.4
HML	-46.7	-4.8	-10.1	25.8
RMW	-5.2	6.2	5.1	26.7
CWA	-20.9	-0.2	-1.5	22.4

Research Design

This study investigates the influence of biodiversity on corporate financial performance by analyzing firm-specific returns in an asset pricing framework using panel data. The Fama-French five-factor model (Fama and French, 1993) is utilized due to its suitability for the dataset and its proven effectiveness in evaluating sector-specific risk in comparison to the overall market.

In this context, the Fama-French factors are employed as control variables, aligning with the approaches endorsed by previous research (Brounen and Marcato, 2018; Mariani et al., 2018).
These control variables are essential for isolating firms' excess returns, which in turn offers a more precise assessment of the impact of biodiversity on financial performance.

Using the Fama-French five-factor model (FF5), several analyses were performed to evaluate the impact of biodiversity factors. Firstly, the total biodiversity score was added to the model to determine its effect. This was implemented in two forms: as a numerical score (Model 1) and by introducing dummy variables for the inclusion of SDG 6 (clean water and sanitation), SDG 14 (life below water), and SDG 15 (life on land)—Sustainable Development Goals associated with biodiversity—in the companies' sustainability plans (Model 2). Additionally, a biodiversity factor (BIO) was developed following the Fama and French methodology, consistent with the approach of Brounen and Marcato (2018) and included in our results as Model 3.

Therefore, our work involves several models to assess the influence of biodiversity factors. In Model 1, we incorporate the total biodiversity score directly into the Fama-French model to evaluate its impact on financial returns. In Model 2, we enhance this approach by including dummy variables for SDGs related to biodiversity (SDG 6, 14, and 15), examining how the integration of these SDGs into companies' sustainability plans affects their financial performance. In Model 3, we develop a dedicated biodiversity factor (BIO) based on the Fama-French methodology, as suggested by Brounen & Marcato (2018). This factor is included to specifically measure the impact of biodiversity considerations on firm returns. All these models are designed to comprehensively investigate the influence of biodiversity on corporate financial performance, ensuring a robust analysis that aligns theoretical expectations with empirical evidence.

The estimated models are therefore:

Model 1:

$$R_{it} - RF_t = a + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 Biodiversity_{it} + \varepsilon_{it}$$

Model 2:

$$R_{it} - RF_t = a + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 SDG6_{it} + \beta_6 SDG14_{it} + \beta_6 SDG15_{it} + \varepsilon_{it}$$

Model 3:

$$R_{it} - RF_t = a + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 BIO_t + \varepsilon_{it}$$

Where RI is the return of the stock, RF is the risk free rate, and MKT, SMB, HML, RMW, and CMA represent the following factors: MKT is the yearly return of the stock market index minus the risk-free rate; SMB (Small Minus Big) captures the size premium; HML (High Minus Low) reflects the value premium based on book-to-market ratios; RMW (Robust Minus Weak) measures the operating profitability premium; and CMA (Conservative Minus Aggressive) represents the investment premium. Here, *i* denotes the i-th observation, and t refers to the time of the observation.

Regarding Model 1 and Model 2, it is crucial to recognize that while biodiversity is a firm-level variable, examining its impact at the market level is justified (Brounen and Marcato, 2018). First, biodiversity factors can exert systematic effects across various industries and sectors, thereby influencing market-wide risk and return dynamics. Second, as investors increasingly incorporate biodiversity considerations into their portfolio allocation decisions, this results in market-wide adjustments in asset prices based on firms' biodiversity performance.

However, Model 3, which constructs a biodiversity factor (BIO) mimicking the Fama and French methodology, should take precedence over Models 1 and 2. This approach ensures a more robust analysis by better accounting for the systematic influence of biodiversity on financial performance. Nevertheless, caution is warranted in interpreting these biodiversity coefficients, as they may still be correlated with other firm characteristics. This approach enhances the robustness of the analysis by more effectively accounting for the systematic influence of biodiversity on financial performance.

Concerning Model 3, this approach appreciably augments our capacity to thoroughly evaluate the impacts of biodiversity. Simultaneously, we introduce a time series that illustrates the return disparity between stocks with high and low biodiversity ratings, integrating this variation as the sixth factor (BIO). BIO is derived by computing the difference in excess returns between the top 25% biodiversity-rated portfolios and the bottom 25% biodiversity-rated portfolios. This calculation enables us to gauge the performance gap between stock portfolios with the highest and lowest biodiversity ratings. By including this additional factor, Model 3 offers a more nuanced comprehension of how biodiversity considerations shape financial performance across diverse firms.

To ensure the reliability of our empirical model, we performed a set of diagnostic tests, specifically targeting: i) stationarity, ii) absence of autocorrelation, and iii) normality. Initially, we treated the sample as independently pooled in our analytical process. However, following the Hausman test, it became evident that the fixed effects model is the suitable approach for each scenario. In fact, this model accommodates time-invariant characteristics within the dataset, enhancing the accuracy of our estimates by mitigating the impact of unobserved heterogeneity.

Secondly, as a control model, the random forest, a machine learning approach, was applied. With the technique, devised by Breiman (2001), an algorithm constructs a series of decision trees, and then a subset of characteristics is selected from each node of each tree, following a bagging technique. For a more comprehensive understanding of random forest, a detailed and precise description can be found in Booth et al. (2014). The random forest technique offers several advantages: i) it is robust to outliers; ii) it is robust to missing data; iii) it facilitates ranking in order of importance each variable in the classification results (Jones et al., 2017). To assess the model's performance, we utilized relative variable importance (RVI), which indicates the average number of times a variable is employed in the decision trees of the model (Dallocchio et al., 2023). An RVI greater than 0 signifies that the variable is utilized in the decision trees of the model, expanding its predictive capabilities.

RESULTS

Results related to Models 1, 2 and 3 using fixed effect regressions are shown in the next table.

TABLE 2 FIXED EFFECTS REGRESSION

Dependent Variable	TOTAL RETURN		
Model	1	2	3
Independent Variables			
BIODIVERSITY RATING	-0.0212		
	(0.0203)		
SG6		-2.225	
		(2.179)	
SDG14		3.967*	
		(2.403)	
SDG15		2.792	
		(2.306)	
BIO FACTOR			494.9***
			(171.0)
Control Variables			
(FAMA-FRENCH Factors)	YES	YES	YES
Constant	-18.31***	-19.32***	114.4**
Year FE	YES	YES	YES
Company FE	YES	YES	YES
Sector FE	YES	YES	YES
Observations	5,772	5,772	5,772
R-squared	0.142	0.143	0.142

***, **, and * indicate a statistical significance level of 1%, 5%, and 10%, respectively.

Regarding Model 1, the biodiversity rating is not significant. In contrast, Model 2 findings indicate that SDG 14 exhibits a positive influence on stock performance, whereas the biodiversity score, SDG 6, and SDG 15 do not demonstrate statistical significance. However, when transitioning from individual stock performance to portfolio performance (Model 3), it becomes apparent that the BIO factor is statistically significant at the 1% level, with a positive impact on company performance. Results related to Models 1, 2 and 3 using the random forest technique are shown in the next figure. Similarly, Model 1 does not show any significance for the biodiversity rating, and in this case, in Model 2, none of the SDGs are relevant. Also, the previous findings from Model 3 are reaffirmed, indicating the presence of a market factor associated with biodiversity. This consistency underscores the robustness of the observed relationship between biodiversity and company performance at the market level.

DISCUSSION

The results of our study confirm the hypothesis that there is a statistically significant positive association between companies investing in biodiversity and their stock performance (Goldman Sachs, 2023). This finding suggests the importance of biodiversity considerations for financial outcomes in the market. Moreover, our study identifies the existence of a market factor specifically related to biodiversity, further highlighting the relevance of this variable as a driver of stock performance.

Comparing these results with previous research, we find consistency with some studies while we also offer new insights (Friede et al., 2015). Prior research has explored the relationship between ESG factors, including biodiversity, and financial performance, with mixed findings.

The significant size of the coefficient for biodiversity suggests a strong relationship between biodiversity investments and stock performance, potentially due to several factors. Firstly, investors may perceive companies investing in biodiversity as sustainable and forward-thinking, leading to positive market reactions and higher stock prices (Salmi et al., 2023). Regulatory advantages, such as tax incentives and reduced risk of fines, can also contribute to better financial performance (Panwar et al., 2023). Additionally, biodiversity investments help mitigate operational and reputational risks, driving innovation and operational efficiencies that translate into improved financial outcomes.

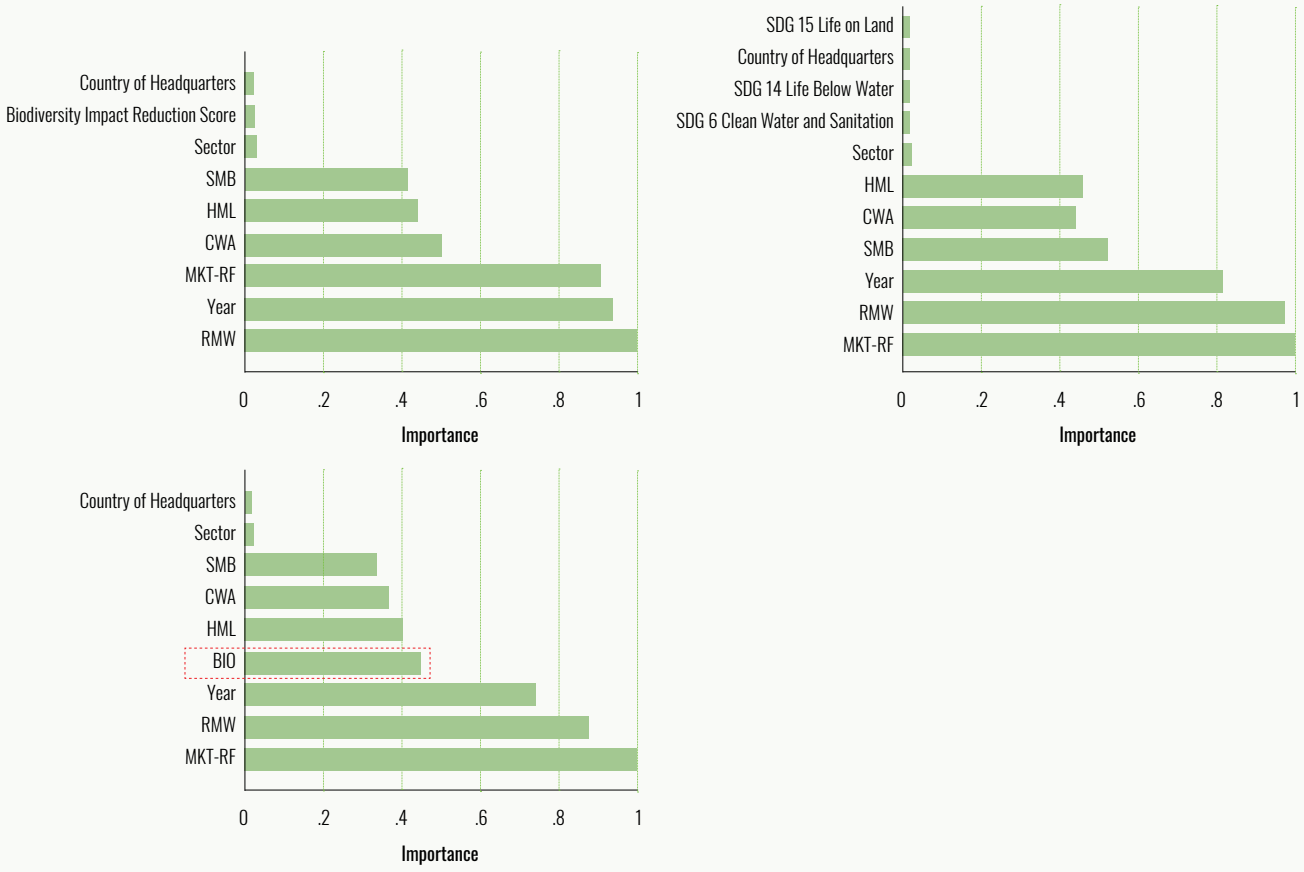
Our study contributes to this body of literature by specifically focusing on biodiversity investments and their impact on stock performance. By identifying a market factor related to biodiversity,

we provide empirical evidence of the financial implications of biodiversity considerations for companies and investors. This adds nuance to the understanding of how ESG factors, particularly biodiversity, influence financial outcomes (Martielli et al., 2022). However, noteworthy is the fact that our research primarily reveals a market reaction to biodiversity investments rather than directly testing the effectiveness of biodiversity priorities compared to other ESG factors. Consequently, while our findings highlight the financial import of biodiversity, we can not necessarily conclude that companies prioritizing biodiversity investments are universally outperforming those focusing on other ESG factors.

In our analysis, SDG 6 (clean water and sanitation) and SDG 15 (life on land), do not demonstrate statistical significance. Several factors could explain this. Firstly, the integration of these SDGs into corporate strategies might still be in nascent stages, leading to inconsistent or minimal impact on financial performance. Secondly, the effects of these specific SDGs may take longer to manifest in financial metrics, and as a result may not be immediately apparent in the current dataset. Additionally, there may be industry-specific variations in how these SDGs impact companies, with some industries deriving more immediate benefits from biodiversity investments than others.

Overall, our findings support the growing recognition of biodiversity as a critical aspect of sustainable business practices. Companies that make biodiversity investments not only contribute to environmental conservation but also enhance their

FIGURE 3 RANDOM FOREST



financial performance, aligning with the broader goals of sustainable development. These results have noteworthy implications for investors, policymakers, and businesses, highlighting the importance of integrating biodiversity considerations into investment strategies and corporate decision-making processes.

CONCLUSION

Our study serves as a preliminary exploration of how financial markets recognize biodiversity investments made by firms. The findings establish a foundational baseline for further investigation into this critical area. Our research provides empirical evidence of a positive association between companies investing in biodiversity and their stock performance. This result underscores the growing recognition of biodiversity as a critical component of sustainable business practices and highlights its relevance for financial outcomes in the market. By identifying a market factor specifically related to biodiversity, our research contributes to a deeper understanding of the financial implications of biodiversity considerations for companies and investors.

Biodiversity has emerged as a megatrend—a global force of change with profound implications for economies, societies, and ecosystems. The decline in biodiversity poses serious risks to the stability and resilience of natural systems, which in turn affect human well-being and economic prosperity. However, recent efforts, such as the Kunming-Montreal Global Biodiversity Framework, signal a growing momentum towards biodiversity conservation and restoration on a global scale. This framework sets ambitious targets for biodiversity preservation and calls for more funding and investments in biodiversity-related initiatives.

The recognition of biodiversity as a megatrend stems from its far-reaching impacts across multiple dimensions, including ecological, economic, and social. Biodiversity loss not only threatens the functioning of ecosystems but also undermines the long-term sustainability of businesses and economies. As such, addressing biodiversity challenges has become increasingly imperative for companies, investors, policymakers, and society as a whole.

Practical implications of our findings suggest that companies should integrate biodiversity into their strategic planning and investment decisions to potentially boost their financial performance and contribute to global sustainability goals (Braat and De Groot, 2012). By incorporating a wider range of factors into strategic planning and risk assessment, companies could better align their practices with emerging regulatory standards and societal expectations. This broader perspective could enhance corporate reputation, compliance, and operational resilience (Winn and Pogutz, 2013). Such an approach can also help companies discover new opportunities for sustainable innovation and stakeholder engagement, ultimately contributing to more effective biodiversity management strategies (Salmi et al., 2023).

Investing in biodiversity for companies involves a range of strategic actions that can lead to improved financial performance (Armenteras and Finlayson, 2012). Key initiatives include restoration projects like reforestation and wetland rehabilitation, which shore up ecosystem services and may provide cost savings and new revenue streams through carbon credits and eco-tourism. Conservation efforts, such as protecting natural habitats and implementing sustainable harvesting practices, could bolster corporate reputation, attract environmentally conscious customers and investors, and ensure long-term resource availability. Compensation mechanisms, such as biodiversity offset schemes, help companies maintain regulatory compliance, avoid penalties, and facilitate project approvals, reducing operational risks. Sustainable supply chain management, which involves sourcing from suppliers practicing sustainable agriculture, forestry, and fishing, minimizes supply chain disruptions and meets consumer demand for sustainably produced goods (Salmi et al., 2023). Corporate partnerships with NGOs, governments, and local communities could build credibility, share

resources, and access new markets and funding opportunities. Additionally, investing in research and innovation to develop biodiversity-supporting technologies and products, like biodegradable materials and sustainable packaging, creates new market opportunities and differentiates companies from their competitors. These investments not only contribute to environmental sustainability but may also improve financial performance by reducing risks, enhancing brand value, upgrading operational efficiencies, and opening up new markets and revenue streams.

Despite the insights our findings provide, our study also has limitations that warrant further investigation. The data used in our analysis may not fully capture all aspects of biodiversity investments, and the models employed might overlook other influential factors. Future research should explore the mechanisms through which biodiversity investments influence stock performance, examine differential effects across industries, regions, and market conditions, and assess the long-term implications of biodiversity investments on corporate profitability, resilience, and risk management. Additionally, developing typologies or taxonomies of biodiversity investments by companies and their relative impact on market performance could provide deeper insights into effective biodiversity strategies. Longitudinal research is also crucial to evaluate the long-term implications of biodiversity investments on corporate profitability, resilience, and risk management. Moreover, our research reveals the need for managers to recognize and address biodiversity drivers, such as pollution and overexploitation.

From a managerial perspective, the current framework suggests that organizational priorities are influenced by established managerial attitudes and systems (Ocasio, 1997), which often concentrate on other ESG factors while biodiversity loss remains underappreciated. In this sense, recent regulatory changes, especially in the European Union, are pushing for greater managerial attention to biodiversity. However, material progress is unlikely until biodiversity loss is recognized as an urgent issue rather than a distant concern (Pinkse and Gasbarro, 2019). Therefore, future research must flesh out how management currently perceives the value of biodiversity in relation to corporate goals and financial outcomes. Secondly, it may be beneficial to classify best practices implemented by organizations that have successfully integrated biodiversity into their management frameworks. Finally, understanding the varying impacts of different biodiversity strategies and actions could provide valuable guidance for both companies and regulators.

In conclusion, our study underscores essential nature of biodiversity as a megatrend that is shaping the future of business and finance. By integrating biodiversity considerations into investment decisions and corporate strategies, companies can not only contribute to environmental conservation but also enhance their financial performance and long-term resilience in an increasingly interconnected and uncertain world.

MANAGERIAL IMPACT FACTOR

- **Strategic Planning**: Incorporating biodiversity considerations into strategic planning processes to align business objectives with environmental sustainability goals.
- **Risk Management**: Identifying and mitigating biodiversity-related risks, such as regulatory compliance, reputational damage, and supply chain disruptions.
- **Innovation and Market Differentiation**: Leveraging biodiversity initiatives as drivers of innovation and market differentiation to gain a competitive edge.
- **Stakeholder Engagement**: Engaging with stakeholders, including investors, customers, and communities, to communicate biodiversity initiatives and enhance corporate reputation.
- **Long-term Sustainability**: Integrating biodiversity considerations into long-term sustainability strategies to ensure business resilience and continuity in the face of environmental challenges.

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