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DISSERTATION

THE IMPACT OF BIODIVERSITY POLICY ON FINANCIAL RISK AND FIRM VALUE: EVIDENCE FROM EUROPEAN LISTED FIRMS

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PROF. CRISTINA GAIO

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"Great things come from
hard work and perseverance.
No excuses."- Kobe Bryant

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ABSTRACT

This study investigates the relationship between firms' biodiversity disclosure and their financial risk as well as firm value. The dataset, sourced from Bloomberg database, includes companies listed in the STOXX 600 index, covering fiscal years from 2015 to 2024. Financial risk is proxied by Altman's Z-Score, while Tobin's Q serves as a measure of firm financial performance. The methodology employs a robust statistical framework based on established literature, incorporating Panel Data techniques and a two-step System GMM estimation.

The findings suggest that firms with higher Biodiversity policy policies have lower financial risk. Additional analysis provides similar conclusion in terms of environment disclosures and environment, social and governance disclosures. Likewise, there's a consistent positive relationship between sustainability indicators and financial performance, showing that firms with stronger sustainability performance tend to achieve higher market valuation. Robustness tests confirm the validity and exogeneity of the instruments for the estimation of Altman's Z-Score model, reinforcing the credibility of the results and highlighting the financial relevance of corporate sustainability initiatives.

These results suggest that biodiversity disclosure can serve as a risk mitigation strategy, while ESG performance can play a meaningful role in reducing firms' financial risk and enhancing its value. The overall evidence underscores the importance of integrating environmental considerations into financial risk management and valuation models for European listed firms.

JEL: G30, G32, G38, D22, Q51, Q56, Q57

Keywords: Altman's Z- Score, Biodiversity, ESG, Financial Distress, Financial Performance, Tobin's Q

RESUMO

Este estudo investiga a relação entre a divulgação da biodiversidade pelas empresas e o seu risco financeiro, bem como o valor da empresa. O conjunto de dados, proveniente da base de dados Bloomberg, inclui empresas cotadas no índice STOXX 600, compreendendo os anos fiscais de 2015 a 2024. O risco financeiro é representado pelo Z-Score de Altman, enquanto o Q de Tobin serve como uma medida do desempenho financeiro da empresa. A metodologia emprega um quadro estatístico robusto baseado na literatura estabelecida, incorporando técnicas de dados em painel e uma estimativa GMM de sistema em duas etapas.

Os resultados sugerem que as empresas com políticas mais exigentes em matéria de biodiversidade apresentam um menor risco financeiro. Uma análise adicional fornece conclusões semelhantes em termos de divulgações ambientais e divulgações ambientais, sociais e de governação. Do mesmo modo, existe uma relação positiva consistente entre os indicadores de sustentabilidade e o desempenho financeiro, mostrando que as empresas com um melhor desempenho em termos de sustentabilidade tendem a obter uma avaliação de mercado mais elevada. Os testes de robustez confirmam a validade e a exogeneidade dos instrumentos para a estimação do modelo Z-Score de Altman, reforçando a credibilidade dos resultados e destacando a relevância financeira das iniciativas de sustentabilidade corporativa.

Estes resultados sugerem que a divulgação da biodiversidade pode servir como uma estratégia de mitigação do risco, enquanto o desempenho ESG pode desempenhar um papel significativo na redução do risco financeiro das empresas e no aumento do seu valor. A evidência geral sublinha a importância de integrar considerações ambientais na gestão do risco financeiro e nos modelos de avaliação das empresas europeias cotadas.

JEL: G30, G32, G38, D22, Q51, Q56, Q57

Palavras-chave: Altman's Z-Score, Biodiversidade, ESG, Desempenho Financeiro, Insolvência Financeira, Tobin's Q

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While I am thankful for all the support I received, I also recognize the effort, discipline, and resilience I had to summon to bring this project to completion.

GLOSSARY

AR - Autoregressive

COP15 - 15th Conference of the Parties

CSRD – Corporate Sustainability Reporting Directive

E Score – Environmental Score

ESG Score – Environmental, Social and Governance Score

EU – European Union

FE – Fixed Effects

GMM – General Method of Moments

JEL – Journal of Economic Literature

RE – Random Effects

ROA – Return on Assets

ROE – Return on Equity

SFDR – Sustainable Finance Disclosure Regulation

TNFD – Taskforce on Nature-related Financial Disclosures

US – United States

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1. INTRODUCTION

In recent years, sustainability has become a central theme in financial and corporate decision-making, driven by increasing regulatory pressures, investor preferences, and environmental risks.

In Europe, particularly, legislative frameworks such as the European Union Taxonomy, a classification system developed to provide a common framework to identify economic activities as environmentally sustainable, aiming to guide investors, companies and policymakers toward activities that support the EU's climate and environmental objectives; and the Corporate Sustainability Reporting Directive, an EU directive that significantly expands the scope and depth of corporate sustainability reporting, have reinforced the importance of transparent Environmental, Social and Governance (ESG) reporting, prompting firms to align their strategies with sustainability objectives.

Within the environmental dimension of ESG, biodiversity and nature-related risks have gained prominence, as firms are increasingly expected to recognize and manage their impacts and dependencies on ecosystems. Biodiversity loss represents not only an environmental concern but also a financial risk. According to the World Economic Forum (2020), over half of global Gross Domestic Product is moderately or highly dependent on nature and its services — such as pollination, water purification, climate regulation, and soil fertility —support key inputs in many industries, making firms highly dependent on nature. As biodiversity declines, businesses face escalating risks from disrupted supply chains, increased operational costs, and more stringent environmental regulations. Initiatives such as the Taskforce on Nature-related Financial Disclosures, which aims to help organizations to identify, assess, manage and disclose nature-related risks and opportunities, providing a framework for companies to report the impact of its operations on nature and in what measure can the nature-related dependencies and risks affect their business, highlight the need to incorporate biodiversity into financial decision-making.

Despite growing policy emphasis and investor interest in biodiversity, empirical research linking firm-level biodiversity governance to financial performance and risk remains scarce. This gap is particularly relevant as firms and financial institutions seek to integrate nature-related risks into decision-making frameworks amid increasing regulatory and reputational pressures. While the literature on ESG and firm value or risk is growing, most studies treat ESG as a composite measure and do not isolate specific environmental components like biodiversity.

Although ESG performance has gained widespread acceptance in practice, its implications for financial outcomes remain an open empirical question. Prior studies have produced mixed findings regarding the impact of ESG on firm performance, risk, and valuation (Velte, 2017; Nguyen & Nguyen, 2023; Vivel-Búa et al., 2023). Some suggest that ESG investment improves firm stability and reputation, while others find little or even negative effects, possibly due to greenwashing or misaligned incentives. However, empirical research specifically examining the financial implications of biodiversity-related disclosures—particularly in terms of risk and valuation—remains limited and underexplored.

This dissertation aims to address this gap by analyzing the relationship between Biodiversity Policies, ESG performance and two key financial outcomes: financial risk and firm value. Using a dataset of 397 listed firms across European countries between 2015 and 2024, this study employs econometric models to evaluate how Biodiversity Policies and ESG scores are associated with risk and valuation, while controlling firm-specific variables such as size, leverage, profitability, and market capitalization; additionally, to address potential heterogeneity across institutional and industrial contexts, the model includes fixed effects for sector. The sectoral dummies are particularly important, as the financial impact of biodiversity governance is likely to vary by a firm's level of dependency on natural capital for its operations. The analysis is divided into two main models: one focused on financial distress risk (using the Altman Z-Score), and the other on market valuation (using Tobin's Q). Other than the ESG Score, a measure to represent firms' overall environmental, social, and governance performance, this study incorporates a firm-level biodiversity policy indicator, alongside a broader environmental metric, to investigate whether biodiversity and nature-related governance influences financial risk and firm valuation. By testing these variables individually, the study disentangles the specific financial effects of biodiversity governance from more generalized ESG performance, offering nuanced insights into sustainability's financial materiality.

To guarantee a more robust analysis and to control for unmeasured variations due to heterogeneity, time-related dependencies, simultaneous causality, and nonlinear patterns, a two-step system General Method of Moments was modelled for all the previous mentioned variables.

This study provides encouraging evidence that sustainability-related indicators hold financial relevance. Most notably, biodiversity policy disclosure is positively associated with the reduction of the risk of financial distress, supporting the idea that firms addressing nature-related risks may be more resilient. In terms of firm valuation, both environmental and broader ESG performance are positively linked to company's performance, suggesting that sustainability efforts may enhance long-term value through improved stakeholder trust, or alignment with investor expectations.

By combining financial and sustainability data at the firm level, this dissertation contributes to the literature in three key ways: first, by isolating biodiversity policy as a distinct explanatory variable apart from general ESG measures; second, by applying robust econometric methods on firm-level European data; and third, by providing policy-relevant insights for firms in nature-intensive sectors facing heightened sustainability scrutiny.

The paper is structured as follows: Section 2 presents a review of the relevant literature; Section 3 outlines the methodology and data used; Section 4 reports and discusses the empirical results; and Section 5 concludes with key findings, limitations, and suggestions for future research.

2. LITERATURE REVIEW

The loss of biodiversity imposes risks to ecosystems, economies, and business operations. Studies have shown that measuring biodiversity is complex due to the multifaceted nature of ecosystems (Heydari et al., 2020). This can cause companies to often underestimate or fail to integrate biodiversity risks into their broader risk management frameworks, leading to missed opportunities for mitigation and adaptation, therefore, it should be a critical focus in corporate sustainability strategies. Biodiversity disclosure has been considered a vital tool for evaluating corporate impacts, improving transparency, and driving measures to mitigate biodiversity-related risks. Adequate strategies and business practices not only address environmental challenges, but also offer tangible benefits, including enhanced operational efficiency and improved market positioning (Hudson, 2024; Azizi et al., 2025; Giglio et al., 2023; Xiong, 2023).

Although biodiversity disclosure has evolved into one of the most important aspects in mitigation of potential risks, previous research found that many firms do not currently disclose biodiversity-related information in their corporate reports (Garel et al., 2024), leading to problems in transparency.

While some don’t disclose it in their corporate reports, others are at a very early stage of integrating biodiversity aspects into management decisions or disclosure practices, which is the case of most of the Financial Institutions (Hudson, 2024). Although they are already subject to various regulations that require transparency and accountability regarding environmental impacts, such as EU taxonomy, Sustainable Finance Disclosure Regulation and CSRD, they seem to be still far from what is ideal in what concerns biodiversity (Azizi et al., 2025).

Corporate reporting practices play a crucial role in shaping public perception. However, the way companies present information is not always entirely transparent, especially in some industries. Blanco-Zaitegi et al. (2024) found that sectors that involve the use of natural resources (namely utilities and energy) are prone to selective reporting, focusing on positive aspects of their operations while omitting or undervaluing negative impacts on biodiversity. This is done using impression management techniques, in which the objective is to present an idealized image of themselves, while controlling the information that is publicly available. While acknowledging the issues, firms attempt to minimize their association with the potential consequences.

Another problem that research finds is that some of the incidents related to biodiversity can only be found in external sources, contributing to the lack of transparency. One possible explanation is that there is a difference in disclosures done by some companies, where they choose to communicate through soft disclosures, a subtle or indirect way of providing information, rather than by hard disclosures, that have objective and verifiable information (Blanco-Zaitegi et al., 2024).

The growing concern over corporate impact on biodiversity has highlighted the need for standardized and transparent reporting frameworks. However, inconsistencies in current disclosure practices make it difficult to assess and compare environmental risks. Hudson (2024) highlights the lack of consistent and reliable frameworks for disclosing and accounting for biodiversity impacts, considering important that companies engage with regulators, advisors, and trade bodies to establish the best practices. Giglio et al. (2023) argues that standardization of disclosure practices by firms can lead to an easier way to quantify and compare risks. Azizi et al. (2025) identifies a concept, mimetic isomorphism – consisting of the influence of peers and customers to companies -, as a potential driver for improving reporting practices.

Understanding the financial implications of biodiversity risk is crucial for assessing corporate performance. Exposure to biodiversity risks can have tangible effects on a firm's efficiency and financial standing, influencing key operational and economic factors. Li et al. (2025) examines the relationship between biodiversity risk and firm efficiency, a significant negative relationship, which causes companies exposed to biodiversity risks to exhibit lower efficiency levels compared to those without such exposure. This greater exposure often confers a higher cost of capital for firms due to the inherent increased risk.

With high capital costs, the impact on firm efficiency becomes even more pronounced, as companies must not only manage the direct financial implications but also face compounded effects from rising financing costs, leading to a significant decline in operational efficiency. This challenge can severely affect strategic planning, requiring firms to maintain larger reserves and rely more on external financing. Consequently, financial stability is prioritized over growth opportunities, restricting the ability to innovate or expand the business (Li et al., 2025).

Overlooking biodiversity can lead to various risks and costs for the financial and economic systems. Reputational risks, which affect their market position and investor confidence, or Regulatory risks, in which some companies can be more susceptible to possible problems due to regulatory changes in biodiversity matters, are some examples. There is a higher chance of disease outbreaks and pandemics, as changes in environmental pressures can cause pathogens to evolve and spread among wildlife, livestock, and humans. Consequently, there can be Macroeconomic risks, such as commodity price volatility and asset destruction, as well as Microeconomic risks, including disruptions in demand or supply chains (Hudson, 2024).

Biodiversity risk can be broadly categorized into physical risks, that arise from ecosystem degradation, and transition risks, from regulatory and consumer responses. Physical risks impact industries reliant on natural resources, especially in sectors like energy and utilities. Transition risks arise from stricter regulations, shifting consumer preferences from firms contributing to biodiversity loss (Giglio et al., 2023).

Companies may face increased exposure to operational risks, leading to potential financial and reputational losses. Li et al. (2025) finds that firms that effectively manage biodiversity risks may not only improve their operational efficiency but also enhance their long-term sustainability and attractiveness to investors, dealing better with possible regulatory changes and not suffering from reputational damage. This perspective aligns with the growing trend of responsible investing, where environmental, social, and governance factors are increasingly considered in investment decisions.

The growing focus on greater transparency and accountability from companies is reshaping corporate and investment landscapes. Giglio et al. (2023) highlights that as awareness of biodiversity risks grows, market participants who are concerned about these issues may push for better risk management practices and more responsible investment strategies.

During the first phase of COP15, the Kunming Declaration was adopted to support the development and implementation of a new framework aimed at halting and reversing biodiversity loss by 2030, while encouraging governments and businesses to integrate biodiversity considerations into policies, planning, and financial decisions. Since its adoption in 2021, evidence suggests that firms with large biodiversity footprints have experienced negative price reactions, indicating that investors have begun demanding a risk premium (Garel et al., 2024). Previously, investors largely overlooked the impact of biodiversity, a phenomenon also confirmed by Xiong (2023), with a particular focus in the US.

Industries that rely heavily on natural resources and fail to manage their biodiversity impact effectively are increasingly likely to face heightened scrutiny from investors. As awareness of environmental risks grows, stakeholders are placing greater emphasis on corporate responsibility and sustainability practices. Kalhoro & Kyaw (2024) finds that the demand for a risk premium on stocks in these sectors indicates that investors are becoming more aware of the potential financial impacts of biodiversity loss and related regulations.

Coqueret et al. (2025) also identifies a biodiversity risk premium, materialized significantly from 2021 onward, that affects expected returns, particularly in sectors highly exposed to the double materiality of biodiversity risks. Double materiality relates with both recognition of impacts (biodiversity included) and financial reporting, two important factors on biodiversity disclosure, that should be interconnected (GRI, 2023).

With the growing awareness and concern for biodiversity risks among investors and with attention to biodiversity issues increasing, companies that proactively manage their biodiversity impacts may not only mitigate risks but also capitalize on opportunities associated with sustainable practices, potentially leading to enhanced financial performance over time. (Xiong, 2023).

With the evidence that firms managing biodiversity risk tend to experience positive market reactions, particularly in anticipation of biodiversity-related policy events (Coqueret et al., 2025), the integration of biodiversity risk management into strategic planning is fundamental for firms across various industries and can serve as a source of competitive advantage.

Two main theories provide a foundation for understanding biodiversity disclosure: Institutional Theory and Legitimacy Theory, which are closely connected. Given its strong relationship with Legitimacy Theory, Stakeholder Theory will also be introduced to offer additional insights into the role of stakeholder expectations in corporate disclosure practices.

Legitimacy Theory, according to Gray et al. (1996) is “a systems-oriented view of the organization and society…. permits us to focus on the role of information and disclosure in the relationships between organizations, the State, individuals and groups”.

Freeman (1983) presents Stakeholder Theory as being focused on “developing and evaluating the approval of corporate strategic decisions by groups whose support is required for the corporation to continue to exist. The behavior of various stakeholder groups is considered a constraint on the strategy that is developed by management to best match corporate resources with their environment.

Deegan (2014) presents Legitimacy Theory as an explanatory Theory, as its purpose is not to an obligation or duty for the corporation to implement, but a way to explain why certain actions are taken by the company. Organizations operate within a “social contract” that includes the expectations, companies that align their operations and disclosures with these expectations can enhance their legitimacy within the community. Companies may adopt specific strategies to communicate their commitment to biodiversity through various channels. These disclosures serve as a mechanism for legitimation, demonstrating corporate accountability and responsiveness to stakeholder concerns regarding biodiversity. Legitimacy theory relates to Stakeholder theory in the sense that organizations must consider the perceptions of their stakeholders, the “social contract” must be taken in account for each group of stakeholders, because they will have different points of view, which can affect the legitimacy of the firm. As public awareness and concern about biodiversity loss grows, stakeholders increasingly demand that companies disclose their environmental practices. Organizations can enhance their legitimacy by acknowledging their impact on biodiversity and actively reporting on their efforts to mitigate those impacts. By proactively engaging in biodiversity disclosure, companies can not only fulfill their social contract but also potentially gain a competitive advantage. Demonstrating leadership in biodiversity management can improve an organization's reputation, attract environmentally conscious consumers, and foster better relationships with stakeholders.

Hoffman (1999) describes Institutional theory as being "how social choices are shaped, mediated, and channeled by the institutional environment". Institutional theory proposes that organizations within the same field tend to adopt similar practices due to three different pressures: coercive, normative, and mimetic, it relates to biodiversity disclosure through its emphasis on how social contexts, norms, and institutional structures shape organizational behaviors, including the reporting of biodiversity impacts.

Through coercive mechanisms, regulatory frameworks and international agreements may compel companies to disclose their biodiversity impacts. firms may publish their impacts on biodiversity to align with industry standards or expectations set by regulators, investors, and civil society. As more organizations report on biodiversity, it becomes a normative expectation in the industry, leading others to adopt similar practices. Normative influences, where Institutional and Legitimacy Theory connect, social norms and values related to environmental stewardship and sustainability can drive organizations to disclose biodiversity data voluntarily. Companies aiming to enhance their reputations or demonstrate corporate social responsibility may adopt biodiversity reporting as part of their sustainability initiatives to meet stakeholder expectations. Mimetic Processes, appear in situations of uncertainty, organizations may look to peers or industry leaders as models for best practices in biodiversity disclosure. If leading firms in an industry produce thorough biodiversity reports, others may follow suit to avoid being seen as non-compliant or lagging. (Higgins & Larrinaga, 2014)

There can also be an institutional change, in our case, Biodiversity disclosure practices can also shift as new initiatives or crises (like biodiversity loss) prompt changes in societal expectations and institutional frameworks. As awareness of biodiversity issues grows, the institutional legitimacy of biodiversity disclosure as a practice increases, influencing more organizations to engage in this reporting.

Azizi et al. (2025) establishes a relationship between biodiversity disclosure in the European financial sector and the three theories that were previously mentioned. Institutional Theory helps explain how regulatory frameworks shape the practices of institutions, create coercive isomorphism, compelling organizations to align their practices with established norms and expectations for sustainability and biodiversity disclosure. Legitimacy theory posits that organizations seek to establish legitimacy by conforming to societal expectations and norms. The paper suggests that financial institutions engage in biodiversity reporting to maintain or enhance their legitimacy within the market and among stakeholders. By demonstrating compliance with reporting standards and regulatory requirements related to biodiversity, these institutions can strengthen their reputation and secure stakeholder trust. Lastly, the Stakeholder Theory and its interplay with Legitimacy should be done through the aligning of reporting practices with institutionalized norms and expectations. This way, financial institutions not only comply with regulatory frameworks but also demonstrate accountability to their stakeholders. This transparency is crucial for achieving legitimacy, as stakeholders increasingly demand that companies disclose their impacts on biodiversity and showcase their efforts in sustainability.

This study has the objective to contribute to academic literature by bridging gaps in biodiversity disclosure and risk management and providing actionable insights for non-financial organizations to improve sustainability practices.

Hypothesis I: Firms with higher biodiversity disclosures exhibit a lower risk of financial distress.

Hypothesis I has the purpose of investigating whether the increase in transparency in biodiversity disclosure can act as risk mitigation strategy.

According to Institutional Theory, companies adapt their reporting practices in response to external pressures, including government regulations and sustainability frameworks (e.g., EU's Corporate Sustainability Reporting Directive, CSRD) (Higgins & Larrinaga, 2014). By disclosing biodiversity efforts, firms comply with regulatory expectations, reducing the risk of fines, sanctions, or legal disputes related to biodiversity harm.

Legitimacy Theory suggests that organizations must align with societal values to maintain public trust (Deegan, 2014). According to Giglio et al. (2023), the increasing awareness of biodiversity risks is driving stakeholders to demand stronger risk management strategies and more sustainable investment approaches. As a result, biodiversity disclosure becomes a crucial tool for companies to maintain legitimacy by demonstrating their commitment to addressing these growing concerns.

Biodiversity disclosure also plays a role in financial risk management, since biodiversity risks are increasingly being considered when making investment decisions. Just like Xiong (2023) states, proactively managing biodiversity impacts can help companies reduce financial risks while unlocking opportunities that enhance long-term financial performance.

Hypothesis II: Companies with higher biodiversity disclosure levels exhibit better financial performance.

In Hypothesis II Li et al. (2025) theory will be tested, to state if the higher biodiversity risk, directly connected to biodiversity disclosure decreases firm efficiency contributing to a higher cost of capital for companies, which can have an even bigger effect on firm efficiency, which eventually will cause firms to have a worse financial performance compared to the ones that do have in account their biodiversity risk.

3. SAMPLE AND METHODOLOGY

3.1 Sample Construction

The sample for this study comprises 397 non-financial companies listed in the STOXX Europe 600 index, covering sixteen industries and eighteen countries across Europe. Given the study's focus on the relationship between biodiversity disclosure, risk mitigation, and financial performance on non-financial institutions in Europe, the sample specifically excludes financial institutions, such as banks or asset management firms due to their distinct financial structures, regulatory environments, and reporting frameworks, which differ significantly from those of non-financial corporations. According to Scholtens (2009) asset management and banking sectors' nature of ESG risk and disclosure is structurally different than other sectors, this will make comparability between different sectors more difficult. The exclusion of these sectors ensures a more homogeneous sample, improving the robustness of regression results. Additionally, some companies were removed due to incomplete data and the sample was further refined by excluding the top and bottom of 1% of observations to mitigate the influence of outliers. The final sample predominantly comprises firms from the United Kingdom, reflecting its strong representation in the dataset, and the Industrial Goods & Services sector emerges as the most represented industry, as represented in Appendix I and II.

It is used a 10-year period, between 2015 and 2024, allowing for a longitudinal panel analysis to capture trends in biodiversity disclosure and its financial implications. By focusing on companies across various industries, this study aims to provide a comprehensive assessment of how biodiversity-related transparency influences corporate risk and financial performance in the European market. All financial and ESG data used in this study were sourced from Bloomberg.

3.2 Methodology

To test the first hypothesis, which examines the relationship between sustainability practices, particularly biodiversity disclosure adoption, and corporate financial risk, this study employs the Altman Z-Score as the dependent variable. Originally developed by Altman (1968), it is a widely recognized indicator used to estimate the probability of financial distress or bankruptcy of a firm. It combines five key financial ratios into a single score, providing a comprehensive view of a firm's solvency and risk profile:

$$Z\text{-}Score = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 1.0X_5 \ ,$$

Where:

X_1 = *Working Capital / Total Assets* is a liquidity ratio, indicating the capacity of a company meeting its current financial obligations. A higher level indicates that the firm is financially healthy in the short term, while a low or negative ratio suggests potential liquidity problems;

X_2 = *Retained Earnings / Total Assets* is a profitability ratio, indicating how much of the company's assets are financed by retained earnings. A high value suggests that there is a history of profitability, and the firm relies less on external debt for financing, while a low ratio might indicate a higher vulnerability to bankruptcy;

X_3 = *EBIT / Total Assets* is used to understand how effectively a company uses its assets to generate profits, while ignoring interest and tax expenses, an indicator of operational efficiency and profitability. A higher ratio means better profitability and more efficient use of assets, while a lower ratio suggests poor operational performance, increasing the risk of financial distress;

X_4 = Market Value of Equity / Total Liabilities measures the firm's ability to cover its liabilities with its market value, with a higher ratio meaning that the company is in a better position to cover its debt with equity;

X_5 = Sales / Total Assets, also named the Asset Turnover Ratio, indicates the efficiency with which a company is using its assets to generate revenue. Being high it reflects the great capacity of the company to generate profits using its resources.

The range used to evaluate the probability of bankruptcy of a company is between 1.8 and 2.99. Values below 1.8 correspond to a company that has high probability of bankruptcy and values above 2.99 identify a company with low probability of bankruptcy. Between the range previously mentioned, the risk of bankruptcy is moderate.

The use of Z-Score in this context is supported by a growing body of literature linking ESG performance to lower financial distress. Goss & Roberts (2011) demonstrate that firms with higher Corporate Social Responsibility engagement benefit from reduced credit risk and financing costs, implying better financial health. Similarly, Nguyen & Nguyen (2023) find that firms with better environmental disclosures tend to have lower financial distress levels, suggesting that improved environmental performance may enhance financial stability. ESG practices, particularly those addressing environmental impacts, are thought to mitigate reputational, regulatory, and operational risk factors that are not fully captured by traditional financial metrics. Therefore, Z-Score is a suitable measure to capture whether companies with stronger sustainability commitments, including biodiversity policies, display lower risk of financial instability.

The impact on the corporate financial risk of the companies, measured by the Altman Z-Score, is evaluated using the following equation to test Hypothesis I:

(2) $Risk_{i,t} = \beta_0 + \beta_1 SustainabilityIndicator_{i,t} + \beta_2 Market\ Cap_{i,t} + \beta_3 Size_{i,t} + \beta_4 ROA_{i,t} + \beta_5 ROE_{i,t} + \beta_6 Leverage_{i,t} + \beta_7 High\text{-}Impact_{i,t} + \varepsilon_{i,t}$,

where i designates each company and t the corresponding year.

The second hypothesis focuses on the potential financial benefits of sustainability and biodiversity-related actions. For this purpose, the dependent variable is Tobin's Q, defined as the market value of a firm divided by the replacement cost of its assets (Fu & Parkash, 2016), is calculated through a simple approximation (Chung & Pruitt, 1994), where the sum of the Market Value of Equity and Book Value of Debt is divided by the Book Value of Total Assets. This ratio captures investors' perceptions of a firm's growth opportunities, intangible assets, and expected profitability.

$$(3)\ Tobin's\ Q = \frac{Market\ Value\ of\ Equity +\ Book\ Value\ of\ Debt}{Book\ Value\ of\ Total\ Assets}$$

Tobin's Q is frequently used in ESG-related studies as a market-based indicator of financial performance (Luo & Bhattacharya, 2006; Flammer, 2015). Sustainability efforts may enhance firm reputation, strengthen stakeholder relations, and signal long-term strategic orientation—factors that can positively influence market valuation. Margolis et al. (2009) and Friede et al. (2015) find robust empirical support for a positive link between ESG performance and market-based value measures, including Tobin's Q.

Using Tobin's Q allows this study to examine whether firms with biodiversity policies and stronger ESG scores achieve higher perceived market value, thus contributing to the understanding of the financial implications of sustainability and most specifically, biodiversity practices.

The impact on the Financial Performance of the companies, measured by Tobin's Q, is analyzed using the following equation to test Hypothesis II:

$$(4)\ Performance_{it} = \beta_0 + \beta_1 SustainabilityIndicator_{i,t} + \beta_2 Size_{i,t} + \beta_3 ROA_{i,t} + \beta_4 ROE_{i,t} + \beta_5 Leverage_{i,t} + \beta_6 High\text{-}Impact_{i,t} + \varepsilon_{i,t}\ ,$$

where i designates each company and t the corresponding year.

To examine the environmental dimension of corporate sustainability in greater depth, three variables, serving as sustainability indicators, are tested individually as the independent variables in the models: *Bio Policy*; *E Score* and *ESG Score*. The variable *Bio Policy* is a binary indicator that takes the value of one if the company has a publicly disclosed biodiversity policy, and zero otherwise. This variable captures whether a firm acknowledges and formally integrates biodiversity-related risks and responsibilities into its corporate governance framework, serving as a proxy for proactive environmental governance. The *E Score* reflects the company's overall performance across various environmental metrics, including emissions, resource usage, and environmental innovation. This continuous variable allows for a more nuanced assessment of how well a company performs in managing its environmental footprint. Including both variables in the model enables the analysis to disentangle the impact of environmental commitment at both the strategic level (via policy presence) and operational level (via performance metrics), providing a comprehensive view of a firm's environmental stance in relation to financial outcomes. Lastly, *ESG Score*, captures the overall sustainability performance of the company evaluating the company's aggregated ESG performance, being a weighted generalized mean of Pillar Scores, being the weights determined by the pillar priority ranking. Its value varies between 0 and 10, being 10 the best. This metric has been used in prior literature by Vivel-Búa et al. (2023), found that higher ESG Scores corresponds to higher Altman Z-Scores, which implying lower default risk. Similarly, Velte (2017), showed a positive association, between ESG Scores and Tobin's Q, suggesting that stronger ESG performance may enhance firm valuation.

By testing each of the variables — *Bio Policy*, *E Score*, and *ESG Score* — separately, the analysis aims to isolate their individual effects on financial performance and risk. This approach allows for a clearer understanding of how distinct dimensions of corporate sustainability, ranging from strategic environmental commitments (such as biodiversity policies) to broader ESG performance metrics, influence firm outcomes. Examining these variables independently ensures that the explanatory power of each factor can be assessed without potential interaction effects, offering robust insights into the specific sustainability drivers that may enhance or mitigate financial risk and firm value.

To account for firm-specific characteristics, a set of five control variables were selected based on the literature: Market Capitalization (*Market Cap), Size*, *Leverage, ROA* and *ROE*. The sector-specific environmental exposure is controlled using a *High-Impact* dummy variable, indicating if the firm operates in an environmentally sensitive sector.

Market Capitalization *(Market Cap)* is the total value of a company's outstanding shares in the market, being the product of the share price by the number of shares, and it is presented as the natural logarithm of Market Cap to reduce the noise that can be caused by the difference in scales. This variable was chosen due to the finding of a strongly negative relation between market capitalization and the probability of default, with smaller firms having higher default probabilities (Hood, 2016).

The size of the firm (*Size*) is measured by the natural logarithm of total assets, to account for scale-related advantages. Larger firms tend to have more diversified operations, better access to financing, and greater ability to invest in ESG initiatives (Moussa & Elmarzouky, 2024). Vivel-Búa et al. (2023) reveals that the impact of ESG scores is notably different for smaller and medium-sized firms compared to larger firms, while for smaller companies a higher ESG score — reflecting improvements in their sustainability practices — is associated with lower default risk, for larger firms this relationship weakens. At a certain size, additional sustainability initiatives may no longer translate into a proportional reduction in risk. According to Velte (2017), there's a positive relation between the size of a firm and Tobin's Q, consequently meaning that larger companies will have better financial performance.

ROA and *ROE* are both measures of profitability. The first being calculated by dividing the total assets by the shareholder's equity, reflecting the efficiency with which a firm utilizes its assets, and the second being the ratio of the net income to the shareholder's equity. Jin Shunyao et al. (2024) shows that when companies have lower profitability, they will have increased default risk, highlighting the importance of operational efficiency in financial health. Bhaskaran et al. (2020) analyze the impact of ESG on financial performance, suggesting that ESG initiatives can lead to enhanced profitability and firm value, confirmed by higher values of both ROA and ROE. ROA is considered to have a significant positive relationship with financial performance, measured by Tobin's Q (Velte, 2017).

Leverage is calculated as the ratio of total debt to the market value of equity, providing a measure of the firm's capital structure. Prior research finds a positive relationship between the level of leverage and the probability of default by the company (Jin Shunyao et al, 2024; Habermann & Fischer, 2021). Velte (2017) finds that leverage is negatively related to Tobin's Q, suggesting that a higher leverage will worsen the financial performance of a firm.

High-Impact is a dummy variable that is considered into the model, depending on whether the company's operations are of high-impact to biodiversity, considering the different sectors that it belongs. It will have the value of one if the sector in which the firm belongs causes high impact to biodiversity and zero otherwise. Based on a report of Finance for Biodiversity Foundation (2023), the sectors considered to be of high impact are: Automobiles & Parts; Basic Resources; Chemicals; Consumer Products & Services;

Construction & Materials; Energy; Food, Beverage & Tobacco; Industrial Goods & Services and Utilities. Additionally, several companies from sectors such as Health Care, Media, Personal Care, Drug and Grocery Stores, Retail, Technology, Telecommunications, and Travel & Leisure are also represented in the sample, reflecting a broader range of industries alongside those previously identified as having a high impact on biodiversity.

4. RESULTS

4.1 Descriptive Statistics

Table I presents the descriptive statistics of all variables incorporated within the models.

Table I – Descriptive Statistics

Variables	Obs.	Mean	Std. Dev.	Minimum	Maximum
Risk	3658	4.058	4.122	0.517	32.455
Performance	3719	2.035	2.012	0.365	16.102
Bio Policy	3658	0.612	0.487	0	1
E Score	3658	4.832	1.182	0	7.770
ESG Score	3658	4.796	1.964	0	10
Market Cap	3658	23.392	1.321	18.836	28.378
Size	3658	23.262	1.511	17.726	27.295
ROA	3658	0.064	0.051	-0.071	0.275
ROE	3658	0.158	0.121	-0.270	0.810
Leverage	3658	0.029	0.014	0.012	0.121

The variable *Risk* shows a mean value of 4.06 with a wide range, from 0.52 to 32.50, indicating substantial variation in firms' exposure to risk-related factors. *Performance* has a mean of 2.04 and reflects the profitability or efficiency of firms, measured on a consistent scale. The standard deviation of 2.01, indicates substantial variation in firm outcomes relative to the average.

Bio Policy is a binary variable indicating whether a firm has adopted biodiversity-related policies; its mean of 0.61 suggests that 61% of firms in the sample report such policies. The *E Score* measures firms' environmental performance, with an average of 4.83 and a maximum of 7.77, suggesting moderate variation across firms. The statistics show an average *ESG Score* of 4.80, which indicates a moderate average value of ESG performance throughout the sample, slightly below the midpoint, with a standard deviation of 1.96, suggesting that although many values are close to the mean, there is still a noticeable range of responses across the scale.

The average market capitalization of companies is 23.39 and the standard deviation is 1.32. Being a relatively low standard deviation, market capitalizations are moderately concentrated around the average value, having limited variability. Similarly, the firm size, measured by the natural logarithm of total assets, has a mean of 23.26 and a standard deviation of 1.51. The range between 17.726 and 27.295 suggests noticeable variation in firm size, though values are generally clustered around the mean.

In terms of profitability, ROA shows a mean of 6.40% and a small standard deviation of 0.051, suggesting that most firms have similar levels of asset efficiency, with values clustering closely around the mean. By contrast, ROE demonstrates greater variability with a standard deviation of 0.121, while the average is 15.80%. The higher standard deviation indicates that equity returns differ more substantially across the sample.

Lastly, the average Leverage is 0.029, which implies that firms tend to maintain low levels of debt relative to assets, confirmed by the narrow standard deviation of 0.014.

4.2 Correlation Matrix

Table II exhibits the correlation matrix among the continuous independent variables. Overall, most correlations are statistically significant at the 1% level, with different strengths and directions.

Table II – Correlation Matrix

	Risk	*Performance*	*Bio Policy*	*E Score*	*ESG Score*	*Market Cap*	*Size*	*ROA*	*ROE*	*Leverage*
Risk	1									
Performance		1								
Bio Policy	-0.220**	-0.218**	1							
E Score	-0.170**	-0.154**	0.201**	1						
ESG Score	-0.203**	-0.185**	0.149**	0.654**	1					
Market Cap	-0.002		0.158**	0.161**	0.159**	1				
Size	-0.450**	-0.410**	0.302**	0.244**	0.271**	0.799**	1			
ROA	0.465**	0.441**	-0.135**	-0.093**	-0.116**	0.018	-0.250**	1		
ROE	0.250**	0.313**	-0.081**	-0.040*	-0.042**	0.068**	-0.130**	0.816**	1	
Leverage	-0.340**	-0.242**	0.153**	0.081**	0.137**	0.060**	0.273**	-0.229**	0.090**	1

Significance levels are denoted as * and ** representing thresholds of 5% and 1%, respectively.

Risk is negatively and significantly correlated with all independent variables, suggesting that firms with better sustainability practices tend to exhibit higher risk exposure, contrary to what is expected from previous literature. It is only positively and significantly correlated with both profitability measures, ROA and ROE.

Performance is also negatively and significantly associated with all variables, except for the profitability ones, although the magnitudes are slightly smaller than for Risk, which could mean that the depth of change due to the policy or the score is lower.

The binary variable *Bio Policy* is positively and significantly related to both *E Score* and *ESG Score*, indicating that, as expected, firms with biodiversity policies tend to have stronger environmental profiles. E Score correlates strongly with ESG Score, as expected, given its role as a component of the composite ESG measure.

Notably, Market Cap and Size are highly positively correlated, which is expected as both measure aspects of firm scale. The variables *Bio Policy*, *E Score*, *ESG Score* show moderate positive correlations with both Market Capitalization and Size, indicating that larger firms tend to have higher Environmental and overall ESG performance, as well as a Biodiversity Policy.

In contrast, ROA is negatively correlated with the three independent variables considered and with Size, suggesting that larger or more sustainably active firms may experience slightly lower asset efficiency. A similar but weaker negative relationship is seen between ROE and Size. As expected, ROA and ROE are strongly positively correlated, reflecting their related roles in assessing firm profitability.

Lastly, Leverage exhibits weak but statistically significant correlations with most variables, including a slight positive and significant association with the E Score, Market Capitalization and ROE, a moderate positive correlation with Bio Policy, ESG Score and Size, and a small negative correlation with ROA.

Results indicate that multicollinearity is generally not a major concern; however, there are strong correlations between Market Capitalization and Size, and between ROA and ROE. These high correlations suggest potential multicollinearity issues that should be kept in mind when interpreting regression coefficients.

Table III presents the Variance Inflation Factor (VIF) which was calculated to understand multicollinearity among the independent variables. With a mean VIF of 2.646, it suggests that multicollinearity is moderate, since it is between the range of 1 to 5.

Table III – Variance Inflation Factor

Variables	VIF	1/VIF
ESG Score	1.153	0.867
Market Cap	3.946	0.253
Size	4.651	0.215
ROA	2.698	0.371
ROE	2.325	0.430
Leverage	1.106	0.905
Mean VIF	2.646	

4.3 Regression Results

In this section, the empirical results obtained from the panel data model are presented and analyzed. Panel data models, which combine cross-sectional and time-series data, allow for a more nuanced understanding of the dynamic relationships among the variables by controlling for unobserved heterogeneity and capturing both temporal and individual-specific effects. This approach enhances the robustness of the analysis by addressing potential biases that arise in purely cross-sectional or time-series models.

Model estimates provided offer insights into how the independent variables influence the dependent variable over time and across different entities. Results are discussed in terms of statistical significance, direction, and magnitude of the coefficients, and their implications for the underlying research hypotheses are evaluated.

Selecting the appropriate estimation method is crucial for obtaining consistent and efficient results. Two commonly employed models are the Fixed Effects and Random Effects models. The FE model controls for all time-invariant individual heterogeneity by allowing each cross-sectional unit to have its own intercept, thereby producing consistent estimates even when these unobserved effects are correlated with the regressors. In contrast, the RE model assumes that these individual-specific effects are uncorrelated with the explanatory variables and treats them as part of the error term, which can lead to more efficient estimates if the assumption holds.

To determine the most appropriate model specification, the Hausman test was conducted, and its results are shown in Appendix III. The test results indicate that the null hypothesis of no correlation between individual effects and regressors is rejected, suggesting that the Fixed Effects model is theoretically preferred. However, due to the low within-entity variability of some key explanatory variables, they do not exhibit sufficient variation over time to be effectively estimated under the Fixed Effects framework.

As a result, important variables are essentially dropped from the Fixed Effects model, limiting the analysis and interpretability of the results. To address this limitation, the Random Effects model was chosen despite the Hausman test recommendation. This approach allows the inclusion of variables with low temporal variation, enabling a more comprehensive examination of the data while acknowledging that the assumption of exogeneity of individual effects may be less strict.

The Random Effects model thus balances the need to retain relevant variables and account for unobserved heterogeneity across entities, providing useful insights despite the theoretical preference for Fixed Effects. This modeling decision is justified by the data characteristics and the practical importance of the low-variability variables in explaining the phenomena under study. Nonetheless, it was estimated a Fixed Effects model using Biodiversity Policy as the independent variable, that can be observed in Appendix IV. This methodology follows the standard panel econometric approach as outlined by Wooldridge (2010).

Table IV presents the coefficients of each variable estimated using Panel Data Regressions with Altman Z-Score as the dependent variable capturing the risk of the firm, and with Bio Policy, E Score and ESG Score as independent variables.

The relationship between Biodiversity Policy and Altman's Z-Score is positive and highly significant, suggesting that firms with biodiversity-related policies tend to exhibit greater financial stability when unobserved heterogeneity is accounted for, as reported in previous literature (Hudson, 2024; Xiong, 2023). Control variables behave largely as expected: Market Capitalization and ROA are positively and significantly associated with the Z-Score, indicating that larger and more profitable firms tend to be more financially resilient. Conversely, Size and ROE show negative relationships, possibly reflecting scale inefficiencies or profit volatility.

Table IV – Panel Data Estimation for Altman Z-Score

Variable	Altman Z-Score	Altman Z-Score	Altman Z-Score
Bio Policy	1.045***		
	(0.359)		
E Score		0.629*	
		(0.344)	
ESG Score			0.935**
			(-0.487)
Market Cap	10.377***	10.265***	10.334***
	(2.431)	(-2.412)	(-2.438)
Size	-10.260***	-10.249***	-10.381***
	(2.427)	(-2.396)	(-2.523)
ROA	15.890**	15.729**	16.116**
	(7.149)	(-7.122)	(-7.225)
ROE	-5.215***	-5.219***	-5.334***
	(1.866)	(-1.85)	(-1.908)
Leverage	7.854	7.509	7.225
	(5.435)	(-5.497)	(-5.336)
Observations	3658	3658	3658
R-squared	0.095	0.095	0.096

Robust standard errors are in parentheses. Significance levels are denoted as *, ** and *** representing thresholds of 10%, 5% and 1%, respectively.

The relationship between Biodiversity Policy and Altman's Z-Score is positive and highly significant, suggesting that firms with biodiversity-related policies tend to exhibit greater financial stability when unobserved heterogeneity is accounted for, as reported in previous literature (Hudson, 2024; Xiong, 2023). Control variables behave largely as expected: Market Capitalization and ROA are positively and significantly associated with the Z-Score, indicating that larger and more profitable firms tend to be more financially resilient. Conversely, Size and ROE show negative relationships, possibly reflecting scale inefficiencies or profit volatility.

This suggests that firms disclosing a clear policy on conserving and managing biodiversity exhibit greater financial resilience, reflecting a reduced risk of financial distress, as suggested by Xiong (2023). It emphasizes the view that addressing biodiversity risks can contribute to a more robust financial position and may help companies better navigate future uncertainties, providing a source of competitive advantage for firms (Coqueret et al, 2025). In this context, just like Azizi et al. (2025) identifies, the role of industry peers and customers becomes particularly important. Peer companies can foster a culture of disclosure and best practices by sharing knowledge and demonstrating the financial benefits of conserving and managing biodiversity. Importantly, customers are increasingly conscious of the environmental practices of the companies they buy from and can influence corporate behaviour through their purchasing choices and loyalty. Together, these mechanisms create a supportive ecosystem that drives companies toward greater financial stability, responsible management of resources, and a more sustainable future.

The results indicate that E Score is positively and significantly associated with the Altman Z-Score, at the 10% level, but it has a weaker effect compared to the model using Biodiversity Policy. The results suggest that firms with stronger environmental practices tend to exhibit better financial health. Control variables, including Market Capitalization, Size, and ROA, retain their expected signs and significance levels, supporting the robustness of the results.

This finding reinforces the view that environmentally conscious firms may also enjoy improved solvency or lower bankruptcy risk (Vivel-Búa et al., 2023). Utilizing E Score provides a more targeted view of the financial relevance of corporate environmental initiatives, aligning with the study's focus on biodiversity and sustainability. The results obtained lend further support to the notion that environmental performance is not only a social responsibility but also a determinant of financial resilience, highlighting the importance of improving environmental disclosure frameworks and guidelines to promote greater transparency contributing to easier decision-making by firms, investors and stakeholders, as Hudson (2024) supports.

For ESG Score, the estimation shows a statistically significant and positive relationship between the variable and Altman's Z-Score, suggesting that firms with higher ESG performance tend to have better financial stability (higher Z-score). The signs of the control variables are aligned with what was observed in the previous tables, with note for the fact that Leverage is not statistically significant. These results suggest that firm-level ESG and financial characteristics, especially market capitalization and profitability, significantly influence financial stability. Importantly, this highlights the potential for comprehensive ESG initiatives to act as a protection against financial vulnerability and encourage greater resiliency in a changing economic environment. Furthermore, this underscores the role of stakeholders in rewarding companies that proactively manage their environmental risks and responsibilities, thereby strengthening market discipline and guiding resources toward more sustainable and resilient businesses.

Table V reports on the estimated effects of the variables Biodiversity Policy, E Score and ESG Score on Tobin's Q.

Table V – Panel Data Estimation for Tobin's Q

Variables	Tobin's Q	Tobin's Q	Tobin's Q
Bio_Policy	-0.451***		
	(0.116)		
E_Score		0.445***	
		(-0.149)	
ESG_Score			0.124*
			(-0.079)
Size	0.076***	-0.028	0.038**
	(0.009)	(-0.035)	(-0.020)
ROA	13.375***	13.549***	13.596***
	(4.297)	(-4.303)	(-4.328)
ROE	-1.238*	-1.264**	-1.262*
	(0.666)	(-0.667)	(-0.674)
Leverage	2.036	1.917	1.961
	(1.554)	(-1.493)	(-1.464)
Observations	3719	3719	3719
R-squared	0.243	0.237	0.237

Robust standard errors are in parentheses. Significance levels are denoted as *, ** and *** representing thresholds of 10%, 5% and 1%, respectively.

The RE estimation reveal a negative and statistically significant relationship between Tobin's Q and Biodiversity Policy, suggesting that firms disclosing biodiversity policies tend to have lower Tobin's Q, contrary to what is expected (Coqueret et al., 2025; Xiong, 2023). Among control variables, Size and ROA show a strong positive link to Tobin's Q, as expected.

This may indicate that there is investor scepticism toward biodiversity initiatives or concerns about potential costs. Importantly, with growing awareness of biodiversity risks, market participants who are more conscious can collectively push and influence companies to pursue more responsible investment strategies, thereby strengthening the role of financial markets in driving sustainable business practices (Giglio et al., 2023).

Nonetheless, this underscores the need for further research to explore how can the disclosure of biodiversity influence market value of companies.

In contrast, the findings reveal a positive and statistically significant relationship between E Score and Tobin’s Q. Control variables have the signs and significance levels as expected, supporting the robustness of the results. The only exception is Size, that contrary to the other estimation has a non-significant and negative relationship with Tobin’s Q.

These results suggest that firms with stronger environmental practices are associated with higher market valuations, aligning with the idea exposed by Li et al. (2025) that investors reward environmental responsibility, potentially due to lower regulatory risks, reputational benefits, or efficiency gains. Importantly, this also reflects a growing trend that is shown by previous literature, such as Coqueret et al. (2024) and Garel et al. (2024), where investors are beginning to demand a risk premium from companies with weak environmental practices, pricing in the potential financial risks associated with poor environmental performance.

The association between ESG Score and firm value, measured by Tobin’s Q, is positively significant, indicating that when controlling for firm-level heterogeneity, better ESG performance may be associated with higher firm valuation, underscoring the importance for firms to consider their broader sustainability practices and for investors to adopt ESG Scores as an indicator of future financial health. Control variables such as Size and ROA remain robustly positive and significant, while ROE exhibits once again contrasting effects, and contrary to what it was expected.

4.4 Robustness Tests

To address potential endogeneity concerns and the dynamic nature of firm risk, this study applies the two-step System Generalized Method of Moments (System GMM) estimator developed by Arellano & Bover (1995) and Blundell & Bond (1998). This approach is particularly appropriate for panel datasets with a relatively short time dimension (T) and a large cross-sectional dimension (N), as is the case with the balanced panel used here (N = 397 firms over T = 10 years).

System GMM enables the inclusion of a lagged dependent variable, controlling for unobserved heterogeneity, simultaneity bias, and measurement error through internal instruments. The two-step estimation improves efficiency by incorporating a robust weighting matrix. In this model, lagged levels and differences of the dependent variable and potentially endogenous regressors are used as instruments, under the assumption of no second-order autocorrelation and instrument validity. This specification includes the lags of the dependent variables, the independent variables and control variables, while also controlling for sector-specific effects using dummy variables.

Diagnostic tests, including the Hansen test of overidentifying restrictions, tests for first and second-order autocorrelation in the residuals and the Wald test for joint significance, are conducted to ensure instrument validity and absence of serial correlation, reinforcing the credibility of the GMM estimates.

Table VI presents the results of the Two-Step System GMM estimation assessing the effect of Bio Policy on Tobin's Q and Altman's Z-Score. The model accounts for potential endogeneity and dynamic relationships, with both Altman's Z-Score and Tobin's Q as the dependent variables and Bio Policy as the primary explanatory variable.

Table VI – Two-Step System GMM – Biodiversity Policy

Variables	Lag Altman Z-Score	Lag Tobin's Q
Bio Policy	4.285*	-0.026
	(2.490)	(0.069)
Market Cap	2.925***	
	(1.073)	
Size	-3.080***	0.019***
	(1.176)	(0.009)
ROA	21.190***	3.655***
	(13.772)	(1.753)
ROE	-17.982**	-0.229
	(9.143)	(0.347)
Leverage	24.819	0.786
	(99.498)	(7.007)
Observations	3658	3719
p-value of AR(1)	0.001	0.047
p-value of AR(2)	0.048	0.464
p-value of Wald test	0.001	0.001

Robust standard errors are in parentheses. Significance levels are denoted as *, ** and *** representing thresholds of 10%, 5% and 1%, respectively.

The results indicate that Biodiversity Policy is positively and significantly associated with the Altman Z-Score, suggesting that firms disclosing biodiversity policies tend to experience improved financial health over time. However, its relationship with Tobin's

Q is negative but statistically insignificant, implying no discernible effect on market valuation. Among the control variables, Market Capitalization and ROA show positive and significant associations with both dependent variables, highlighting their importance in driving financial and market performance. Size and ROE show mixed results, while *Leverage* is statistically insignificant in both models.

Table VII reports coefficient estimates from the System GMM approach, evaluating how ESG Score influences Tobin's Q and Altman's Z-Score. The model controls for unobserved heterogeneity and simultaneity bias, treating the E Score as a potentially endogenous regressor.

Table VII – Two-Step System GMM – Environmental Score

Variables	Lag Altman Z-Score	Lag Tobin's Q
E Score	0.244	-0.038
	(0.691)	(0.031)
Market Cap	1.607***	
	(0.544)	
Size	-1.696**	0.021**
	(0.594)	(0.001)
ROA	0.148	3.596**
	(10.198)	(1.791)
ROE	-1.206	-0.369
	(13.105)	(0.369)
Leverage	89.975	6.582
	(96.579)	(7.844)
Observations	3658	3719
p-value of AR(1)	0.434	0.036
p-value of AR(2)	0.408	0.433
p-value of Wald test	0.001	0.001

Robust standard errors are in parentheses. Significance levels are denoted as *, ** and *** representing thresholds of 10%, 5% and 1%, respectively.

E Score is not statistically significant in either model, indicating no robust relationship between environmental performance and financial stability or market valuation in this sample. Control variables behave as expected in some cases, such as ROA and Market Capitalization, Size shows opposing effects—negatively linked to financial stability but positively associated with firm value.

Table VIII reports coefficient estimates from the System GMM approach, evaluating how ESG Score influences Tobin's Q and Altman's Z-Score. The model controls for unobserved heterogeneity and simultaneity bias, treating ESG Score as a potentially endogenous regressor.

Investigating the dynamic relationship between ESG Score and both financial distress and firm value, the results show that the coefficient for ESG Score is positive but statistically insignificant in the Z-Score model, indicating no conclusive link between ESG performance and financial distress risk. In contrast, ESG Score shows a statistically significant negative association with Tobin's Q, suggesting that higher ESG scores may be viewed by the market as costly or value-reducing in the short term. Among control variables, Market Capitalization is positively and significantly associated with financial stability, while ROA and Size are positively linked to firm value.

Table VIII – Two-Step System GMM – ESG Score

Variables	Lag Altman Z-Score	Lag Tobin's Q
ESG Score	0.721	-0.068**
	(1.231)	(0.034)
Market Cap	1.767***	
	(0.654)	
Size	-1.928**	0.024**
	(0.775)	(0.009)
ROA	5.17	3.644**
	(13.067)	(1.756)
ROE	-7.540	-0.452
	(10.404)	(0.383)
Leverage	35.019	10.099
	(118.561)	(8.408)
Observations	3658	3719
p-value of AR(1)	0.459	0.035
p-value of AR(2)	0.388	0.414
p-value of Wald test	0.001	0.001

Robust standard errors are in parentheses. Significance levels are denoted as *, ** and *** representing thresholds of 10%, 5% and 1%, respectively.

Instrument validity was assessed using Hansen test of over-identifying restrictions and the AR(2) test for serial correlation of residuals: for the models estimating Altman's Z-Score, the Hansen test p-values, present in Appendix V and Appendix VI, were large across all specifications, suggesting that instruments used are valid and exogenous, furthermore the AR(2) p-values greater than 0.05 indicate no second-order serial correlation. In the case of models estimating Tobin's Q, the Hansen test p-values are small, rejecting the null of instrument exogeneity, while AR(2) P-values are also above 0.05, ruling out serial dependence of residuals, questioning the validity of instruments when examining Tobin's Q. Overall, these diagnostics highlight the importance of addressing endogeneity in panel data and choosing appropriate instruments to produce reliable estimates.

5. CONCLUSION

This study's results enable us to draw a few important conclusions about the roles of the variables examined. This dissertation set out to investigate the relationship between sustainability indicators —specifically Biodiversity Policies, Environmental Score and ESG performance—and firm-level financial outcomes, measured through financial risk and firm valuation, in the European context. The research was motivated by a growing recognition of sustainability's role in financial markets and the rising urgency surrounding biodiversity loss and environmental degradation. Although many companies report sustainability metrics in corporate reporting, empirical research linking these indicators to financial measures, such as risk and financial performance remain relatively scarce. Through a robust econometric analysis employing Random Effects, Fixed Effects, and two-step System GMM models on a balanced panel dataset of 397 listed European firms spanning from 2015 to 2024, this study aimed to fill this gap.

The analysis revealed several important insights into the financial materiality of sustainability-related indicators. Firstly, and most critically for the contribution of this study, the analysis of Biodiversity Policy as a stand-alone variable yielded insightful results. Its direct effect on Altman’s Z-Score is positively and significantly associated with financial risk (Z-Score), suggesting a link between biodiversity disclosure and lower default risk. However, its relationship with firm value (Tobin’s Q) is negative and significant. The findings imply that biodiversity policies and disclosures, while not yet fully internalized by markets, may be financially relevant, especially in sectors with high nature-dependence or under increasing environmental regulations, and that biodiversity disclosure can serve as a risk mitigation strategy.

Secondly, the Environmental Score, that presents results that align with previous literature. This variable has a positive and significant association with both financial risk and financial performance. These findings indicate that the impact of environmental initiatives can contribute to a decrease in the risk of financial distress, while possibly enhancing long-term valuation through reputational benefits or alignment with investor preferences.

Thirdly, the ESG Score, a composite measure, shows relationships with both financial risk and performance, like the ones presented for E Score. In the Z-Score and Tobin's Q regressions, it is positively and significantly associated. These results reinforce the broader financial relevance of ESG performance, suggesting that firms with stronger overall sustainability practices tend to be more resilient and better valued in the market, mirroring the patterns observed with the Environmental Score and highlighting the strategic importance of integrated ESG efforts.

This study contributes to the expanding field of sustainable finance by empirically isolating the role of biodiversity governance. Much of the existing literature tends to test only the ESG Score, and its pillars independently (Velte, 2017; Vivel-Búa et al., 2023). By testing the ESG Score, Environmental Score, and Biodiversity Policy independently, this dissertation offers a more nuanced understanding of how different aspects of sustainability affect firm performance.

In line with stakeholder theory and the resource-based view of the firm, the findings support the notion that proactive sustainability engagement, especially when embedded in strategic areas such as biodiversity, is not merely a cost but can constitute a competitive advantage. This aligns with prior research suggesting that firms with strong environmental governance are better positioned to anticipate regulatory shifts, manage operational risks, and respond to changing stakeholder expectations (Li et al., 2025).

Moreover, the mixed findings on Environmental Score and Biodiversity Policy also resonate with legitimacy theory, suggesting that while firms may disclose sustainability efforts to maintain legitimacy, the market may not yet uniformly reward these actions unless they are material and verifiable. This highlights the importance of advancing disclosure standards and developing universally accepted biodiversity indicators that reflect actual performance rather than symbolic compliance.

Overall, the results offer support for the first hypothesis, as biodiversity policy disclosure appears to mitigate financial risk through a positive association with the Altman Z-Score. However, the second hypothesis—that such disclosure enhances financial performance—is not confirmed, with the evidence showing mixed or negative effects on Tobin's Q. This suggests that while biodiversity efforts may improve internal financial health, they are not yet consistently valued by the market.

From a managerial perspective, the results underscore the importance of integrating biodiversity considerations into core business strategies. As markets and regulators increasingly recognize the systemic risks posed by climate change and biodiversity loss, companies that align themselves with transparent, science-based sustainability practices may gain access to lower financing costs, reduced risk premiums, and enhanced investor confidence.

For investors, the study provides empirical support for incorporating environmental and biodiversity indicators into financial analysis and portfolio construction. The evidence suggests that beyond reputational concerns, sustainability performance can carry tangible financial implications, particularly in relation to risk reduction. This could inform asset managers and analysts when screening firms or engaging with companies on sustainability disclosures.

Policy implications also arise from this research. Regulators aiming to promote sustainable finance in Europe may consider enhancing disclosure requirements related to biodiversity and nature-related risks. While reporting is advancing through directives such as the CSRD, biodiversity-specific metrics remain underdeveloped. Policymakers may take interest in the finding that biodiversity-related governance is beginning to show financial relevance, thus justifying further institutionalization of frameworks like the TNFD across Europe.

While some of the findings are robust and relevant, this study is not without limitations. The Biodiversity Policy indicator, although valuable, may not fully capture the complexity and depth of a firm's interactions with nature. Additionally, the ESG and Environmental Scores are sourced from third-party rating agencies, which may introduce methodological inconsistencies or subjective biases. Although widely used, ESG ratings are not standardized, and discrepancies between providers can affect comparability and reliability. Lastly, the study focuses exclusively on European non-financial listed firms, which may limit generalizability to other regions or private firms. Europe's advanced regulatory environment and investor awareness could lead to more pronounced effects than in markets where sustainability is less integrated.

Given these limitations, future research could expand upon this study in several ways. As TNFD reporting becomes more widespread, future datasets will enable more detailed and consistent measurement of biodiversity-related dependencies and impacts. This could lead to the development of new indicators that reflect nature-related financial risks more accurately. Sector-specific studies may also prove fruitful, especially in industries like agriculture, mining, and energy, which have direct and measurable interactions with ecosystems. These sectors may exhibit different patterns of risk exposure and valuation effects than service-oriented firms. Finally, cross-regional comparisons between Europe and emerging markets could illuminate the varying roles that institutional environments and investor pressures play in shaping the financial relevance of ESG and biodiversity performance.

In conclusion, this dissertation offers timely and policy-relevant evidence on the financial implications of ESG engagement and biodiversity governance. By isolating and analyzing the effects of Biodiversity Policies, Environmental Score and ESG Score on firm-level financial risk and value, this study contributes to a better academic understanding of the relationship between corporate sustainability practices and financial outcomes within a panel data context. The findings reaffirm the growing importance of sustainability—not just as an ethical or reputational consideration, but as a financially material factor that shapes firm outcomes in increasingly tangible ways.

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APPENDICES

Appendix I – Sample Composition by Country

Country	Frequency	Percentage
Austria	4	1.01%
Belgium	5	1.26%
Denmark	20	5.04%
Faroe Islands	1	0.25%
Finland	16	4.03%
France	53	13.35%
Germany	47	11.84%
Ireland	7	1.76%
Italy	21	5.29%
Luxembourg	3	0.76%
Netherlands	20	5.04%
Norway	11	2.77%
Poland	4	1.01%
Portugal	4	1.01%
Spain	18	4.53%
Sweden	38	9.57%
Switzerland	43	10.83%
United Kingdom	82	20.65%
Total	397	100.00%

Appendix II – Sample Composition by Sector

Sector	Frequency	Percentage
Automobiles and Parts	11	2.77%
Basic Resources	17	4.28%
Chemicals	18	4.53%
Construction and Materials	27	6.80%
Consumer Products and Services	28	7.05%
Energy	19	4.79%
Food, Beverage and Tobacco	27	6.80%
Health Care	48	12.09%
Industrial Goods and Services	90	22.67%
Media	7	1.76%
Personal Care, Drug and Grocery Stores	13	3.27%
Retail	11	2.77%
Technology	28	7.05%
Telecommunications	17	4.28%
Travel and Leisure	11	2.77%
Utilities	25	6.30%
Total	397	100.00%

Appendix III - Hausman Specification Test

	Risk	Performance
Chi-square test	109.4	170.47
P-value	0.001	0.001

Appendix IV – Fixed Effects Regression

Variables	Altman Z-Score	Tobin's Q
Bio Policy	2.541***	-0.9981
	0.694	0.069
Market Cap	11.078***	
	2.159	
Size	-15.831	0.072***
	3.097	0.011
ROA	9.109	26.43***
	6.48	5.639
ROE	-3.374	-2.831
	1.192	1.177
Leverage	4.132	0.846
	2.832	2.499
Observations	3658	3719
R-squared	0.0911	0.2432

Appendix V - Hansen Test for GMM – Altman's Z-Score

	Bio_Policy	E_Score	ESG_Score
Hansen Test	P > chi = 0.999	P > chi = 0.996	P > chi = 0.997

Appendix VI - Hansen Test for GMM – Tobin's Q

	Bio_Policy	E_Score	ESG_Score
Hansen Test	P > chi = 0.002	P > chi = 0.011	P > chi = 0.013