Corvinus University of Budapest

Doctoral School of Economics and Business Informatics

Essays on Nature-Related Risk Premia in Equity Markets

Thesis booklet

Gergely János Czupy

Supervisors: Helena Naffa & Péter Csóka

Budapest 2026

Literature and Topic Relevance

Biodiversity loss has emerged as a critical challenge for the global economy and financial systems. The IPBES Global Assessment (IPBES, 2019) reports that 75% of the land surface is significantly altered and 66% of the ocean area is experiencing increasing cumulative impacts. Over USD 44 trillion of economic value generation - more than half of global GDP - is moderately or highly dependent on nature and ecosystem services (GSIA, 2024), while approximately USD 7.2 trillion of enterprise value is exposed to unmanaged biodiversity risk (Carvalho et al., 2023). These numbers establish biodiversity loss as both a systemic and a systematic financial risk: its effects propagate through supply chains, regulatory channels, and macroeconomic aggregates, and cannot be diversified away within an equity portfolio.

Regulators have started to responded to this problem. For example, the EU Sustainable Finance Disclosure Regulation (SFDR) mandates disclosure of biodiversity-related Principal Adverse Impact (PAI) indicators, the Corporate Sustainability Reporting Directive (CSRD) requires double-materiality assessments, and the Kunming-Montreal Global Biodiversity Framework (2022) sets targets for nature protection. Central banks, through the Network for Greening the Financial System (NGFS), have highlighted the system-wide consequences of collapsing ecosystems and called for integration of nature-related risks into financial frameworks (NGFS, 2022).

Despite the regulatory efforts, the academic literature on how financial markets price biodiversity and nature-related risks is limited. While climate finance has a well-established body of literature documenting a carbon premium (Bolton & Kacperczyk, 2021, 2024) and green-versus-brown return differentials (Pastor et al., 2021, 2022), biodiversity-specific pricing is less explored. Early contributions include Garel et al. (2024), who document investor reactions to biodiversity news; Coqueret et al. (2025), who identify a biodiversity premium using factor-based approaches; and Giglio et al. (2026), who show that biodiversity risk pricing is a recent, still-evolving phenomenon. However, the literature lacks practical, portfolio-level estimates of the cost investors bear when managing biodiversity risk, and the relationship between firms' impacts on ecosystems and their dependencies on ecosystem services remains underexplored.

This dissertation addresses these gaps. After introducing the key terms in biodiversity finance, it introduces the Biodiversity Risk Premium (BRP) and the Nature Risk Premium (NRP) as new concepts for quantifying nature-related financial risks. The BRP captures the cost of biodiversity risk mitigation within a portfolio optimization framework that mirrors real-world sustainable investment strategies, while the NRP extends the analysis to include both climate and biodiversity risks through the lens of double materiality. The dissertation also identifies Earth Observation (EO) data as a potential next step for overcoming the limitations of current disclosure-based biodiversity metrics. Finally, example calculations of an ecosystem condition indicator, the Tree Cover Density, are presented, showcasing a metric that can be used in future research.

Applied Methods

The empirical analyses employ three complementary methodological approaches, and builds on global datasets (including financial, and ESG attributes of approximately 3000 MSCI All Country World Index members, sub-sector-level ecosystem service dependencies and pressures from the ENCORE database, Principal Adverse Impact indicators from the LSEG database).

The first approach utilizes portfolio optimization with biodiversity screening (Chapter 3). Biodiversity-screened portfolios are constructed by excluding firms with the lowest MSCI Biodiversity and Land Use scores at three intensity levels (25%, 50%, 75%). Optimal portfolios are computed using mean-variance optimization with a Ledoit-Wolf shrinkage estimator for the covariance matrix, and their performance is benchmarked against randomly screened portfolios of equal size. The Biodiversity Risk Premium (BRP) is estimated as the difference in Relative Sharpe Ratio Loss (RSRL) and Return Loss (RL) between biodiversity-screened and randomly screened portfolios. Regression models control for Fama-French five factors, momentum, liquidity, sector composition, ESG attributes, portfolio risk, and geographic composition. The biodiversity score difference is orthogonalized against carbon, social, and US-location metrics to isolate a ”pure” biodiversity component. The sample covers the period between 2013-2023.

The second approach, Fama-MacBeth two-step procedure, is applied in Chapter 4 to estimate risk premia for individual PAI indicators and ENCORE ecosystem service dependency and pressure levels. In the first step, firm-level excess returns are regressed on lagged biodiversity risk characteristics and control variables in yearly cross-sections. In the second step, the risk premium is estimated as the time-series average of the yearly coefficient estimates, with Newey-West standard errors (one lag) to account for autocorrelation. In this analysis, the sample covers 2019-2024.

For the third approach, long-short portfolio analysis (Chapter 4), portfolios are sorted on ENCORE-based pressure and dependency scores to construct a high-pressure/low-dependency (HPLD) and a low-pressure/high-dependency (LPHD) portfolio. The return spread is regressed on the Fama-French five factors, momentum, and liquidity. In robustness tests, alternative models are constructed using firm size-scaled ENCORE scores, EU-only subsample, and a post-2022 subsample. A significant intercept (the adjusted return difference) would indicate a distinct trade-off between biodiversity physical and transition risks beyond standard factor exposures.

Main Results

The dissertation has the following results:

1. The Biodiversity Risk Premium exists and is non-linear.

   Biodiversity-screened portfolios exhibit lower risk-adjusted returns compared to randomly screened portfolios of equal size. The total Relative Sharpe Ratio Loss (RSRL) ranges from 1.19% to 4.14% of the maximum attainable Sharpe ratio across low, moderate, and high screening levels. The biodiversity-specific additional return loss amounts to approximately 1, 5, and 11 basis points for the three levels, respectively. The BRP is statistically indistinguishable from zero at low-to-moderate screening intensities and becomes statistically significant only at the strictest (75%) screening level. The small cost (1 basis point) suggests that the adoption of moderate-intensity biodiversity screens carries negligible sacrifice. Biodiversity-screened portfolios also exhibit improved social pillar scores and carbon-intensity metrics. A structural change in the BRP is observed around the COVID-19 period, which highlights the need for consistent monitoring and harmonized disclosure frameworks.

2. Climate-related transition risks are robustly priced; biodiversity-specific transition risks are not yet priced.

   The carbon footprint carries a positive and significant risk premium of 0.6% per unit ($p = 0.019$), scope 3 GHG emissions carry a significant positive premium ($p = 0.038$), and UNGC and OECD violations command a significant positive premium ($p = 0.043$). However, biodiversity-specific transition risk measures (the biodiversity-sensitive areas PAI indicator, most ENCORE pressures) are not statistically significant, suggesting that biodiversity transition risks are not yet systematically reflected in the cross-section of global equity returns. Non-significance can also be explained by the sample size and data availability limitation, though.

3. Ecosystem service dependencies are priced in a direction supporting investor-taste models.

   Firms highly dependent on solid waste remediation, visual amenity, and soil and sediment retention earn significantly lower subsequent returns. This pattern is consistent with investor taste premia (Pastor et al., 2021), whereby investors accept lower expected returns on assets aligned with ecosystem services, and with market mispricing of operational resilience (Huang et al., 2024). At the portfolio level, the ENCORE-based long-short strategy, which reveals the difference between the pricing of low-dependency / high-pressure and high-dependency / low-pressure portfolios, does not generate significant adjusted returns after controlling for standard risk factors. This implies that investors do not yet distinguish between physical and transition biodiversity risk sources. The EU subsample comes closest to statistical significance, and the post-2022 period shows a substantial increase in model explanatory power, suggesting that this distinction may emerge as disclosure frameworks mature.

4. EU-mandated PAI indicators are partially effective signals of priced nature-related risks.

   Certain PAI indicators, like the carbon footprint, Scope 3 GHG emissions, and UNGC/OECD violations, are significantly associated with equity risk premia. However, other PAI indicators (non-renewable energy share, energy intensity, water emissions, biodiversity impact) are not statistically significant. PAI indicators appear effective for easily quantifiable risk sources but less informative for risks that are harder to measure.

5. Double materiality is essential for comprehensive nature-related risk assessment.

   The progression from biodiversity-specific ratings (Chapter 3) to double-materiality-aligned impact and dependency indicators (Chapter 4) demonstrates that distinguishing between firms' impacts on ecosystems and their dependencies on ecosystem services is essential for a complete understanding of financial exposure. The dissertation argues that spatially estimated, forward-looking Earth Observation data, combined with ecosystem accounting frameworks such as the SEEA-EA, can overcome the measurement limitations of current disclosure-based metrics by providing unbiased, verifiable, and comparable measures of ecosystem condition at the asset-location level.

Main References

Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, *142*(2), 517–549. https://doi.org/10.1016/j.jfineco.2021.05.008

Bolton, P., & Kacperczyk, M. (2024). Are carbon emissions associated with stock returns? comment. *Review of Finance*, *28*(1), 107–109. https://doi.org/10.1093/rof/rfad019

Carvalho, S. H. C. D., Cojoianu, T., & Ascui, F. (2023). From impacts to dependencies: A first global assessment of corporate biodiversity risk exposure and responses. *Business Strategy and the Environment*, *32*(5), 2600–2614. https://doi.org/10.1002/bse.3142

Coqueret, G., Giroux, T., & Zerbib, O. D. (2025). The biodiversity premium. *Ecological Economics*, *228*, 108435. https://doi.org/10.1016/j.ecolecon.2024.108435

Garel, A., Romec, A., Sautner, Z., & Wagner, A. F. (2024). Do investors care about biodiversity? *Review of*

Finance, *28*(4), 1151–1186. https://doi.org/10.1093/rof/rfae010

Giglio, S., Kuchler, T., Stroebel, J., & Zeng, X. (2026). Biodiversity risk. https://doi.org/10.1093/rof/rfaf063

GSIA. (2024). *Global sustainable investment review*. https://www.gsi-alliance.org/members-resources/gsir2022/

Huang, Y., Créti, A., Jiang, B., & Sanin, M. E. (2024). Biodiversity risk, firm performance, and market mispricing. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4765039

IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://files.ipbes.net/ipbes-web-prod-public-files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf

Lovas, A., Czupy, G., & Naffa, H. (2026). Return Trade-Offs between Biodiversity Physical and Transition Risk in Global Equity Markets. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=6085026

Naffa, H., & Czupy, G. (2024). Biodiversity risk premium. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4751958

NGFS. (2022). *Central banking and supervision in the biosphere: An agenda for action on biodiversity loss, financial risk and system stability*. https://www.ngfs.net/system/files/import/ngfs/medias/documents/central_banking_and_supervision_in_the_biosphere.pdf

Pastor, L., Stambaugh, R. F., & Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics*, *142*(2), 550–571. https://doi.org/10.1016/j.jfineco.2020.12.011

Pastor, L., Stambaugh, R. F., & Taylor, L. A. (2022). Dissecting green returns. *Journal of Financial Economics*, *146*(2), 403–424. https://doi.org/10.1016/j.jfineco.2022.07.007

Yusifzada, L., Lončarski, I., Czupy, G., & Naffa, H. (2025). Return trade-offs between environmental and social pillars of ESG scores. *Research in International Business and Finance*, *75*, 102779. https://doi.org/10.1016/j.ribaf.2025.102779

Other main references in the dissertation, not included in the extract

Cochrane, J. H. (2009). *Asset pricing: Revised edition*. Princeton university press.

Eskildsen, M., Ibert, M., Jensen, T. I., & Pedersen, L. H. (2024). In search of the true greenium. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4744608

Fama, E. F., & French, K. R. (2015). A five-factor asset pricing model. *Journal of Financial Economics*, *116*(1), 1–22. https://doi.org/10.1016/j.jfineco.2014.10.010

Karolyi, G. A., & Tobin-de La Puente, J. (2023). Biodiversity finance: A call for research into financing nature. *Financial Management*, *52*(2), 231–251. https://doi.org/10.1111/fima.12417

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, *7*(1), 77–91. https://doi.org/10.1111/j.1540-6261.1952.tb01525.x

Pedersen, L. H., Fitzgibbons, S., & Pomorski, L. (2021). Responsible investing: The ESG-efficient frontier.

Journal of Financial Economics, *142*(2), 572–597. https://doi.org/10.1016/j.jfineco.2020.11.001

Xin, Y., Ekeland, I., & Peyrat, T. (2025). Stock returns and biodiversity risk: Evidence from ESG ratings. *SSRN Electronic Journal*.

The author's publications

- Yusifzada, L., Lončarski, I., Czupy, G., & Naffa, H. (2025). Return trade-offs between environmental and social pillars of ESG scores. *Research in International Business and Finance*, *75*, 102779. https://doi.org/10.1016/j.ribaf.2025.102779

- Naffa, H., & Czupy, G. (2024). Biodiversity risk premium. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4751958

- Lovas, A., Czupy, G., & Naffa, H. (2026). Return Trade-Offs between Biodiversity Physical and Transition Risk in Global Equity Markets. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=6085026