Biodiversity and Climate: Friends or Foes?

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Motivation

- Investors are increasingly concerned about environmental risks: Climate change, now Biodiversity loss as well
- Climate change and biodiversity are interconnected:

"Climate change is a primary driver of biodiversity loss. And climate change depends on biodiversity as part of the solution. So clearly the two are linked, and cannot be separated."

Elizabeth Mrema, Executive Secretary, United Nations Convention on Biological Diversity

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Motivation

- Examples of mechanisms of interconnection:
  - Climate change alters marine, terrestrial, and freshwater ecosystems
  - Biodiversity influences climate through carbon sequestration
- Investors need methods to incorporate both biodiversity and climate objectives into portfolios
- **Research questions:**
  - Can investors improve biodiversity and climate exposures without sacrificing returns?
  - Are there trade-offs between biodiversity and climate objectives?

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Contributions

- Develop an analytical framework to incorporate multiple sustainability objectives into optimal portfolios
- Sole study of biodiversity risks alongside climate in sovereign bond portfolios:
  - Optimize portfolios with *both* biodiversity and climate objectives
  - Identify potential trade-offs between objectives
  - Empirical analysis over 20-year sample

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Literature Review: Biodiversity Finance

- Biodiversity finance research remains limited [Starks, 2023]
- Effectiveness of private vs blended biodiversity finance [Flammer et al., 2023]
- Textual measures of biodiversity risk
  - News and 10-K reports [Giglio et al., 2023]
  - Impact on equity prices but not municipal bonds
  - Brazilian and Australian corporate bonds [Cherief et al., 2022]
- Biodiversity risk affects CDS slopes [Hoepner et al., 2023]
- Corporate biodiversity footprint and equity pricing [Garel et al., 2024, Coqueret et al., 2023]
- Biodiversity impact on sovereign CDS pricing [Giglio et al., 2024]

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Literature Review: Other Relevant Literature

- Optimizing portfolios with sustainability objectives
  - ESG criteria and Sharpe ratio [Pedersen et al., 2021]
  - Incorporating sustainability in tracking error optimization [Blitz et al., 2024, Soupe and Kovarcik, 2024]

- Low-carbon and net-zero sovereign bond investing [Barahhou et al., 2023, Cheng et al., 2022, Schwaiger et al., 2023]

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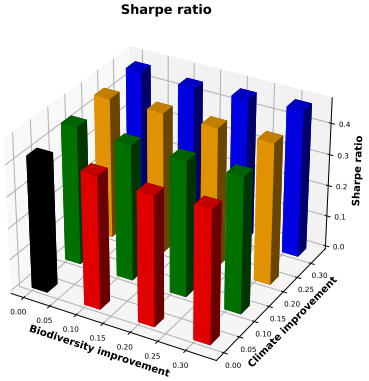
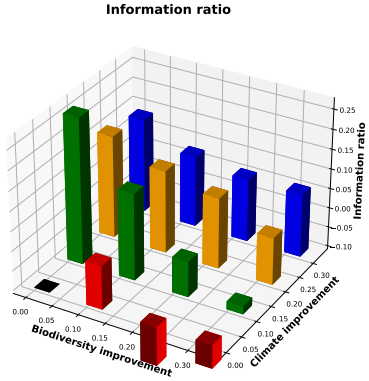
Preview of the results

- Improving biodiversity and climate without significant deterioration of risk-adjusted returns is possible





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Outline

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Relative Risk Minimization with Two Sustainable Objectives: Problem

- Minimize tracking error variance vs benchmark $\frac{1}{2}\Delta w^T \Omega \Delta w$ subject to:
  - Active weights Δw ("tilt")
  - Variance-covariance matrix of returns Ω
  - Biodiversity improvement target $\Delta w^T s_1 = \Delta s_1^*$
  - Climate improvement target $\Delta w^T s_2 = \Delta s_2^*$
  - Zero-sum active weights $\Delta w^T 1 = 0$
  - No expected return assumptions
- Extension of previous analytical literature on relative return-risk optimization with no [Roll, 1992, Jorion, 2003] or one sustainable objective [Soupe and Kovarcik, 2024]
- Consistent with practitioners' implementation of portfolio construction with sustainable objectives [Andersson et al., 2016, Bajo and Rodríguez, 2023, Barahhou et al., 2023, Blitz et al., 2024, Bolton et al., 2022, Cheng et al., 2022, Schwaiger et al., 2023]

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Relative Risk Minimization with Two Sustainable Objectives: Solution

- Optimal portfolio active weights:

$$\Delta w^* = \theta_1 \, w_{\text{SCM}_1} + \theta_2 \, w_{\text{SCM}_2} - (\theta_1 + \theta_2) \, w_{\text{GMV}}$$

  - θ_k: scaled preference for sustainability characteristic k
  - w_{SCM_k}: sustainability characteristic-mimicking portfolio for objective k
  - w_{GMV}: global minimum variance portfolio

- Extends the two-fund combination associated with Markowitz's original program to a three-fund combination (see [Fama, 1996, Pedersen et al., 2021])

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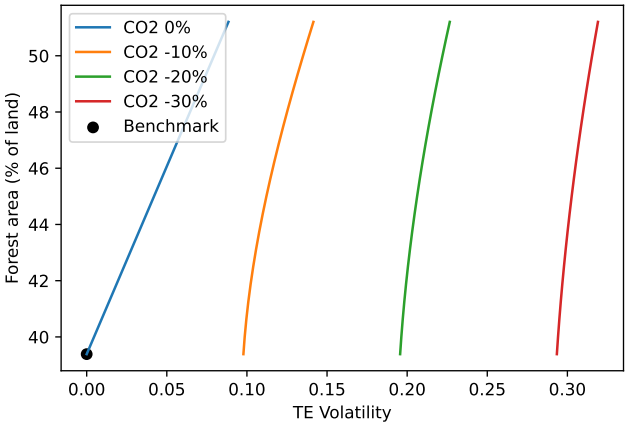
Tracking Error vs Biodiversity (forest area) Objective



Long-short portfolio that minimizes the ex-ante tracking error volatility for given levels of biodiversity in December 2023

Increasing biodiversity targets leads to higher tracking error, with steeper increases for more ambitious climate targets.

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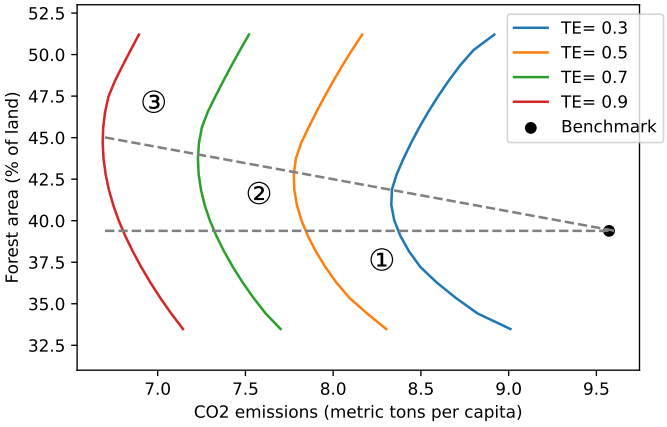
Ex-Ante Efficient Frontier: Climate vs Biodiversity



Including long-only constraints. December 2023.

Long-only constraints introduce trade-offs between biodiversity and climate objectives, particularly for more ambitious targets

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Decomposition of Active Risk

- Tracking error volatility:

$$\text{TEV}^* = \left[\pi_{11}\left(\Delta s_1^*\right)^2 + \pi_{22}\left(\Delta s_2^*\right)^2 + 2\,\pi_{12}\,\Delta s_1^* \Delta s_2^*\right]^{1/2}$$

  - $\pi_{11} > 0$, $\pi_{22} > 0$: individual preferences for each sustainability objective
  - π_{12} ($>$ or <0): trade-off between both sustainable objectives

- Tracking error volatility decomposition:

$$\text{TEV}^* = \left(\underbrace{\lambda_1 \sum_{i=1}^{N} \Delta w_i^* s_{1i}}_{\text{Contribution of SCM}_1} + \underbrace{\lambda_2 \sum_{i=1}^{N} \Delta w_i^* s_{2i}}_{\text{Contribution of SCM}_2} \right) / \text{TEV}^*$$

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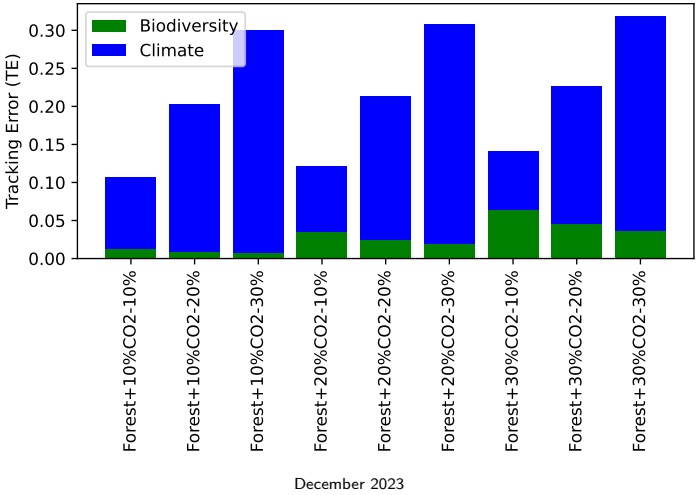
Ex-Ante TEV decomposition



Climate objective consistently contributes more to tracking error than biodiversity, regardless of target levels.

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Sovereign Bond Indices

- ICE BofA Developed Markets Sovereign Bond Index (WSAV)
- 21 countries: Jan 2003 - Dec 2023
- Indices in USD, hedged against currency risk

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Sustainability Characteristics

- Biodiversity measure:
  - Forest area (% of total land area) - World Bank Sovereign ESG Data Portal
- Climate measure:
  - CO2 emissions (metric tons per capita) - World Bank Sovereign ESG Data Portal
- Alternative database: Yale Environmental Performance Index (EPI)
  - Ecosystem Vitality (biodiversity)
  - Climate Change (climate)
- Annual data, 2000-2020

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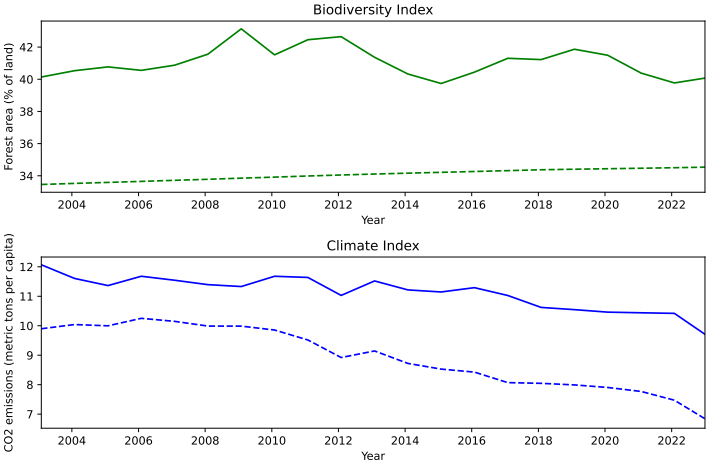
Biodiversity and Climate Characteristics Over Time



Weighted average forest area (top panel) and CO2 emissions (bottom panel) across developed countries, market capitalization (solid) or equal-weighting (dashed)

While forest area has remained stable for large issuers (solid line) but has increased on average across all countries (dashed line), CO2 emissions have decreased over time for all

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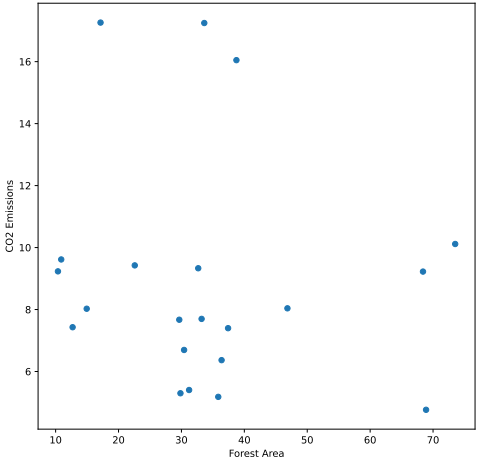
Biodiversity and Climate Characteristics Across Countries



Average biodiversity (forest area) and climate (CO2 emissions) characteristics across developed countries, January 2003 to December 2023.

There is a weak negative correlation between forest area and CO2 emissions, suggesting potential for joint improvement

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Climate-Biodiversity Strategy: Absolute Statistics

	CAGR	Ann. Vol.	Sharpe Ratio	Max. DD	Calmar Ratio	Turnover
Forest+0% & CO2-0% (Bench.)	3.08%	3.56%	0.42	14.61%	0.10	10.07%
Forest+10% & CO2-0%	3.09%	3.56%	0.42	14.78%	0.10	19.64%
Forest+20% & CO2-0%	3.06%	3.54%	0.41	14.80%	0.10	23.45%
Forest+30% & CO2-0%	3.06%	3.50%	0.42	14.79%	0.10	22.87%
Forest+0% & CO2-10%	3.17%	3.58%	0.44	14.59%	0.11	21.98%
Forest+10% & CO2-10%	3.14%	3.55%	0.43	14.56%	0.11	26.74%
Forest+20% & CO2-10%	3.12%	3.53%	0.43	14.54%	0.10	28.37%
Forest+30% & CO2-10%	3.10%	3.49%	0.43	14.37%	0.10	30.82%
Forest+0% & CO2-20%	3.22%	3.60%	0.45	14.64%	0.11	33.45%
Forest+10% & CO2-20%	3.20%	3.56%	0.45	14.49%	0.11	30.18%
Forest+20% & CO2-20%	3.19%	3.52%	0.45	14.17%	0.11	36.65%
Forest+30% & CO2-20%	3.17%	3.48%	0.45	14.04%	0.11	39.99%
Forest+0% & CO2-30%	3.29%	3.64%	0.46	14.64%	0.12	41.63%
Forest+10% & CO2-30%	3.24%	3.60%	0.45	14.58%	0.11	40.03%
Forest+20% & CO2-30%	3.23%	3.55%	0.46	14.28%	0.11	44.80%
Forest+30% & CO2-30%	3.24%	3.50%	0.47	13.75%	0.12	45.41%

January 2003 to December 2023.
"CAGR" stands for Compound Annual Growth Rate, "Ann. Vol." for Annualized Volatility,
"S.R." for Sharpe Ratio, "Max. DD" for Maximum Drawdown,
"Turnover" for One-Way Turnover.

Improving climate and biodiversity exposures can be achieved without sacrificing absolute risk-adjusted returns, with the highest Sharpe ratios for portfolios combining ambitious climate and biodiversity targets

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Climate-Biodiversity Strategy: Relative Statistics

	Alpha	Tracking Error	Information Ratio
Forest+10% & CO2-0%	0.01%	0.09%	0.11
Forest+20% & CO2-0%	-0.02%	0.20%	-0.10
Forest+30% & CO2-0%	-0.02%	0.36%	-0.06
Forest+0% & CO2-10%	0.08%	0.22%	0.37
Forest+10% & CO2-10%	0.06%	0.26%	0.22
Forest+20% & CO2-10%	0.03%	0.35%	0.09
Forest+30% & CO2-10%	0.01%	0.45%	0.02
Forest+0% & CO2-20%	0.14%	0.52%	0.26
Forest+10% & CO2-20%	0.11%	0.53%	0.21
Forest+20% & CO2-20%	0.10%	0.60%	0.18
Forest+30% & CO2-20%	0.08%	0.67%	0.12
Forest+0% & CO2-30%	0.20%	0.82%	0.24
Forest+10% & CO2-30%	0.15%	0.83%	0.18
Forest+20% & CO2-30%	0.14%	0.87%	0.16
Forest+30% & CO2-30%	0.15%	0.92%	0.16

January 2003 to December 2023. Analytics relative to the market capitalization benchmark portfolio.

Adding biodiversity to climate-focused portfolios increases relative risk and reduces alpha, but this trade-off diminishes for more ambitious sustainable portfolios, suggesting potential synergies at higher sustainability targets

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Robustness: Alternative Sustainability Measures

- Yale Environmental Performance Index (EPI) scores
- Returns increase with both climate and biodiversity
- Risk increases too
- Stable risk-adjusted returns
- Modest turnover increase
- All positive alphas and higher IRs for more sustainable portfolios

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Impact of Constraints

- Removing long-only constraint
- More stable profiles across portfolios
- Limited change in risk-return vs benchmark
- Much smaller tracking errors
- But much higher turnover

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Conclusions

- Analytical framework to incorporate biodiversity and climate in optimal portfolios
- Over 21 years in sovereign bonds universe:
  - Can improve biodiversity and climate exposures without sacrificing absolute risk-adjusted returns
  - But relative to benchmark, adding biodiversity to climate objective increases risk and reduces alpha
  - Trade-off smaller for more ambitious sustainable portfolios
- Trade-off implied by long-only constraints
- Results robust to different sustainability measures and set-ups
- Can be applied to other sustainability multi-objective contexts

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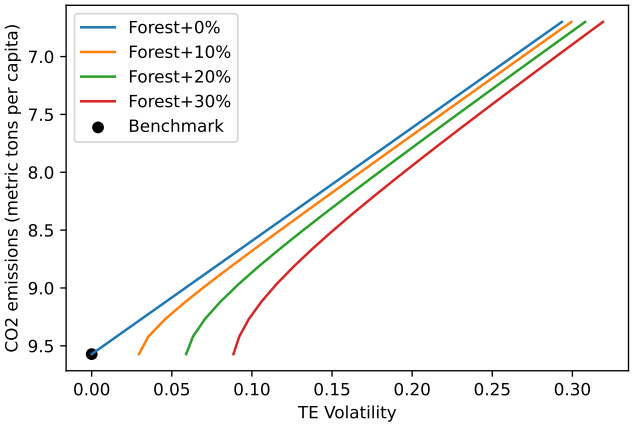
Tracking Error vs Climate (CO2) Objective



Long-short portfolio that minimizes the ex-ante tracking error volatility for given levels CO2 emissions in December 2023.

Reducing CO2 emissions targets results in higher tracking error, with less impact from forest area targets.

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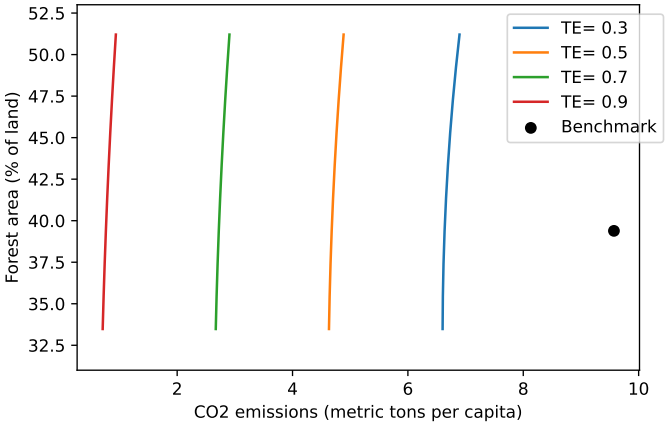
Ex-Ante Efficient Frontier: Climate vs Biodiversity II



Long-short. December 2023.

In long-short portfolios, biodiversity and climate objectives can be improved simultaneously without significant trade-offs.

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