From Pledges to Portfolios: Integrating Countries' Climate Commitments into Sovereign Bond Investments

Fabio Alessandrini, Eric Jondeau, Lou-Salomé Vallée

University of Lausanne - HEC
&
Center for Risk Management Lausanne - CRML

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Context and Motivation

- The 2015 Paris agreements marks the beginning of the transition towards a net-zero (NZ) economy by 2050.
- Aligning sovereign bond portfolios with the transition to a NZ economy benefits both sovereign entities and institutional investors.
- The release of two rounds of NDCs (2015 post-COP21 and 2021 post-COP26) provides a useful proxy for assessing sovereign commitments to reduce GHG emissions.

Research Question

Research question

Can Nationally Determined Contributions (NDCs) help to build sovereign bond portfolios aligned with NZ targets, without compromising financial performance?

Literature Review

NZ portfolio optimization:

- Corporate-focused: Bolton et al. (2022), Kaul et al. (2022)
- Sovereign-focused: Kaul et al. (2022), Cheng et al. (2022)

Heterogeneity in NDC formats and ambition:

- Carraro (2018), Pauw et al. (2018), King and van den Bergh (2019), Pizarro et al. (2024), Jeudy-Hugo et al. (2024)

Contribution:

- Use of sovereign NDCs as forward-looking data
- Backward and forward analyses (2015-2021 and 2021-2030)
- Country fairness considerations

Data Sources

- **Benchmark**: J.P. Morgan GBI Global and GBI-EM Broad (weights, hedged returns)
- **Emissions**: production-based GHG emissions from Our World in Data - OWID
- **GDP**: expressed in constant U.S. dollars (2015) from the World Bank data portal (WDI)

  = Sample of 13 advanced and 25 emerging countries

- **NDCs**: 1st and 2nd NDCs' submissions from the United Nations Framework Convention on Climate Change - UNFCCC registry

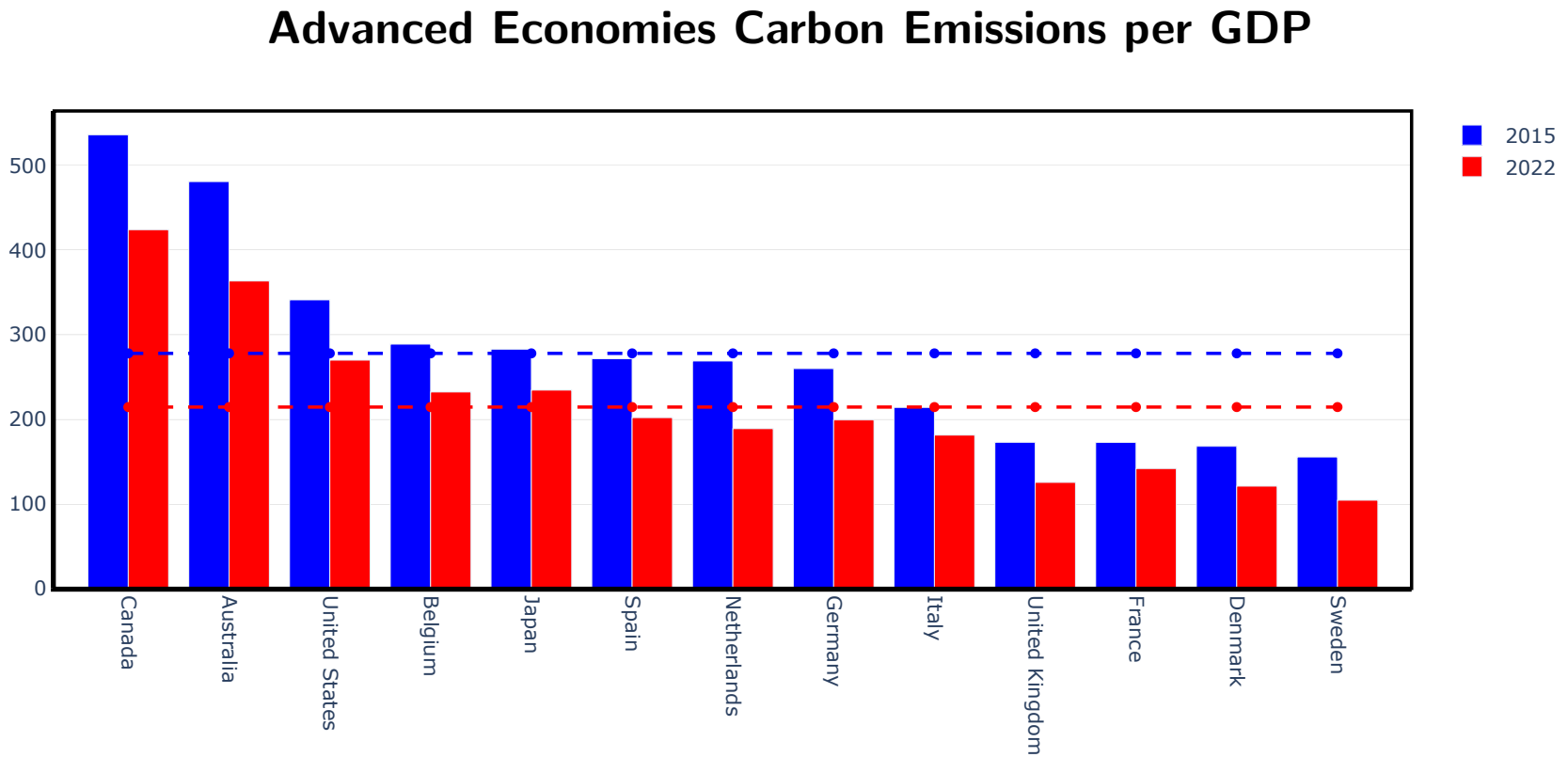
NDC-Based GHG Intensity Trajectories

For each country, we derive a GHG intensity path based on their NDC target for 2030.

Average annual GHG intensity reduction (benchmark weights):

- **Actual reduction (2015-21)**: 2.42% (adv), 2.24% (em)
- **First NDCs (2015-21)**: 1.26% (adv), 1.27% (em)
- **Second NDCs (2021-30)**: 5.07% (adv), 3.4% (em)

Carbon Emissions per GDP



Note: This figure displays the carbon intensity of the advanced countries under consideration for 2015 (in blue) and 2022 (in red). Carbon intensity is the production-based metric in tonnes of CO_2 equivalent per million U.S. dollars of GDP. Countries are sorted by decreasing carbon intensity as of 2015. Horizontal lines are weighted averages for each year.

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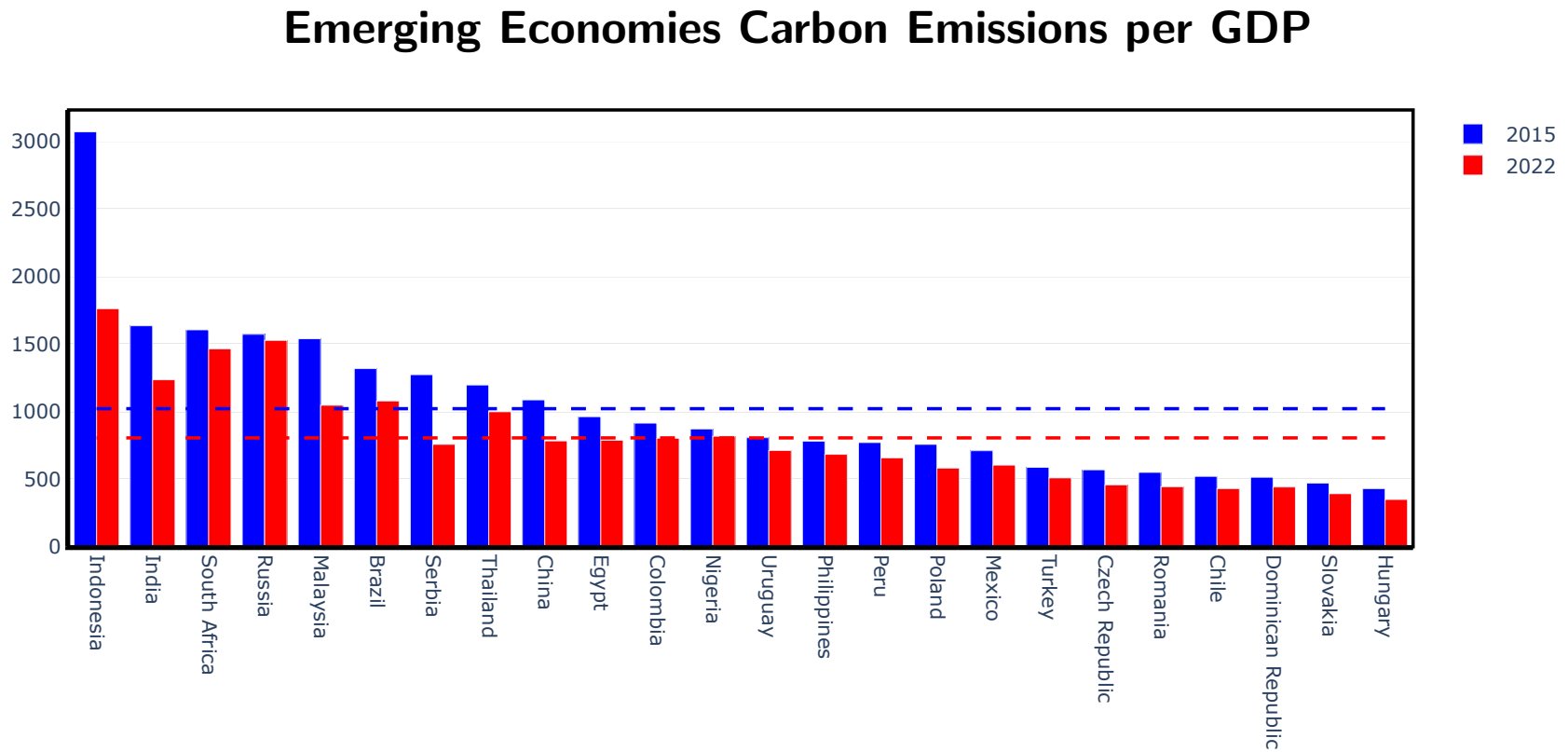

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Methodology

Objective: Minimize the ex-ante tracking error relative to the benchmark, while reducing GHG intensity over time, at a constant target rate.

- **Two prediction scenarios for GHG intensity $\widetilde{CI}_{i,y}$:**
  - **Scenario 1 (Constant)**: $\widetilde{CI}_{i,y} = CI_{i,y_0}$
  - **Scenario 2 (NDC-Based)**: $\widetilde{CI}_{i,y} = CI_{i,y}^{(NDC)}$

  Annual emissions reduction rates θ: 5%, 7% and 10%

- **Two different analyses:**
  - **Backward looking approach:** 2015-2021
  - **Forward looking approach:** 2021-2030

Methodology

Optimization problem (for $y = y_0 + 1, ..., Y$)

$$\min_{w_{y-1}^{(p)}} \widetilde{TE}_y^{(p)} = \sqrt{(w_{y-1}^{(p)} - w_{y-1}^{(b)})' \, \widetilde{\Sigma}_y \, (w_{y-1}^{(p)} - w_{y-1}^{(b)})}$$

s.t.

$$\widetilde{CI}_y^{(p)} = \sum_{i=1}^{N_{y_0}} w_{i,y-1}^{(p)} \widetilde{CI}_{i,y} \leq CI_{y_0}^{(b)} \times (1-\theta)^{y-y_0}$$

Where:

- $CI_{y_0}^{(b)}$: benchmark GHG intensity in $y_0 = 2015$ or 2021
- $\widetilde{CI}_{i,y}$: predicted GHG intensity for country i in year y
- $\widetilde{\Sigma}_y$: 5 years predicted covariance matrix
- $w_{i,y-1}^{(b)}$, $w_{i,y-1}^{(p)}$: weight of country i in the benchmark and in the portfolio at the end of year $y-1$, respectively
- N_{y_0}: number of countries in the benchmark in year y_0

Methodology

Three levels of portfolio constraints:

- **Unconstrained:** No restriction on portfolio weights in solving the optimization problem.
- **Regional Constraint:** Keeps the total weight of emerging economies (EE) equal to their benchmark weight in y_0:

$$\sum_{i \in EE} w_{i,y-1}^{(p)} = \sum_{i \in EE} w_{i,y_0}^{(b)}$$

- **Country Constraint:** Prevents excessive deviation from benchmark weights:

$$\frac{1}{5} w_{i,y_0}^{(b)} \leq w_{i,y-1}^{(p)} \leq 5 w_{i,y_0}^{(b)}$$

Key Results

- NDC-based portfolios achieve comparable GHG intensity reductions to constant-intensity scenarios, with significantly lower tracking error.
- Incorporating NDCs leads to more balanced and diversified portfolio allocations.
- Updated NDCs from COP26 (more ambitious) enable strong GHG reductions at marginal financial cost.
- Constraints (regional/country) preserve equity but limit the ability to meet ambitious reduction targets and increase tracking errors.
- Emphasizes the need for cautious portfolio design that balances climate goals, equity concerns, and market constraints.

GHG and Financial Performance – BL

GHG and Financial Performance – Backward-looking

	Bench -mark	Scenario 1: 2015 intensities 5%	7%	10%	Scenario 2: NDC intensities 5%	7%	10%
Reduction Target (%)		**26.5**	**35.3**	**46.9**	**26.5**	**35.3**	**46.9**
Panel A: No restriction							
Ex-ante achieved reduction (%)		26.5	35.3	46.9	26.5	35.3	46.9
Ex-post achieved reduction (%)	15.1	34.0	40.9	50.7	29.6	37.0	46.6
Ex-ante tracking error (%)		0.18	0.41	0.80	0.11	0.26	0.62
Ex-post tracking error (%)		**0.22**	**0.46**	**0.90**	**0.16**	**0.29**	**0.67**
Ex-post Sharpe Ratio	0.74	0.72	0.70	0.66	0.72	0.71	0.69
Panel B: Regional restrictions							
Ex-ante achieved reduction (%)		26.5	35.3	46.9	26.5	35.3	46.9
Ex-post achieved reduction (%)	15.1	34.2	41.2	51.1	30.1	37.1	47.3
Ex-ante tracking error (%)		0.28	0.53	0.96	0.17	0.39	0.76
Ex-post tracking error (%)		**0.32**	**0.59**	**0.96**	**0.20**	**0.43**	**0.81**
Ex-post Sharpe Ratio	0.74	0.68	0.67	0.64	0.70	0.68	0.67
Panel C: Regional and country restrictions							
Ex-ante achieved reduction (%)		26.5	33.3	33.3	26.5	35.3	37.9
Ex-post achieved reduction (%)	15.1	33.6	40.3	43.4	29.3	36.3	43.4
Ex-ante tracking error (%)		0.50	0.95	1.27	0.30	0.68	1.18
Ex-post tracking error (%)		**0.75**	**1.35**	**1.51**	**0.45**	**1.00**	**1.48**
Ex-post Sharpe Ratio	0.74	0.66	0.60	0.62	0.68	0.62	0.63

Note: The table reports GHG intensity reduction and financial performance for the backward-looking exercise from the end of 2015 to the end of 2020. Each scenario of GHG intensity prediction is associated to three GHG emission reduction targets, $\theta = 5\%$, 7%, and 10%.

GHG and Financial Performance – FL

GHG and Financial Performance – Forward-looking

	Scenario 1: 2021 intensities			Scenario 2: NDC intensities		
	5%	7%	10%	5%	7%	10%
Reduction Target (%)	**40.1**	**51.6**	**65.1**	**40.1**	**51.6**	**65.1**
Panel A: No restriction						
Ex-ante achieved reduction (%)	40.1	51.6	65.1	40.1	51.6	65.1
Ex-ante tracking error (%)	**0.04**	**0.15**	**0.34**	**0.00**	**0.01**	**0.06**
Panel B: Regional restrictions						
Ex-ante achieved reduction (%)	40.1	51.6	58.0	40.1	51.6	65.1
Ex-ante tracking error (%)	**0.07**	**0.19**	**0.42**	**0.00**	**0.01**	**0.09**
Panel C: Regional + country restrictions						
Ex-ante achieved reduction (%)	31.7	31.8	31.7	40.1	51.6	55.5
Ex-ante tracking error (%)	**0.46**	**0.61**	**0.73**	**0.00**	**0.12**	**0.58**

Note: The table reports GHG and financial performance for the forward-looking exercise from the end of 2021 to the end of 2030. Each scenario of GHG intensity prediction is associated to three GHG emission reduction targets, $\theta = 5\%$, 7%, and 10%.

Optimal Weights (No Restriction) - BL

Optimal Weights at End 2020 (No Restriction)

	Bench -mark	Scenario 1: 5%	Scenario 1: 7%	Scenario 1: 10%	Scenario 2: 5%	Scenario 2: 7%	Scenario 2: 10%
Advanced economies							
Australia	1.20	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	1.69	0.00	0.00	0.00	0.17	0.00	0.00
Canada	1.16	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.42	1.10	0.00	0.00	2.91	0.00	0.00
France	6.38	11.15	11.44	10.12	9.87	10.89	8.65
Germany	4.96	0.00	0.00	0.00	0.00	0.00	0.00
Italy	6.45	9.98	13.38	16.72	7.21	10.44	14.80
Japan	19.63	23.59	22.67	11.91	23.78	23.04	21.35
Netherlands	1.68	0.00	0.00	0.00	0.00	0.00	0.00
Spain	3.60	1.75	0.00	0.00	3.68	2.18	0.02
Sweden	0.33	8.44	18.73	37.53	3.61	13.99	30.33
United Kingdom	7.37	11.88	17.92	23.73	8.32	13.19	19.72
United States	38.49	31.66	15.86	0.00	38.46	26.28	5.12
Total advanced economies	**93.36**	**99.55**	**100.00**	**100.00**	**98.02**	**100.00**	**100.00**
Total emerging economies	**6.64**	**0.45**	**0.00**	**0.00**	**1.98**	**0.00**	**0.00**
Active share (in %)	–	25.9	44.0	67.6	16.1	31.4	54.7

Note: The active share in year y is defined as: $AS_y^{(p)} = \frac{1}{2} \sum_{i=1}^{N_{y0}} |w_{i,y}^{(p)} - w_{i,y}^{(b)}|$.

Optimal Weights (Regional Restrictions) - BL

Optimal Weights at End 2020 (Regional Restrictions)

	Bench -mark	Scenario 1 5%	Scenario 1 7%	Scenario 1 10%	Scenario 2 5%	Scenario 2 7%	Scenario 2 10%
Emerging Economies							
Brazil	0.68	0.00	0.00	0.00	0.00	0.00	0.00
Chile	0.04	2.15	1.35	0.00	1.82	1.92	0.01
China	1.98	0.00	0.00	0.00	0.00	0.00	0.00
Colombia	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.15	3.60	5.29	6.64	2.02	4.18	6.55
India	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.26	0.00	0.00	0.00	0.00	0.00	0.00
Malaysia	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.70	0.00	0.00	0.00	2.18	0.54	0.00
Peru	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.01	0.00	0.00	0.00	0.00	0.00	0.09
Poland	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Romania	0.08	0.90	0.00	0.00	0.00	0.00	0.00
Russia	0.15	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.24	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.29	0.00	0.00	0.00	0.62	0.00	0.00
Total Emerging Economies	**6.64**	**6.64**	**6.64**	**6.64**	**6.64**	**6.64**	**6.64**
Total Advanced Economies	**93.36**	**93.36**	**93.36**	**93.36**	**93.36**	**93.36**	**93.36**
Active Share (%)	–	34.6	51.7	79.3	24.0	40.3	64.5

Note: The active share in year y is defined as: $AS_y^{(p)} = \frac{1}{2} \sum_{i=1}^{N_{y0}} |w_{i,y}^{(p)} - w_{i,y}^{(b)}|$.

Optimal Weights (Regional + Country Restrictions) - BL

Optimal Weights at End 2020 (Regional + Country Restrictions)

	Bench -mark	**Scenario 1** 5%	7%	10%	**Scenario 2** 5%	7%	10%
Advanced Economies							
Australia	1.20	0.24	0.24	0.24	0.24	0.24	0.24
Belgium	1.69	0.34	0.34	0.34	0.34	0.34	0.34
Canada	1.16	0.23	0.23	0.23	0.23	0.23	0.23
Denmark	0.42	2.09	2.09	2.09	2.09	2.09	2.09
France	6.38	22.45	31.88	31.88	18.20	31.88	31.88
Germany	4.96	0.99	0.99	0.99	0.99	0.99	0.99
Italy	6.45	10.38	6.40	6.40	7.10	11.35	6.40
Japan	19.63	23.54	3.93	3.93	23.12	12.15	3.93
Netherlands	1.68	0.34	0.34	0.34	0.34	0.34	0.34
Spain	3.60	0.72	0.72	0.72	3.51	0.72	0.72
Sweden	0.33	1.64	1.64	1.64	1.64	1.64	1.64
United Kingdom	7.37	22.44	36.86	36.86	15.45	23.69	36.86
United States	38.49	7.97	7.70	7.70	20.11	7.70	7.70
Total advanced economies	**93.36**	**93.36**	**93.36**	**93.36**	**93.36**	**93.36**	**93.36**
Total Emerging Economies	**6.64**	**6.64**	**6.64**	**6.64**	**6.64**	**6.64**	**6.64**
Active Share (%)	–	46.3	62.3	62.3	31.4	54.1	62.3

Note: The active share in year y is defined as: $AS_y^{(p)} = \frac{1}{2} \sum_{i=1}^{N_{y0}} |w_{i,y}^{(p)} - w_{i,y}^{(b)}|$.

Optimal Weights (No Restriction) - FL

Optimal Weights End at end 2030 (No Restriction)

	Bench -mark	**Scenario 1** 5%	7%	10%	**Scenario 2** 5%	7%	10%
Emerging economies							
Brazil	0.48	0.00	0.00	0.00	0.33	0.00	0.00
Chile	0.08	0.00	0.00	0.00	0.13	0.65	0.00
China	4.97	0.00	0.00	0.00	4.83	1.93	0.00
Hungary	0.14	0.00	0.00	0.00	0.10	0.74	0.00
India	1.70	0.00	0.00	0.00	1.23	0.00	0.00
Indonesia	0.61	0.00	0.00	0.00	0.38	0.00	0.00
Mexico	0.42	0.00	0.00	0.00	0.25	0.00	0.00
Peru	0.08	0.00	0.00	0.00	0.27	0.01	0.00
Philippines	0.01	0.00	0.00	0.00	0.00	0.00	1.35
Poland	0.28	0.00	0.00	0.00	0.45	0.00	0.00
Russia	0.29	0.00	0.00	0.00	0.15	0.04	0.00
Turkey	0.05	0.00	0.00	0.00	0.00	0.01	0.05
Uruguay	0.00	0.00	0.00	0.00	0.56	0.95	0.00
Total emerging economies	**10.63**	**0.00**	**0.00**	**0.00**	**8.68**	**4.33**	**1.39**
Total advanced economies	**89.37**	**100.0**	**100.0**	**100.0**	**91.30**	**95.67**	**98.61**
Active share (in %)	–	39.2	62.5	92.1	**5.0**	**17.9**	39.3

Note: The active share in year y is defined as: $AS_y^{(p)} = \frac{1}{2}\sum_{i=1}^{N_{y0}} |w_{i,y}^{(p)} - w_{i,y}^{(b)}|$.

Optimal Weights (Regional + Country Restrictions) - FL

Optimal Weights at End of 2030 (Regional + Country Restrictions)

	Bench -mark	**Scenario 1** 5%	7%	10%	**Scenario 2** 5%	7%	10%
Advanced economies							
Australia	1.55	0.31	0.31	0.31	1.41	0.31	0.31
Belgium	1.37	0.27	0.27	0.27	0.27	0.27	0.27
Canada	1.77	0.35	0.35	0.35	1.38	0.35	0.35
Denmark	0.29	1.45	1.45	1.45	1.45	1.45	1.45
France	5.91	29.56	29.56	29.56	6.08	29.56	29.56
Germany	4.03	0.81	0.81	0.81	0.81	0.81	0.81
Italy	5.31	11.25	11.25	11.25	5.20	1.06	1.06
Japan	16.60	3.32	3.32	3.32	16.63	11.21	3.32
Netherlands	1.16	0.23	0.23	0.23	3.83	0.23	0.23
Spain	3.43	0.69	0.69	0.69	3.54	8.74	10.87
Sweden	0.18	0.89	0.89	0.89	0.68	0.89	0.89
United Kingdom	6.39	31.96	31.96	31.96	6.39	17.40	31.96
United States	41.39	8.28	8.28	8.28	41.71	17.08	8.28
Total advanced economies	**89.37**	**89.37**	**89.37**	**89.37**	**89.37**	**89.37**	**89.37**
Total emerging economies	**10.63**	**10.63**	**10.63**	**10.63**	**10.63**	**10.63**	**10.63**
Active share (in %)	–	62.5	62.5	62.5	**7.0**	**47.9**	65.6

Note: The active share in year y is defined as: $AS_y^{(p)} = \frac{1}{2} \sum_{i=1}^{N_{y0}} |w_{i,y}^{(p)} - w_{i,y}^{(b)}|$.

Conclusion

- NDCs provide a credible, forward-looking basis for constructing net-zero sovereign bond portfolios.
- They enable significant GHG intensity reductions with minimal impact on financial performance.
- Imposing constraints reveals a trade-off between climate ambition, portfolio equity, and feasibility.
- Our findings underscore the need for more ambitious, transparent, and standardized NDCs in the future.

Thank You

Thank you for your attention!