An EDHEC-Risk Institute Publication

Measuring and Managing ESG Risks in Sovereign Bond Portfolios and Implications for Sovereign Debt Investing

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Foreword

This paper has been produced as part of the "ETF, Indexing and Smart Beta Investment Strategies" Research Chair at EDHEC-Risk Institute, in partnership with Amundi ETF, Indexing & Smart Beta.

Over the past decade, sustainable and responsible investing have gained momentum and continue to grow in popularity among investors, and it is increasingly recognized that the financial system has a particularly important role to play in the transition towards a low-carbon and climate-resilient economy. The integration of sustainability considerations into the decision-making process for investments, as measured by Environmental, Social and Governance (ESG) indicators, has been driven by investor demands, fiduciary duty, climate change and the development of new regulations and values. Sustainability in the financial sector is becoming mainstream and is reshaping global markets.

The integration of ESG constraints into investment decisions ex-ante involves an opportunity cost with respect to the outcome that would be optimally achieved in the absence of ESG considerations. This opportunity cost can be measured in terms of a possible increase in the risk and reduction in performance and/or in terms of an increase in tracking error with respect to the benchmark.

This study, "Measuring and Managing ESG Risks in Sovereign Bond Portfolios and Implications for Sovereign Debt Investing" demonstrates that implementation choices regarding how ESG constraints are incorporated in the context of sovereign bond portfolio construction have a material impact on this opportunity cost.

In particular, we find that higher environmental scores for developed countries and higher social scores for emerging countries are associated with lower costs of borrowing for issuers and consequently with lower yields for investors. We also confirm that negative screening leads to more diversified portfolios and lower levels of tracking error, while positive screening leads to higher levels of improvement of ESG scores, at the cost of an increase in absolute and relative risk budgets.

In an attempt to alleviate some of these concerns, we find that a dedicated focus on absolute or relative risk reduction at the selection stage allows investors to reduce the opportunity costs along the dimension that is most important to them. Finally, we provide evidence that ESG momentum strategies in sovereign bond markets can be used to further reduce some of the aforementioned opportunity costs.

Overall, our results suggest that sound risk management practices are critically important in allowing investors to incorporate ESG constraints in investment decisions at an acceptable cost in terms of dollar or risk budgets.

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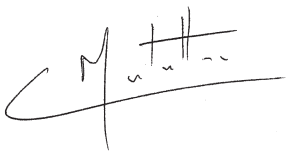
We wish you a useful and informative read.



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ABOUT THE AUTHORS

Lionel Martellini is Professor of Finance at EDHEC Business School and Director of EDHEC-Risk Institute. He has graduate degrees in economics, statistics, and mathematics, as well as a PhD in finance from the University of California at Berkeley. Lionel is a member of the editorial board of the *Journal of Portfolio Management* and the *Journal of Alternative Investments*. An expert in quantitative asset management and derivatives valuation, his work has been widely published in academic and practitioner journals and he has co-authored textbooks on alternative investment strategies and fixed-income securities.

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Sustainable Investing in Sovereign Bond Markets

Over the past decade, sustainable and responsible investing have gained momentum and continue to grow in popularity among investors, and it is increasingly recognized that the financial system has a particularly important role to play in the transition towards a low-carbon and climate-resilient economy. The integration of sustainability considerations into the decision-making process for investments, as measured by Environmental, Social and Governance (ESG) indicators, has been driven by investor demands, fiduciary duty, climate change and the development of new regulations and values. Sustainability in the financial sector is becoming mainstream and is reshaping global markets.

Nevertheless, the integration of ESG factors into sovereign bond investment analysis and investment decision-making is not systematic due to a lack of understanding among investors of how to integrate ESG issues into sovereign debt analysis and a lack of consistency in defining and measuring material ESG factors. The absence of a coherent investment framework for such integration is consistent with the relative scarcity of available academic research on the subject, which has focused more on ESG investing in equity markets.

In this paper, we explore the impact of ESG factors on the risk and return of sovereign bonds from an investor perspective, in particular investigating how to measure and manage ESG risks in sovereign bond portfolios and their implications for sovereign bond portfolio strategies.

Impact of ESG Criteria on Risk and Return Characteristics of Sovereign Bonds

We first provide an assessment of the materiality and impact of ESG scores[1] taken individually on key risk and return indicators of relevance to asset owners in both developed and emerging markets.[2] Our main goal is to analyze whether cross-sectional differences in the risk and return of sovereign bonds from various developed or emerging issuing countries can be explained partly by cross-sectional differences in E, S or G scores. We draw an important distinction between the perspective of long-term buy-and-hold investors, for whom performance can be captured by bond yield spreads, and the perspective of shorter-term investors, who will not hold the bond until maturity, and as such cannot use bond yield as a measure of expected performance because of the uncertainty regarding the selling price of the sovereign bonds held in their portfolios. In the latter case, we will instead use average annualized return as a measure of performance. In both cases, we conduct univariate and multivariate regression analyses[3] to explore to what extent ESG dimensions influence sovereign bond yield spreads in addition to information already contained in the economic fundamentals, as suggested by the literature on the determinants of sovereign bond yield spreads.

Regarding the impact of cross-sectional differences in each score (E, S and G) on sovereign bond yield spreads, our estimation results allow us to extract two key conclusions (see Exhibit 1.1). First, we find that for developed countries, after controlling for economic[4] scores and other fixed effects, the E dimension has a significant and negative impact on bond yield spread. These results mean that a

1 - We use the Verisk Maplecroft database for ESG indicators.
2 - Our sample comprises annual observations for 20 developed countries, of which the US will be used as the reference country when a risk-free rate is needed, as well as 15 emerging countries from 2010 to 2020, resulting respectively in 200 observations for developed countries and 150 observations for emerging countries.
3 - More information on the panel regression models and estimation methods used is provided below.
4 - We prefer to use the Verisk Maplecroft Economics Risk Indices rather than credit ratings, since credit rating agencies might already incorporate ESG criteria into their analyses.

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higher E score is associated with a lower spread for 1-year, 5-year and 10-year bond maturity, and this impact is more pronounced in the medium run. From an issuer standpoint, better E scores can therefore lead to reduced borrowing costs, everything else being equal. From the investor standpoint, this result suggests that a lower yield is to be expected when investing in countries with higher environmental performance, which tells us that a negative premium is associated with this reduction in environmental risk. On the other hand, for emerging countries, after controlling for economic scores and other fixed effects, we find that the S dimension has a significant and negative impact on bond yield spread, meaning that a higher S score is associated with a lower spread for 5-year and 10-year bond maturity, and this impact is more pronounced in the short run. Hence, from an investor standpoint, a lower yield is to be expected when investing in countries with higher social performance, suggesting that a negative premium is associated with this reduction in social risk.

We then turn to the impact of cross-sectional differences in E, S and G on the performance characteristics of short-term sovereign bond returns (see Exhibit 1.2). We find that for developed countries, after controlling for economic scores and other fixed effects, both the E and G dimensions have a significant and negative impact on bond returns, meaning that higher E and G scores are associated with lower bond return, and the impact of the G dimension on bond returns is more pronounced in the long run. On the other hand, for emerging countries, and also controlling for economic scores and other fixed effects, we find that the S dimension has a significant and negative impact on bond returns, meaning that a higher S score is associated with lower bond return, and the impact is more pronounced in the short run.

Exhibit 1.1: Estimation results for developed and emerging countries of the impact of E, S and G scores on sovereign bond yield spreads

	Developed Countries		
	Bond Yield Spreads *Spread_(i,t)*		
	1Y	5Y	10Y
Spread_(i,t-1)	0.713***	0.686***	0.661***
	(0.065)	(0.066)	(0.067)
Eco_(i,t-1)	-0.003	-0.002	-0.003
	(0.003)	(0.004)	(0.003)
Env_(i,t-1)	-0.013**	-0.025***	-0.023***
	(0.005)	(0.006)	(0.004)
Soc_(i,t-1)	0.003	0.005*	0.003*
	(0.003)	(0.004)	(0.003)
Gov_(i,t-1)	0.013**	0.013*	0.009*
	(0.005)	(0.006)	(0.005)
Observations	190	190	190
Countries	19	19	19
Fixed effects	Yes	Yes	Yes
R-sq	0.651	0.629	0.633

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

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Exhibit 1.1: Estimation results for developed and emerging countries of the impact of E, S and G scores on sovereign bond yield spreads

Emerging Countries			
	Bond Yield Spreads *Spread_(i,t)*		
	1Y	5Y	10Y
Spread_(i,t-1)	0.710***	0.852***	0.604***
	(0.073)	(0.079)	(0.090)
Eco_(i,t-1)	-0.003	-0.003	-0.005**
	(0.004)	(0.003)	(0.003)
Env_(i,t-1)	0.001	0.002	0.002
	(0.006)	(0.005)	(0.004)
Soc_(i,t-1)	-0.007***	-0.004**	-0.001
	(0.002)	(0.002)	(0.001)
Gov_(i,t-1)	0.004	0.004	0.002
	(0.003)	(0.002)	(0.002)
Observations	150	150	150
Countries	15	15	15
Fixed effects	Yes	Yes	Yes
R-sq	0.676	0.602	0.419

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

Exhibit 1.2: Estimation results for developed and emerging countries of the impact of E, S and G scores on sovereign bond returns

Developed Countries			
	Bond Returns *Ret_(i,t)*		
	1Y	5Y	10Y
Eco_(i,t-1)	-4.22E-06	-0.045	-0.030
	(0.021)	(0.033)	(0.048)
Env_(i,t-1)	-0.110***	-0.082	-0.051
	(0.037)	(0.058)	(0.083)
Soc_(i,t-1)	-0.017	-0.049	-0.078
	(0.0245)	(0.038)	(0.055)
Gov_(i,t-1)	-0.096**	-0.139**	-0.201**
	(0.038)	(0.060)	(0.086)
β_0	2.683***	3.378***	3.822***
	(0.370)	(0.577)	(0.827)
Observations	200	200	200
Countries	20	20	20
Fixed effects	Yes	Yes	Yes
R-sq	0.118	0.102	0.074

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

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Emerging Countries			
	Bond Returns *Ret_(i,t)*		
	1Y	5Y	10Y
Eco_(i,t-1)	-0.061	-0.052	-0.046
	(0.041)	(0.038)	(0.049)
Env_(i,t-1)	-0.012	-0.081	-0.125*
	(0.061)	(0.057)	(0.075)
Soc_(i,t-1)	-0.082***	-0.047**	-0.017
	(0.023)	(0.021)	(0.028)
Gov_(i,t-1)	0.011	-0.022	-0.044
	(0.035)	(0.033)	(0.044)
β_0	1.835***	2.222***	2.439***
	(0.434)	(0.403)	(0.530)
Observations	150	150	150
Countries	15	15	15
Fixed effects	Yes	Yes	Yes
R-sq	0.144	0.112	0.056

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

Implications for Sovereign Bond Portfolio Management

In the second step, we explore the portfolio implications of these findings, investigating the impact of integrating ESG criteria at the selection and portfolio construction stages. In particular, we analyze how to measure and minimize the opportunity costs associated with the introduction of ESG constraints with respect to an otherwise comparable unconstrained sovereign bond portfolio strategy. Our main goal is to investigate how implementation choices regarding how ESG criteria are incorporated into a portfolio can have a direct impact on this opportunity cost. Finally, we also explore the benefits of ESG momentum strategies, defined as strategies designed to exploit time-series differences in ESG scores, as opposed to exploiting cross-sectional differences in these scores.

The first approach to the introduction of ESG criteria into the investment process is to include them at the selection stage. To do so, we sort for each region (developed and emerging) sovereign bonds based on the four available dimensions, namely Economics , Environmental , Social and Governance, and for each dimension we form four quartiles. Quartile 1 corresponds to the 25% lowest-ranked bonds, whereas Q4 corresponds to the 25% best-rated bonds. Our negative screening strategy is to exclude the 25% lowest-ranked bonds (Q1). Our positive screening strategy is to select the 25% best-ranked bonds (Q4). For both strategies, we build separate portfolios of the selected 5-year maturity bonds for developed and emerging countries. These portfolios are equally weighted, and the portfolios are rebalanced on an annual basis, which is consistent with the fact that Verisk scores are updated on an annual basis

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(see Exhibit 1.4). The benchmark portfolio for both developed and emerging countries is an equally-weighted portfolio of all quartiles, which is also rebalanced on an annual basis (see Exhibit 1.3). Starting with the negative screening strategy, we find that increasing the sustainability (E, S and G criteria taken separately) of a portfolio using negative screening does not lead to substantially lower returns and increases volatility by only 0.5% on average for developed countries and 0.9% for emerging countries. However, the corresponding increase in E, S and G scores remains quite limited, up to 4.8% on average for developed countries and 8.4% on average for emerging countries. Regarding the positive screening strategy for developed countries, increasing the sustainability of a portfolio using positive screening comes at a cost for the E dimension, while it slightly enhances returns and increases volatility for the S and G dimensions. For emerging countries, increasing the sustainability of a portfolio using positive screening also comes at a clear cost since for all dimensions it implies a lower annualized return and higher volatility. The higher the increase in the score (the more sustainable a portfolio is, based on our different criteria taken individually), the higher the cost. For each dimension, we confirm that the scores are systematically higher compared to the benchmark portfolios, and also with respect to the less aggressive negative screening strategy, which makes sense since these portfolios only include the 25% best-ranked bonds.

We then investigate the impact of integrating E, S and G criteria into the global minimum variance[4] (GMV) portfolio. We are interested in measuring the increase in variance of the ESG-constrained portfolio with respect to the corresponding unconstrained portfolio.[5] To this end, we first build the minimum variance portfolios with no E, S or G constraints (see Exhibit 1.5).[6] We then calculate the E, S and G scores of each of the portfolios at the initial date (2010) as the weighted average of all country scores. The next step is to integrate E, S and G constraints into the optimization process. The level of these constraints is set in terms of a given improvement with respect to the E, S and G scores of the previously built minimum variance portfolios with no E, S or G constraints. We report results for the maximum increase obtained for each dimension. As before, we build separate portfolios of 5-year maturity sovereign bonds for developed and emerging countries (see columns 2 and 3 in Exhibit 1.6).

For both developed and emerging counties, we find that there is a clear tradeoff between increasing E, S and G scores and generating low portfolio variance. For developed countries, we managed to increase the E score by 10%, the S score by 15% and the G score by 5%. The annualized performance for the E dimension is less than for the portfolio with no E constraints as well as the benchmark, while in both cases it is higher for the S and G dimensions. For the E, S and G dimensions respectively, the volatility is 52.55%, 87.83% and 69.38% higher and the Sharpe ratio is 42.53%, 23.08% and 18.74% lower, compared to the portfolio with no E, S or G constraints. For emerging countries, we managed to increase the E score by 15%, the S score by 50% and the G score by 15%. The annualized returns of these portfolios are lower than for the portfolio with no E, S or G constraints and the benchmark, while the annualized volatility is higher. For the E, S and G dimensions respectively, the volatility is 85.34%,

4 - In addition to minimum variance (GMV portfolio), we also investigate the impact of integrating E, S and G criteria into the maximum Sharpe ratio (MSR) portfolio.
5 - We perform an in-sample analysis since our main motivation is not to provide a horse race out-of-sample analysis of competing optimization strategies, which would not lead to robust conclusions given the relatively short sample history, but instead to measure the opportunity cost of introducing ESG constraints.
6 - For each portfolio, in addition to the constraint that the sum of the weights allocated to the assets must be equal to 1, we add a minimum weight constraint so that the minimum weight of each asset must be greater than or equal to $\frac{1}{2N}$, where N is the total number of assets in a portfolio (20 for developed countries and 15 for emerging countries). This is meant to avoid corner solutions that are typical of straightforward optimization procedures.

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68.47% and 49.55% higher and the Sharpe ratio is 52.80%, 57.90% and 49.70% lower, compared to the portfolio with no E, S or G constraints.

In our second analysis, in order not to hamper the optimization process (with excessively high E, S and G constraints) and be able to compare selection strategy to optimization strategy, we set the E, S and G constraints equal to the E, S and G scores previously obtained with the negative screening strategy (see columns 4 and 5 in Exhibit 1.6). Our results show that the optimization approach leads to better performance, except for the E dimension in the case of emerging countries. Indeed, for developed countries as well as emerging countries, we managed to increase the minimum variance portfolio scores for each dimension up to their target level.

Exhibit 1.3: Benchmark results over the sample period 2010–2020 for developed and emerging countries

Benchmark								
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.46				12.60			
Annualized Volatility (%)	8.76				6.68			
Sharpe Ratio	0.85				1.89			
Max Drawdown (%)	71.66				42.20			
Benchmark Score (mean)	Eco	E	S	G	Eco	E	S	G
	6.15	7.00	7.68	7.83	6.04	5.47	4.55	5.84

Exhibit 1.4: Results of the negative and positive screening strategies over the sample period 2010–2020 for developed and emerging countries

	Negative Screening								Positive Screening							
	Economics															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	7.20				11.54				5.77				11.37			
Annualized Volatility (%)	9.32				7.15				9.22				8.15			
Sharpe Ratio	0.77				1.61				0.63				1.40			
Tracking Error (%)	1.40				1.36				2.69				1.36			
Max Drawdown (%)	70.88				46.62				56.97				41.90			
	Eco	E	S	G	**Eco**	E	S	G	**Eco**	E	S	G	**Eco**	E	S	G
Score (mean)	**6.45**	7.15	7.88	8.04	**6.37**	5.47	4.58	5.90	**7.19**	7.47	7.78	8.16	**6.89**	4.96	4.39	5.78
Diff Score / Benchmark Score (%)	**4.92**	2.18	2.64	2.71	**5.51**	0.17	0.56	1.03	**16.93**	6.68	1.28	4.19	**13.97**	-9.18	-3.52	-0.97
	Environment															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	7.78				12.80				6.55				9.49			
Annualized Volatility (%)	9.14				7.69				6.71				11.05			
Sharpe Ratio	0.85				1.66				0.98				0.86			
Tracking Error (%)	1.11				1.96				6.58				1.96			
Max Drawdown (%)	63.50				50.32				50.78				61.96			
	Eco	**E**	S	G	Eco	**E**	S	G	Eco	**E**	S	G	Eco	**E**	S	G
Score (mean)	6.27	**7.30**	7.92	7.94	5.91	**5.92**	5.01	6.02	6.98	**8.00**	8.26	8.49	6.49	**6.46**	6.27	6.55
Diff Score / Benchmark Score (%)	1.90	**4.31**	3.19	1.44	-2.13	**8.39**	10.11	3.08	13.41	**14.28**	7.58	8.51	7.38	**18.21**	37.76	12.12

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	Social															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	7.48				11.92				8.19				8.73			
Annualized Volatility (%)	9.60				7.63				10.00				10.85			
Sharpe Ratio	0.78				1.56				0.82				0.80			
Tracking Error (%)	1.15				1.89				2.67				1.89			
Max Drawdown (%)	74.20				46.57				65.95				64.94			
	Eco	E	**S**	G	**Eco**	E	**S**	G	**Eco**	E	**S**	G	**Eco**	E	**S**	G
Score (mean)	**6.33**	7.24	**8.08**	8.16	**6.03**	5.71	**5.15**	6.19	**6.55**	7.57	**8.52**	8.64	**5.96**	6.27	**6.83**	6.60
Diff Score / Benchmark Score (%)	**2.98**	3.39	**5.24**	4.22	**-0.13**	4.47	**13.15**	5.94	**6.41**	8.11	**10.89**	10.35	**-1.33**	14.72	**50.03**	13.03
	Governance															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	7.23				12.05				8.58				10.31			
Annualized Volatility (%)	9.05				7.96				10.39				9.02			
Sharpe Ratio	0.80				1.51				0.83				1.14			
Tracking Error (%)	1.47				1.98				3.39				1.98			
Max Drawdown (%)	62.59				47.15				59.62				38.70			
	Eco	E	S	**G**	**Eco**	E	S	**G**	**Eco**	E	S	**G**	**Eco**	E	S	**G**
Score (mean)	**6.32**	7.22	8.00	**8.22**	**5.99**	5.78	5.09	**6.24**	**6.60**	7.67	8.46	**8.70**	**6.43**	5.72	5.05	**7.00**
Diff Score / Benchmark Score (%)	**2.74**	3.14	4.14	**4.96**	**-0.78**	5.78	11.65	**6.76**	**7.21**	9.60	10.11	**11.12**	**6.42**	4.65	10.93	**19.86**

Exhibit 1.5: Results of the minimum variance strategy over the sample period 2010–2020 for developed and emerging countries[7]

	Minimum Variance							
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.74				13.01			
Annualized Volatility (%)	5.05				4.47			
Sharpe Ratio	1.14				2.91			
Max Drawdown (%)	63.54				39.00			
Mininmum Variance Score (mean)	Eco	E	S	G	Eco	E	S	G
	5.60	6.52	6.92	7.93	6.07	4.96	3.85	5.45

7 - In this analysis we compare the E, S and G scores of each portfolio based on the E, S and G scores of each country at the initial date (2010).

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Exhibit 1.6: Results of the minimum variance strategies with Maximum E, S and G constraints and "Negative Screening" E, S and G constraints over the sample period 2010–2020 for developed and emerging countries

	Minimum Variance + "Max" E/S/G Constraints								Minimum Variance + "Negative Screening" E/S/G Constraints							
	Economics															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	4.83				9.64				5.17				11.04			
Annualized Volatility (%)	8.76				6.10				7.08				4.85			
Sharpe Ratio	0.55				1.58				0.73				2.28			
Tracking Error (%)	3.28				5.00				2.71				3.42			
Max Drawdown (%)	47.30				65.12				47.04				48.79			
Diff Ret / Min Var (%)	-15.77				-25.89				-9.92				-15.09			
Diff Vol / Min Var (%)	73.37				36.50				40.19				8.49			
Diff SR / Min Var (%)	-51.42				-45.71				-35.74				-21.74			
Diff MDD / Min Var (%)	-25.55				66.97				-25.96				25.09			
Diff Ret / Negative Screening (%)	-				-				-28.27				-4.31			
Diff Vol / Negative Screening (%)	-				-				-24.02				-32.17			
Diff SR / Negative Screening (%)	-				-				-5.59				41.07			
Diff MDD / Negative Screening (%)	-				-				-33.63				4.64			
	Eco	E	S	G	**Eco**	E	S	G	**Eco**	E	S	G	**Eco**	E	S	G
Score (mean)	**7.00**	7.35	7.45	7.93	**6.68**	4.56	3.44	5.17	**6.45**	7.04	7.26	7.94	**6.37**	4.86	3.71	5.37
Diff Score / Min Variance Score (%)	25.00	12.78	7.57	0.02	10.00	-8.06	-10.76	-5.01	4.94	2.59	1.55	0.05	5.51	-2.44	-4.52	-1.69
Diff Score / Benchmark Score (%)	13.72	5.00	-3.02	1.32	10.59	-16.63	-24.47	-11.44	-4.54	-4.50	-8.46	1.36	6.07	-11.53	-19.18	-8.34
Diff Score / Negative Screening Score (%)	-	-	-	-	-	-	-	-	0.00	-1.55	-7.94	-1.21	0.00	-11.18	-19.08	-8.98
	Environment															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	5.03				11.38				4.88				13.80			
Annualized Volatility (%)	7.71				8.28				8.39				5.56			
Sharpe Ratio	0.65				1.37				0.58				2.48			
Tracking Error (%)	2.78				5.53				3.08				4.04			
Max Drawdown (%)	46.35				47.71				46.91				63.42			
Diff Ret / Min Var (%)	-12.33				-12.51				-14.84				6.07			
Diff Vol / Min Var (%)	52.55				85.34				66.01				24.50			
Diff SR / Min Var (%)	-42.53				-52.80				-48.70				-14.81			
Diff MDD / Min Var (%)	-27.05				22.33				-26.17				62.62			
Diff Ret / Negative Screening (%)	-				-				-37.23				7.81			
Diff Vol / Negative Screening (%)	-				-				-8.25				-27.68			
Diff SR / Negative Screening (%)	-				-				-31.58				49.07			
Diff MDD / Negative Screening (%)	-				-				-26.12				26.04			
	Eco	**E**	S	G	Eco	**E**	S	G	Eco	**E**	S	G	Eco	**E**	S	G
Score (mean)	6.66	**7.17**	7.34	7.95	6.23	**5.70**	5.23	6.11	6.88	**7.30**	7.42	7.95	6.27	**5.76**	5.52	6.00
Diff Score / Min Variance Score (%)	19.06	10.00	5.99	0.21	2.64	15.00	35.63	12.21	8.23	4.32	2.58	0.09	-0.71	8.39	12.58	5.94
Diff Score / Benchmark Score (%)	8.32	2.41	-4.45	1.51	3.19	4.29	14.79	4.62	-1.55	-2.89	-7.52	1.39	-0.18	-1.71	-4.72	-1.23
Diff Score / Negative Screening Score (%)	-	-	-	-	-	-	-	-	9.76	0.00	-6.34	0.11	6.01	-2.69	9.98	-0.41

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	Social															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	8.29				9.22				9.16				10.45			
Annualized Volatility (%)	9.49				7.53				10.15				6.18			
Sharpe Ratio	0.87				1.22				0.90				1.69			
Tracking Error (%)	2.07				2.81				3.50				2.09			
Max Drawdown (%)	61.94				45.07				59.16				40.02			
Diff Ret / Min Var (%)	44.47				-29.13				59.73				-19.64			
Diff Vol / Min Var (%)	87.83				68.47				101.02				38.35			
Diff SR / Min Var (%)	-23.08				-57.94				-20.54				-41.92			
Diff MDD / Min Var (%)	-2.52				15.56				-6.89				2.61			
Diff Ret / Negative Screening (%)	-				-				22.46				-12.31			
Diff Vol / Negative Screening (%)	-				-				5.82				-18.94			
Diff SR / Negative Screening (%)	-				-				15.73				8.18			
Diff MDD / Negative Screening (%)	-				-				-20.27				-14.06			
	Eco	E	**S**	G	Eco	E	**S**	G	Eco	E	**S**	G	Eco	E	**S**	G
Score (mean)	6.19	7.14	**7.96**	8.37	5.67	5.42	**5.78**	6.29	6.21	7.29	**8.08**	8.43	5.79	5.33	**5.15**	6.04
Diff Score / Min Variance Score (%)	10.59	9.52	15.00	5.60	-6.69	9.43	50.00	15.52	3.54	3.59	5.24	1.96	-2.26	4.61	13.15	4.73
Diff Score / Benchmark Score (%)	0.62	1.96	3.67	6.98	-6.19	-0.76	26.96	7.71	-5.81	-3.57	-5.13	3.29	-1.74	-5.13	-4.23	-2.35
Diff Score / Negative Screening Score (%)	-	-	-	-	-	-	-	-	-1.98	0.67	0.00	3.31	-4.10	-6.58	0.00	-2.46
	Governance															
	Developed Countries				Emerging Countries				Developed Countries				Emerging Countries			
Annualized Return (%)	7.80				9.78				7.25				10.02			
Annualized Volatility (%)	8.56				6.68				7.50				6.47			
Sharpe Ratio	0.91				1.46				0.97				1.55			
Tracking Error (%)	2.20				2.41				2.43				2.73			
Max Drawdown (%)	51.45				51.87				51.16				54.80			
Diff Ret / Min Var (%)	35.94				-24.78				26.38				-22.96			
Diff Vol / Min Var (%)	69.38				49.55				48.49				44.81			
Diff SR / Min Var (%)	-19.74				-49.71				-14.89				-46.80			
Diff MDD / Min Var (%)	-19.03				33.00				-19.47				40.52			
Diff Ret / Negative Screening (%)	-				-				0.33				-16.87			
Diff Vol / Negative Screening (%)	-				-				-17.09				-18.73			
Diff SR / Negative Screening (%)	-				-				21.00				2.28			
Diff MDD / Negative Screening (%)	-				-				-18.25				16.24			
	Eco	E	S	**G**	Eco	E	S	**G**	Eco	E	S	**G**	Eco	E	S	**G**
Score (mean)	5.98	7.01	7.68	**8.33**	6.02	5.32	4.83	**6.26**	5.85	6.87	7.47	**8.22**	6.16	5.28	4.46	**6.24**
Diff Score / Min Variance Score (%)	6.79	7.58	10.98	5.00	-0.81	7.44	25.25	15.00	6.74	7.53	10.89	4.96	-0.80	5.41	6.97	6.76
Diff Score / Benchmark Score (%)	-2.84	0.16	0.05	6.37	-0.28	-2.57	6.01	7.22	-2.90	0.10	-0.03	6.33	-0.27	-4.41	-9.47	-0.46
Diff Score / Negative Screening Score (%)	-	-	-	-	-	-	-	-	-7.42	-4.81	-6.59	0.00	2.73	-8.60	-12.37	0.00

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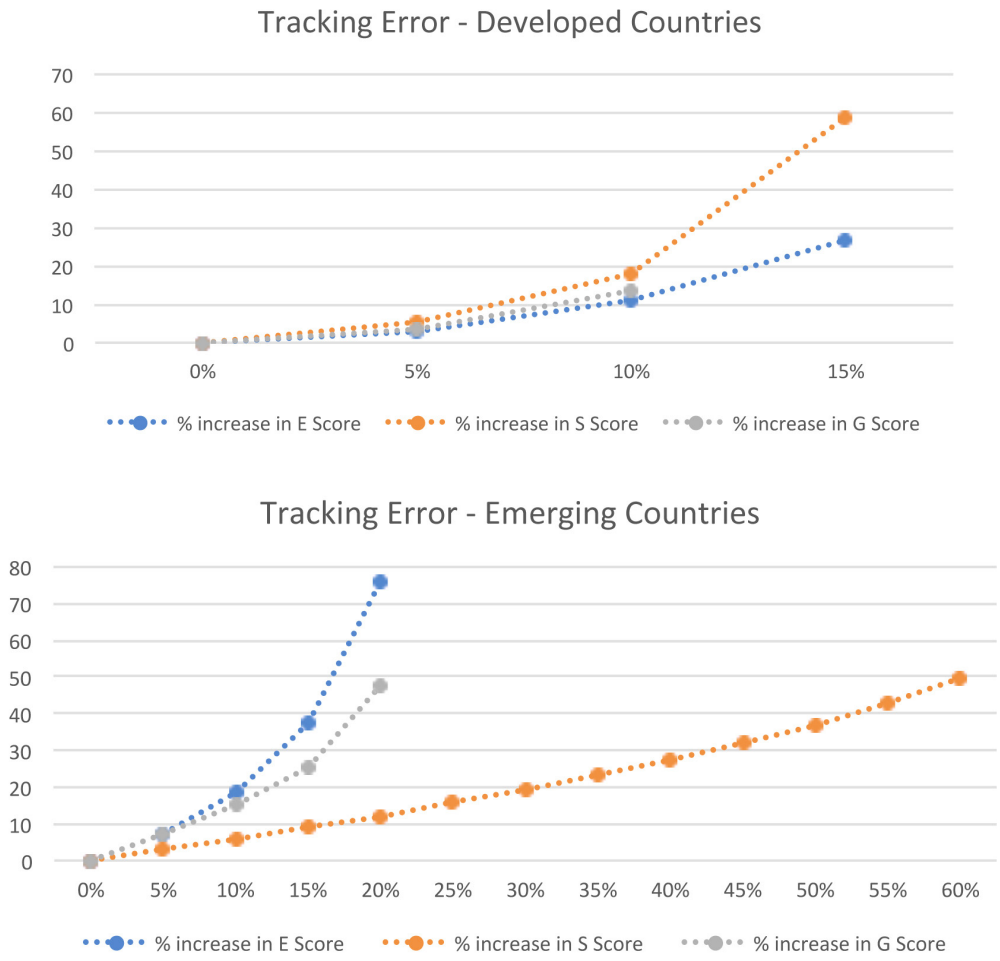
We also investigate the impact of integrating E, S and G criteria into the optimization approach, which is to minimize the tracking error of a portfolio (see Exhibit 1.7), without any constraint except for a no leverage constraint. Here the tracking error is again computed with respect to a benchmark portfolio, which is defined for both developed and emerging countries as an equally-weighted portfolio of all sovereign bonds, rebalanced on an annual basis. 20 countries composed the developed countries universe and 15 that of the emerging countries. For each portfolio, the only constraint is that the sum of the weights allocated to the assets must be equal to 1. We confirm that a dedicated focus on relative risk minimization leads to a lower increase in tracking error with respect to other selection or optimization strategies for the same target level of improvement in ESG scores.

Exhibit 1.7: Tracking Error (bps) of E, S and G constraint portfolios over the sample period 2010–2020 for developed and emerging countries



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Finally, we explore the benefits of ESG momentum strategies (see Exhibit 1.8). We find that for developed countries, regardless of bond maturity, the top 15% of bonds exhibiting positive changes in E and G scores outperformed the bottom 15% on average from 2010 to 2020. Moreover, the long-short ESG momentum strategy based on the E dimension offers attractive levels of performance, substantially higher than the strategy based on changes in G scores, while for emerging countries, regardless of bond maturity, the top 15% of bonds exhibiting positive changes in S scores outperformed the bottom 15%. Regarding G,

Exhibit 1.8: Long-short ESG momentum strategy, based on Economic, Environmental, Social and Governance dimensions for developed and emerging countries

Developed Countries				
Long-Short Strategy 2010-2020				
	Eco	E	S	G
1-Year Maturity Bonds				
Average Return (%)	-7.99	6.87	-2.08	5.35
Maximum Return (%)	13.07	29.11	13.65	22.09
Minimum Return (%)	-41.21	-17.63	-13.28	-9.96
5-Year Maturity Bonds				
Average Return (%)	1.13	14.54	-2.48	6.75
Maximum Return (%)	53.06	34.29	30.93	23.70
Minimum Return (%)	-38.47	-16.63	-27.35	-18.80
10-Year Maturity Bonds				
Average Return (%)	14.55	20.24	-4.53	8.13
Maximum Return (%)	102.92	39.02	32.26	48.77
Minimum Return (%)	-39.33	-13.86	-49.68	-28.91

Emerging Countries				
Long-Short Strategy 2010-2020				
	Eco	E	S	G
1-Year Maturity Bonds				
Average Return (%)	-7.78	-4.57	4.45	12.01
Maximum Return (%)	63.08	31.61	50.82	52.43
Minimum Return (%)	-65.62	-44.67	-44.72	-14.34
5-Year Maturity Bonds				
Average Return (%)	9.66	-4.55	21.14	4.87
Maximum Return (%)	73.70	32.29	64.12	24.96
Minimum Return (%)	-62.10	-40.60	-17.03	-29.61
10-Year Maturity Bonds				
Average Return (%)	22.52	-4.46	37.30	-2.28
Maximum Return (%)	66.44	22.18	92.09	50.26
Minimum Return (%)	-57.43	-34.28	-23.52	-69.82

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the top 15% of bonds exhibiting the highest differences in scores outperformed the bottom 15% for 1-year and 5-year bond maturity only. These results suggest that additional value can be added by implementing portfolio decisions informed not only by cross-sectional differences in ESG scores, but also by variations in these scores over time, suggesting the presence of some form of under-reaction to news related to changes in ESG scores.

Measuring and Managing the Opportunity Costs of ESG Investing in Sovereign Bond Markets

The integration of ESG constraints into investment decisions can be assumed to involve an opportunity cost with respect to the outcome that would be optimally achieved in the absence of ESG considerations. This opportunity cost can be measured in terms of a possible increase in risk and reduction in performance (particularly meaningful for the benchmark-free investor) and/or in terms of an increase in tracking error with respect to the benchmark (particularly meaningful for the benchmark-driven investor).

The main contribution of our analysis is to demonstrate that several competing implementation choices exist with respect to how ESG constraints are incorporated in the context of sovereign bond portfolio construction, and different choices have different impacts on these opportunity costs. In particular, we find that higher Environmental scores for developed countries and higher Social scores for emerging countries are associated with lower costs of borrowing for issuers and consequently with lower yields for investors. We also confirm that negative screening leads to more diversified portfolios and lower levels of tracking error, while positive screening leads to higher levels of improvement in ESG scores, at the cost of an increase in absolute and relative risk budgets. In an attempt to alleviate some of these concerns, we find that a dedicated focus on absolute or relative risk reduction at the selection stage allows investors to reduce the opportunity costs along the dimension that is most important to them. Finally, we provide evidence that ESG momentum strategies in sovereign bond markets can be used to further reduce some of the aforementioned opportunity costs.

Overall, our results suggest that sound risk management practices are critically important in allowing investors to incorporate ESG constraints into their investment decisions at an acceptable cost in terms of dollar or risk budgets.

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2. Introduction

2. Introduction

The main focus of this paper is to develop a formal framework for incorporating Environmental, Social and Governance (ESG) criteria into risk management and investment decisions involving sovereign bonds. In just under ten years, the global bond markets increased from USD 87 trillion in 2009 to over USD 115 trillion in mid-2019 according to the International Institute of Finance (IIF). This growth was mostly seen in the sovereign bond market, which is one of the most important asset classes held by investors around the world, representing 47% of global bond markets, compared to 40% in 2009. Traditionally considered as a risk-free asset class, this perception has been challenged since 2008, and there is a critical need for a better understanding of the full range of risks, including non-financial risks, involved in sovereign bonds.

Over the past decade, sustainable and responsible investing have gained momentum and continue to grow in popularity among investors, and it is increasingly recognized that the financial system has a particularly important role to play in the transition towards a low-carbon and climate-resilient economy. The integration of sustainability considerations into the decision-making process for investments, as measured by ESG indicators, has been driven by investor demands, fiduciary duty, climate change and the development of new regulations and values. Sustainability in the financial sector is becoming mainstream and is reshaping global markets.

Following the launch of the United Nations-supported Principles for Responsible Investment (UN-PRI) in April 2006, the number of signatories to the six Principles reached 2,232 in 2018, corresponding to a 21% increase in the number of signatories in one year and representing over USD 85 trillion of assets under management. According to the 2018 Global Sustainable Investment Review (GSIR) released in April 2019, there were USD 30.7 trillion of sustainable investing assets in the following five major markets: Europe, the US, Japan, Canada, and Australia & New Zealand, which represents an increase of 34% in two years. At the beginning of 2018, the largest sustainable investment strategies globally were negative/exclusionary screening at USD 19.8 trillion, ESG integration at USD 17.5 trillion and corporate engagement/shareholder action at USD 9.8 trillion. The report also finds that negative screening is the largest strategy in Europe, while ESG integration is most common in the US, Canada, Australia and New Zealand in asset-weighted terms. In Japan, engagement and shareholder action remains the dominant strategy.

Nevertheless, the integration of ESG factors into sovereign bond investment analysis and investment decision-making is not systematic due to a lack of understanding among investors of how to integrate ESG issues into sovereign debt analysis and a lack of consistency in defining and measuring material ESG factors. The absence of a coherent investment framework for such integration is consistent with the relative scarcity of available academic research on the subject, which has focused more on ESG investing in equity markets.

In this paper, we explore the impact of ESG factors on the risk and return of sovereign bonds from an investor perspective, in particular investigating how to measure and manage ESG risks in

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sovereign bond portfolios and their implications for sovereign bond portfolio strategies.

We first analyze the materiality and impact of ESG scores taken individually on key risk and return indicators of relevance to asset owners in both developed and emerging markets. In the second step, we explore the portfolio implications of these findings. In particular, we analyze how to minimize the efficiency loss involved in the introduction of ESG constraints in a robust sovereign bond portfolio construction process. The paper also analyzes the benefits and limits of ESG momentum strategies in sovereign bond markets. The main objective of this second part of the paper is to assess whether a significant improvement of the portfolio ESG score or ESG momentum score can be achieved without a substantial increase in absolute and relative risk budgets, or a substantial decrease in expected performance.

> ...we find that the Social dimension has a significant and negative impact on bond yield spread...

Our main results can be summarized as follows. First, regarding the impact of cross-sectional differences in each of the Environmental, Social, and Governance dimensions on sovereign bond yield spreads, we find that for developed countries, after controlling for economic scores and other fixed effects, the Environmental dimension has a significant and negative impact on bond yield spread. These results mean that a higher Environmental score is associated with a lower spread, for 1-year, 5-year and 10-year bond maturity, and this impact is more pronounced in the medium run. From an issuer standpoint, better Environmental scores can therefore lead to reduced borrowing costs, everything else being equal. From the investor standpoint, this result suggests that a lower yield is to be expected when investing in countries with higher environmental performance, suggesting that a negative premium is associated with this reduction in environmental risk. On the other hand, for emerging countries, after controlling for economic scores and other fixed effects, we find that the Social dimension has a significant and negative impact on bond yield spread, meaning that a higher Social score is associated with a lower spread for 5-year and 10-year bond maturity, and this impact is more pronounced in the short run. Hence, from an investor standpoint, a lower yield is to be expected when investing in countries with higher social performance, suggesting that a negative premium is associated with this reduction in social risk. Then, regarding the impact of cross-sectional differences in each of the Environmental, Social and Governance dimensions on the performance characteristics of short-term sovereign bonds returns, we find that for developed countries, after controlling for economic scores and other fixed effects, the Environmental and Governance dimensions both have a significant and negative impact on bond returns, meaning that higher Environmental and Governance scores are associated with lower bond returns, and the impact of the Governance dimension on bond returns is more pronounced in the long run. On the other hand, for emerging countries, after controlling for economic scores and other fixed

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effects, we found that the Social dimension has a significant and negative impact on bond returns, meaning that a higher Social score is associated with lower bond returns, and the impact is more pronounced in the short run.

When it comes to the portfolio implications of these findings, we investigate the impact of integrating E, S and G criteria at the selection and portfolio construction stages. Starting with the negative screening strategy, we find that increasing the sustainability (Environmental, Social and Governance criteria taken separately) of a portfolio using negative screening does not lead to substantially lower returns and increases volatility by only 0.5% on average for developed countries and 0.9% for emerging countries. However, the corresponding increase in Environmental, Social and Governance scores remains quite limited, up to 4.8% on average for developed countries and 8.4% on average for emerging countries. Regarding the positive screening strategy for developed countries, increasing the sustainability of a portfolio using positive screening comes with a cost for the Environmental dimension, while it slightly enhances returns and increases volatility for the Social and Governance dimensions. For emerging countries, increasing the sustainability of a portfolio using positive screening also comes at a clear cost since for all dimensions it leads to a lower annualized return and higher volatility. The higher the increase in the score (the more sustainable a portfolio is, based on our different criteria taken individually), the higher the cost.
We then investigate the impact of integrating E, S and G criteria as part of two different optimization approaches, namely the maximum Sharpe ratio (MSR) portfolio and the global minimum variance (GMV) portfolio. Starting with the MSR strategy with maximum ESG constraints, for developed countries we find that there is a tradeoff between increasing E, S and G scores maximizing the Sharpe ratio, and the cost to pay (in terms of reduction of Sharpe ratio) is generally higher than the associated benefits in terms of improvement of ESG scores. For emerging countries, increasing E, S and G scores of a maximum Sharpe ratio portfolio comes with an opportunity cost also in terms of performance. Regarding the minimum variance strategy with maximum ESG constraints, for both developed and emerging countries we find, also as expected, a clear tradeoff between increasing E, S and G scores and generating a low variance for the portfolio.

Interestingly, for the negative and positive screening strategies as well as the maximum Sharpe ratio with maximum ESG constraints and minimum variance strategy with maximum ESG constraints, our results show that for developed countries there is no conflict between the various dimensions of ESG, insofar as an investor with a core focus on improving the portfolio along the E, S or G dimension can be assumed to enjoy a benefit in the other two dimensions, even if they are not explicitly targeted. In the case of emerging countries, this conclusion is not systematic.

We also introduce ESG constraints for the maximum Sharpe ratio and minimum variance portfolios so as to obtain E, S and G score improvements equal to those obtained with a negative screening strategy. This allows us to compare the selection and the optimization approach when it comes to integrating ESG criteria into sovereign bond portfolios. Our results

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show that the optimization approach leads to better performance, except for the Environmental dimension in the case of emerging countries.

Turning to the benchmark-driven investor, and investigating the impact of integrating E, S and G criteria as part of the optimization approach of minimizing the tracking error of a portfolio, we characterize the tradeoff between increasing ESG scores and increasing tracking error and confirm that a dedicated focus on relative risk minimization leads to a lower increase in tracking error with respect to other selection or optimization strategies for the same target level of improvement in ESG scores.

Finally, we also explore the benefits of ESG momentum strategies and find, for developed countries and regardless of bond maturity, that the top 15% of bonds exhibiting positive changes in Environmental and Governance scores outperformed the bottom 15% on average in 2010–2020. Moreover, the long-short ESG momentum strategy based on the Environmental dimension offers attractive levels of performance, substantially higher than the strategy based on changes in Governance scores, while for emerging countries, regardless of bond maturity, the top 15% of bonds exhibiting positive changes in Social scores outperformed the bottom 15%. Regarding Governance, the top 15% of bonds exhibiting the highest score differences outperformed the bottom 15% for 1-year and 5-year bond maturity only. These results suggest that additional value can be added by implementing portfolio decisions informed not only by cross-sectional differences in ESG scores, but also by variations of these scores over time, suggesting the presence of some form of under-reaction to news related to changes in ESG scores.

The rest of the paper is structured as follows. Section 3 provides a detailed overview of the related academic and practitioner literature and argues that most of it has focused on the issuer's perspective as opposed to that of the investor. In Section 4, we present the database used, including both ESG and bond market data. In Section 5, we present an analysis of the impact of differences over issuers and over time of ESG scores on risk and return indicators for sovereign bonds. Section 6 explores the portfolio implications. Finally, Section 7 discusses the main findings and presents some conclusions and suggestions for further research. Additional results are provided in a dedicated Appendix.

2. Introduction

3. Literature Review

3. Literature Review

In what follows, we present a detailed review of the academic and practitioner literature on the relationship between ESG indicators and risk and performance analysis for fixed-income markets, after providing a brief overview of the related literature in equity markets.

3.1. Academic Research on ESG Investing in Equity Markets

Considerable academic research has been conducted on the relationship between ESG investing and risk and performance on equity markets (Markowitz (1952); Kempf & Osthoff (2007); Galema, Plantinga, & Scholtens (2008); Statman & Glushkov (2009); Manescu (2011); El Ghoul, Guedhami, & Pittman (2011); Humphrey, Lee, & Shen (2012); Borgers, Derwall, Koedijk, & Ter Horst (2013); Kim, Li, & Li (2014); Lean & Nguyen (2014); Flammer (2015); Friede, Busch, & Bassen (2015); Clark, Feiner, & Viehs (2015); Khan, Serafeim, & Yoon (2016); Lins, Servaes, & Tamayo (2017); Lioui (2018a), (2018b); Sherwood & Pollard (2017); Cao, Titman, Zhan, & Zhang (2019); Eccles, Lee, & Stroehle (2019); Jacobsen, Lee, & Ma (2019); Breedt, Ciliberti, Gualdi, & Seager (2019); Gibson, Glossner, Krueger, Matos, & Steffen (2019); Pedersen, Fitzgibbons, & Pomorski (2019)) and the mutual fund industry (Kreander, Gray, M., & Sinclair (2005); Statman (2000); Bauer, Otten, & Rad (2006); Bauer, Koedijk, & Otten (2005); Gregory & Whittaker (2007); Renneboog, Ter Horst, & Zhang (2008); Scholtens (2010); Nosfinger & Varma (2014); Bialkowski & Starks (2016); Borgers, Derwall, & Ter Horst (2015); Statman & Glushkov (2016); El Ghoul & Karoui (2017)), while a smaller but growing strand of the literature addresses the role of ESG on debt markets.

Friede, Busch, & Bassen (2015) and Clark, Feiner, & Viehs (2015), who conducted two different sustainability meta-studies, find that a large majority of the studies analyzed show a positive relationship between ESG factors and corporate performance. The literature also suggests that better ESG scores are associated with lower risk. For example, Dunn, Fitzgibbons, & Pomorski (2017) find that stocks with the worst ESG exposures have total and stock-specific volatility that is up to 10–15% higher, and betas up to 3% higher, than stocks with the best ESG exposures. On the other hand, the literature offers a rather mixed message regarding the impact of ESG filters on expected returns. For one thing, asset pricing theory suggests that if ESG scores form an observable proxy for exposure to some underlying rewarded risk factor, then one might expect a risk premium from holding stocks with poor, as opposed to good, ESG profiles.

3.2. Academic research on ESG Investing in Bond Markets

Compared to the wealth of results available in equity markets, academic research on the relationship between ESG factors and fixed-income markets still remains at its infancy. We provide a detailed analysis of this literature in what follows.

3. Literature Review

3.2.1. Fixed-income Funds and ESG indicators

Some attention has been paid to the link between financial performance and country ESG factors at the fund level (Derwall & Koedijik (2009); Scholtens (2010); Leite & Cortez (2016); Henke (2016); Hoepner & Nilsson (2017)).

For instance, Derwall & Koedijik (2009) who study the financial performance of fixed-income SRI mutual funds on the US market, found that the average SRI fixed-income funds perform similarly to conventional funds. Focusing on the European market, the conclusion reached by Leite & Cortez (2016) is similar, but they show that it also depends on geographic areas: French SRI bond funds match the performance of their peers, UK funds underperform conventional funds, and German funds slightly outperform.

A larger empirical study on SRI fixed-income funds was conducted by Henke (2016). Analyzing the risk-adjusted performance of 103 SRI fixed-income funds from both the US and the Euro area, in comparison with conventional funds, he found that the SRI fixed-income funds significantly outperformed their conventional peers by 0.5% annually. He further investigated the fund holdings in relation to ESG ratings to show that this difference in terms of performance comes from the exclusion of bond issuers with the lowest ESG ratings.

3.2.2. Corporate Bonds and ESG Indicators

At the asset level, the majority of the existing literature on ESG factors and fixed income markets focuses on corporate bonds (Klock, Mansi, & Maxwell (2005); Bauer & Hann (2010); Schneider (2011); Chava (2014); Bektic (2017); Menz (2010); Attig, El Ghoul, Guedhami, & Suh (2013); Oikonomou & Pavelin (2014); Polbennikov, Desclée, Dynkin, & Maitra (2016); Ge & Liu (2015); Stellner, Klein, & Zwergel (2015); Cooper & Uzun (2015); Huang, Hu, & Zhu (2018); Dynkin, Desclée, Dubois, Hyman, & Polbennikov (2018); Barth, Hübel, & Scholz (2019)).

Most of these studies report that a high ESG rating significantly reduces the credit risk of corporate bonds, evidence that markets are rewarding higher ESG ratings with a lower cost of debt (credit spreads) and higher credit ratings. Moreover, several studies show that ESG integration is not associated with a loss of performance.

For instance, Bauer & Hann (2010) find empirical evidence that the credit standing of borrowing firms is influenced by legal, reputational and regulatory risks associated with Environmental incidents. More specifically, the authors document that Environmental concerns are associated with a higher cost of debt financing and lower credit ratings, and proactive Environmental practices are associated with a lower cost of debt. Polbennikov, Desclée, Dynkin, & Maitra (2016) analyze spread and performance for a corporate bond portfolio associated with MSCI ESG ratings. They find that high ESG ratings are accompanied by an incremental increase in return and lower-than-average spreads. Oikonomou & Pavelin (2014) study the impact of various dimensions of sustainability performance on the pricing of

corporate debt and credit quality of specific bond issues. Their analysis suggests that each CSR factor substantially lessens the risk premia, reducing the cost of corporate debt. Cooper & Uzun (2015) find that firms with strong performance on corporate social responsibility (CSR) criteria have a lower cost of debt. Moreover, Hoepner & Nilsson (2017) show that bonds issued by companies with no concerns and no controversies significantly outperform the market benchmark. Similarly, Chava (2014) shows that firms with multiple Environmental concerns must pay higher costs on their bank loans. They conclude that socially responsible lending has the potential to have an impact on the Environmental policies of the firm through the cost of capital channels. Schneider (2011) supports the hypothesis that a firm's Environmental performance is reflected in bond prices.

3.2.3. Sovereign Bonds and ESG indicators

Relative to corporate bonds, little attention has been paid to the impact of ESG factors on sovereign bonds. However, a small but increasing body of literature indicates optimistic prospects regarding the materiality of ESG risks to sovereign creditworthiness.

3.2.3.1. Academic studies with a focus on the perspective of the issuer

Most academic papers investigate the impact of E, S and G factors (individually and/or aggregated) on sovereign debt from an issuer perspective, focusing on the link between ESG factors and the cost of debt, measured by sovereign bond spreads. The main results reveal a negative and statistically significant relationship, supporting the idea that high ESG performance is associated with a low cost of debt and that ESG factors are relevant in explaining sovereign bond spreads.

Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens (2019) construct their own ESG index using a method based on PCA analysis. Examining a panel dataset of 20 OECD countries from 1996 to 2012, they show that countries with good ESG performance have lower bond spreads. Moreover, they find that the longer the maturity of the bonds, the stronger the relationship, suggesting that ESG performance is a long-lasting phenomenon. Similarly, Crifo, Diaye, & Oueghlissi (2017) examine a panel data of 23 OECD countries from 2007 to 2012 and use Vigeo sustainability country ratings to show that high ESG ratings are associated with low borrowing costs. However, they find a stronger impact for short-maturity bonds. When it comes to emerging markets, Berg, Margaretic, & Pouget (2016) analyze 52 emerging economies from 2000 to 2012. Based on Yale University's Environment Indicator and the World Bank's Human Development Index and Governance indicators as proxies of a country's extra-financial performance, they show that ESG factors are a good supplement to credit ratings and traditional indicators to explain credit spreads. While the research papers mentioned above all agree on the financial materiality of ESG factors for sovereign debt, their conclusions are different when the analysis is carried out at the ESG sub-factor level, that is for particular dimensions of ESG criteria taken in

3. Literature Review

isolation. The materiality of ESG sub-factors also vary with the investment time horizon and level of development. Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens (2019) find that Governance has a stronger financial impact than Social performance, and Environment appears to have no impact. Conversely, Berg, Margaretic, & Pouget (2016), find that Governance is not significant in explaining sovereign bond spreads while the Environmental factor is. Their research indicates that emerging economies seem to be more vulnerable to Environmental and Social risks. Investigating further the impact of ESG factors on credit ratings, they also find that Governance and Environmental factors are both significant in explaining credit ratings.

Hübel (2019) further investigates the link between ESG factors and country credit risks, conducting a global study that explores the impact of ESG performance on sovereign CDS spreads, and the time dimension of ESG through the term structures of sovereign credit curves. Analyzing 60 countries from 2007 to 2017, he finds that ESG impacts both the level and slope of the term structure of sovereign credit spreads: higher ESG performance is associated with lower CDS spreads and flatter CDS implied credit curves. This research is evidence of a long-term risk-mitigating effect of country sustainability.

Another strand of the literature focuses on the link between sovereign bond spreads and/or credit ratings and one particular dimension of the ESG criteria (either E, S or G).

They find that the countries most exposed to these risks, such as members of the "Vulnerable 20", face a higher cost of capital.

Regarding the Environmental factor, Gervich (2011) suggests that the observation of specific Environmental indicators could be used as an "early warning" system to foresee a nation's financial collapse before it is predicted by standard financial indicators. Indeed, this could have helped predicted the downgrade of the US's credit ratings by the S&P in 2011. Indicators such as national petroleum consumption, CO2 emissions per capita, and the return on investment that a nation receives for its pollution (annual GDP/annual CO2 emissions) could be useful Environmental indicators of a country's future fiscal performance. When it comes to climate change as a source of risk for sovereign bonds, Burh & Volz (2018) study the impact of physical climate risks on sovereign borrowing rates. They find that the countries most exposed to these risks, such as members of the "Vulnerable 20", face a higher cost of capital. From 1996 to 2016, climate risks increased the cost of debt of these countries by 117 basis points on average, representing an additional $40 billion in interest payments in government debt alone. Their results also highlight that market and policy initiatives to enhance the physical and economic resilience of these countries are crucial in dealing with the consequences of climate risks and reducing this financial burden. Battiston & Monasterolo (2019) have developed

a new methodology for climate-related financial risk assessments under uncertainty. Applying it to the Austrian national bank's non-monetary policy portfolio, they found that the timing and credibility of the introduction of credible climate policies matter for the economic competitiveness and financial stability of countries. Countries that align with a credible trajectory of 2°C warming can strengthen their fiscal and financial position and have negative climate-related yields on sovereign bonds (negative climate spread), while a misalignment with this trajectory can increase sovereign bond yields (positive climate spread), which negatively affect the value of the sovereign portfolio of investors exposed to such countries. Regarding the Social factor, Bundala (2013) finds that the inequality-adjusted human development index and the unemployment rate respectively influence the probability of a country defaulting and dishonoring its debt obligation negatively and positively. Therefore, the study recommends using these factors as a pre-requisite when assessing a country's creditworthiness. Hoepner, Oikonomou, Scholtens, & Schröder (2016) investigate the link between the Sustainable Development Culture of a country and country risk. They show that high ratings for culture, in terms of Social, Environment and Political issues, reduce government bond yields, meaning that culture is priced by sovereign bond markets.

Regarding the Governance factor, Eichler (2014) analyzes the political determinants of sovereign bond yield spreads for emerging countries and shows that sovereign risk is higher for parliamentary systems than presidential regimes. Moreover, based on the degree of democracy and the quality of elections, a low quality of Governance is associated with higher sovereign yield spreads, and the impact of these political determinants is even more important in autocratic and closed regimes. Erb, Harvey, & Viskanta (1996), comparing five different measures of country risk, find that the ICRG (International Country Risk Guide) indicator, which measures political risk, is an important determinant for a country's overall risk premium. Haque, Kumar, Mark, & Mathieson (1998) examine the impact of political and economic variables on a country's credit ratings and find that political variables can improve the explanatory power of the regressions on sovereign credit ratings. Butler, Fauver, & Mortal (2009) show that state corruption has a strong and negative effect on credit risk and bond yields. Finally, Ciocchini (2003) studies the relationship between corruption and borrowing costs as measured by sovereign bond spreads for governments in emerging markets and shows that corruption is priced by sovereign bond markets (countries perceived as more corrupt have to pay higher bond yields).

3.2.3.2. Academic studies with a focus on the perspective of the investor

While some (aforementioned) research is available on the relationship between ESG indicators and the cost of debt, the impact of cross-sectional or time-series changes in ESG scores on the risk and performance of sovereign bonds has not yet been fully explored, and further academic research focusing on the investor perspective is needed. As a result, the implications for investors

of the integration of ESG considerations at the security selection and/or portfolio construction levels require further investigation.

To the best of our knowledge, only three research papers have focused on analyzing the risk and performance of sovereign bond portfolios based on ESG criteria.

Drut (2010) shows that investors can construct a portfolio with higher ESG performance without making sacrifices in the risk and return relationship. He examines a dataset of 20 OECD countries using data from 1994 to 2008 and Vigeo sustainability country rating as an ESG score. His empirical findings suggest that ESG-optimized portfolios have a higher volatility but a lower skewness and kurtosis (less exposure to extreme risks), and that an ESG worst-in-class exclusion strategy in the sovereign bonds of developed countries does not cause a significant loss in diversification. Hübel (2019) examines the performance of a CDS ESG-based credit-neutral long-short portfolio strategy for investment grade sovereign CDS between 2010 and 2017. His results show that ESG integration into sovereign CDS portfolios does not hurt returns, suggesting that investors can potentially benefit from ESG variation within countries with similar credit ratings. Badia, Pina, & Torres (2019) build equally weighted portfolios integrating ESG criteria based on the RobecoSAM country sustainability ranking. They use the Sharpe ratio and Ledoit & Wolf (2008) procedure to compare the performance of several portfolios. The preliminary results provide evidence that integrating ESG scores into the investment process does not mean sacrificing returns.

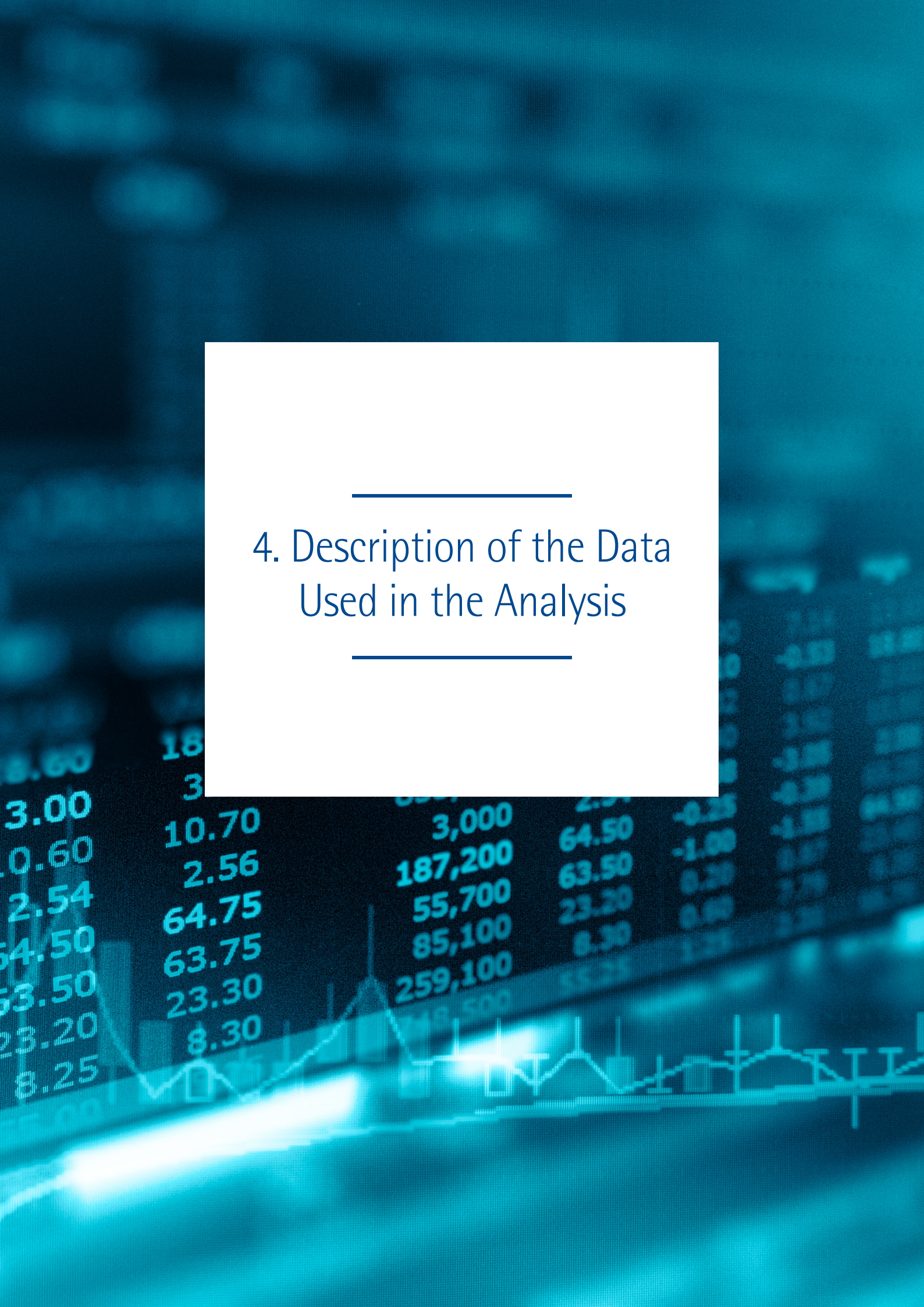
3.2.3.3. Industry studies

Industry research has also been undertaken on the relationship between ESG and sovereign bonds, with the main focus on how markets price ESG risks. The main empirical findings suggest that ESG factors are important determinants of the financial performance and risk of sovereign bonds. For instance, and in line with most studies, Allianz (2017) shows that country credit ratings do not fully incorporate sovereign issuers' ESG risk factors and further explore the relationship between 5-year CDS spreads and ESG risks using MSCI ESG government ratings. They find that ESG risks are priced into sovereign credit risk: sovereign issuers with higher aggregate ESG performance tend to have lower CDS spreads (default risk). This relationship is of a non-linear nature and markets seem to penalize the lowest ESG scoring countries. While the materiality of ESG risk varies across countries, regions and economic environments, at the sub-factor level, the paper results show that Governance is the most important risk factor for investors, followed by the Social factor. Regarding Environmental risks, they seem not to be priced yet, or at least not adequately priced into sovereign credit risk. According to Bluebay & Verisk Maplecroft (2019), investors not only ignore a country's Environmental performance but even penalize better Environmental performance in the future with higher spreads. Differentiating between current and future risk is of primary importance, especially when it comes to Environmental risk. Indeed, the Environmental factor is expected to become more financially material over time due to the growing pressure from climate change

3. Literature Review

risks. To measure how countries differ from each other in terms of ESG performance and how each country's ESG performance changes over time, these authors introduced a new way of measuring country ESG scores based on nine ESG dimensions, allowing them to take into account current and future performance as well as the resilience of each of the three dimensions. Assessing the current materiality and trajectory of ESG factors is important in understanding how they can be integrated into sovereign bond portfolios to optimize risk and return opportunities. From a sovereign bond portfolio perspective, AXA Investment Managers (2013) find empirical evidence that the best-scoring ESG portfolio of developed countries substantially outperforms the worst-scoring ESG portfolio. Comparing the financial performance of sovereign bond portfolios for emerging and developed markets from 2005 to 2012, they conclude that the ESG-weighted portfolio of emerging and developed economies leaves the major portfolio characteristics unchanged while increasing ESG performance.

The growing number of ESG data providers has helped and facilitated the growth of ESG investing. However, recent academic papers on equity markets (Berg, Kölber, & Rigobon (2019); Gibson, Kruger, Riand, & Schmidt (2019)) have highlighted significant divergence in ESG ratings, as well as the lack of consistent and relevant ESG data available. In the absence of standardization in terms of methodology to assess the ESG performance of countries, using ESG ratings requires careful contextualization and interpretation. Moreover, data accuracy and quality, and in particular the ability to rely on a sufficiently long sample of historical data, are crucial to obtain coherent and relevant results. This is what we turn to next.



4. Description of the Data Used in the Analysis

4. Description of the Data Used in the Analysis

We now present the database used in our analysis, starting with ESG data before moving on to bond market data as well as economic and financial factors used as control variables.

4.1. ESG Indicators

We use the Verisk database for ESG indicators, which we briefly present below.[8]

Verisk Maplecroft is a global risk analytics company providing ESG, climate, political and economic risk data for leading institutional investors and multinational corporations. It combines proprietary quantitative and qualitative risk indices and datasets with expert research on countries, industries and commodities.

The Verisk Maplecroft database is divided into 6 themes (Economics, Environment and Climate Change, Financial Crime, Forecasting, Human Rights and Development, Governance) and contains 177 risk indices for up to 198 countries globally, updated annually and quarterly and available from 1995. Each theme is further divided into sub-themes, such as business versus economy, climate change and environment risks versus natural hazards, development versus human rights, and dynamic versus structural political risks. The risk indices cover diverse issues ranging from dependence on fossil fuel exports, climate change vulnerability and deforestation to child labor, government stability, corruption and civil unrest. They are built from the analysis of more than 900 quantitative and qualitative indicators selected from a variety of structured and unstructured third-party and proprietary sources. Public sources include large international organizations such as the IMF, World Bank and UN, as well as geospatial data providers like NASA and NOAA. Unstructured sources are exploited using machine learning algorithms. Proprietary datasets are developed internally, relying on Verisk Maplecroft's team of regional and thematic experts.

Each Verisk Maplecroft index is rated on a scale ranging from 0 to 10 (best rate), offering insights into the investment risks and opportunities associated with each country and allowing easy comparison of multiple risk issues across time horizons and locations. From the Verisk Maplecroft database, 58 risk indices and 371 indicators are available from 2010–2020 for the four following themes: Economics, Environment and Climate Change, Human Rights and Development, Governance (see Appendix A.4.1) and for a total of 35 countries (20 developed, 15 emerging). Even though the definition of ESG criteria varies from one data provider to another, we will use in what follows the standard names Environment (E), Social (S) and Governance (G) to refer to Verisk Environment and Climate Change, Human Rights and Development, and Governance indicators, respectively. The Verisk Maplecroft Economics index, which aggregates macroeconomic indicators, will be used as a control variable in our different regression analyses to isolate the impact of the E, S and G dimensions on a given dependent variable.[9]

8 - We would like to express our gratitude to Verisk Maplecroft for providing us with access to their database.
9 - We prefer to use the Verisk Maplecroft Economics index rather than credit ratings, since credit rating agencies might already incorporate ESG criteria into their analyses.

4. Description of the Data Used in the Analysis

4.2. Sovereign Bond Yield Spreads

From the Thomson Reuters and ICAP Datastream databases, we extract yield on 12-month, 5-year and 10-year sovereign bonds for 35 countries (20 developed, 15 emerging countries) from 2010 to 2020. The countries are classified based on the MSCI 2019 market classification (see Appendix A.4.2).

We define government bond yield spreads as the difference between the yield on sovereign bonds for a given country and the yield on the US sovereign bond with the corresponding maturity. In other words, we use the yield on the US sovereign bond as the "risk-free" rate.

4.3. Macro and Microeconomic Control Variables

In what follows, we present the economic and financial control variables used in our analysis. In line with Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens (2019), Berg, Margaretic, & Pouget (2016) and the literature on the determinants of sovereign risk (Cantor & Packer (1996); Eichengreen & Mody (1998); Attinasi, Checherita, & Nickel (2009); Barbosa & Costa (2010); Afonso, Arghyrou, & Kontonikas (2012); D'Agostino & Ehrmann (2014)), we include country specific macroeconomic control variables in our analysis to isolate the impact of ESG on sovereign bond spreads.

We use the Verisk Economics dimension as a macroeconomic control variable, which includes indexes such as Economic Growth (GDP growth, annual %), External Balance (Current account balance, % of GDP), Inflation (% change in consumer price index), Import Cover (total foreign exchange reserves to total imports), Fiscal Balance (% of GDP) and Public Debt (% of GDP), among others.

Credit rating are partly based on macroeconomic and financial variables and partly based on non-financial ESG variables. Given that credit ratings may already incorporate ESG dimensions, using them as control variables would not allow us to disentangle the effect of financial versus non-financial factors in the risk and performance of sovereign bonds. For this reason, we prefer to use the Verisk Economics score as a control variable, since it has a pure focus on macro and microeconomic factors.

Note that it would obviously have been desirable to use a liquidity proxy as an additional control variable. Regarding measures of liquidity in sovereign bond yields, the related literature has used two main proxies, namely yield spreads between government-guaranteed agency bonds and government bonds, and bid-ask spreads. The problem with using the first proxy in our analysis is that yield spreads are the independent variable that we are trying to explain in the first place. Regarding the second proxy, the analysis we develop is based on implied prices extracted from the yield curves for the developed and emerging market countries in the sample, and we do not have access to bid-ask market spread levels for underlying bonds.

4. Description of the Data Used in the Analysis

Other proxies for sovereign liquidity exist, but these are either not reliable or not available at all in many markets beyond the US. Regarding trading-based liquidity measures for sovereign bonds, there are problems with both availability and quality since these bonds are mostly traded on an OTC basis. The estimation and evaluation by Fleming (2003) of various liquidity measures for the US Treasury market reveal that the simple bid-ask spread (difference between bid and offer prices) is a true and useful measure for assessing and tracking liquidity. Other measures, such as quote and trade sizes, prove to be only modest tools for assessing and tracking liquidity, while trading volume and frequency are in fact poor measures of liquidity. Monfort & Renne (2014) proxy liquidity factor by the spread between the German Bund and the KfW (German agency) emissions. Similarly, Schwarz (2013) proposes a multi-country European model in which liquidity is proxied by the spread between the sovereign German bond and the KfW bond. Hund & Lesmond (2008) include as global liquidity proxies the difference in the yield between Eurodollar deposits and the three-month US Treasury Bill because this quantity is related to the short-term swap rates (Campbell & Taksler (2003)). Favero, Pagano, & Von Thadden (2008) use the bid-ask spread to capture liquidity risk and the spread between the US sovereign yield and the US corporate swap rate for credit risk. Dubecq, Monfort, Renne, & Rousellet (2013) proxy liquidity premia by the first principal component of the KfW Bund spread, Tbill-repo spread, and a factor based on an ECB survey, and credit premia by the first principal component of 36 Eurozone banks' CDS rates.

In this context, and in the absence of reliable market proxies for liquidity, differences in liquidity will not be accounted for as part of the control variable and will be reflected as part of the fixed effects.

5. Analysis of the impact of ESG on Risk and Return

5. Analysis of the Impact of ESG on Risk and Return

We start by conducting a thorough descriptive statistical analysis of the impact of ESG scores taken individually.

Our main goal is to analyze whether cross-sectional differences in the risk and return of sovereign bonds from various developed or emerging issuing countries can be explained partly by cross-sectional differences in E, S or G scores.

5.1. Descriptive Statistics

To provide a better understanding of the data, a preliminary analysis consists of descriptive statistics for the main variables used in our empirical analysis. In this section, we further explore our dataset at a country level, ranking countries based on ESG scores.

Our sample comprises annual observations for 20 developed countries, as indicated above, of which the US will be used as the reference country when a risk-free rate is needed, as well as 15 emerging countries from 2010 to 2020, resulting in 200 observations for developed countries and 150 observations for emerging countries.

In Appendices A.5.1 to A.5.10 we present estimates for the (annualized) mean and standard deviation, as well as various percentiles (min, max, 25th pctl., 50th pctl., 75th pctl.) of the distribution of 1-year, 5-year and 10-year bond yields, and bond yield spreads, for each country over the sample period 2010–2020.

In Appendices A.5.11 and A.5.12 we present estimates for the (annualized) mean and standard deviation, as well as various percentiles (min, max, 25th pctl., 50th pctl., 75th pctl.) of the distribution of Economic, Environmental, Social and Governance dimensions for each country over the sample period 2010–2020.

Appendices A.5.13 and A.5.14 show the distribution of the average of each dimension, namely Economic, Environmental, Social and Governance, over the study period 2010–2020 for developed and emerging countries.

Environmental, Social and Governance dimensions have higher average scores for developed countries than emerging countries over the sample period 2010–2020 and lower standard deviation.

For developed countries, Economic scores range on average from 5.6 to 6.5 with the lowest average score for the United States (5.10) and the highest for Switzerland (8.17). Environmental scores range on average from 6.67 to 7.23 with the lowest average score for Israel (5.31) and the highest for Switzerland (8.26). Social scores range on average from 7.24 to 8.06 with the lowest average score for Israel (4.88) and the highest for Switzerland (8.70). Governance scores range on average from 7.52 to 8.10 with the lowest average score for Israel (5.70) and the highest for Switzerland (8.92). For emerging countries, Economic scores range on average from 5.57 to 6.51 with the lowest average score for South Korea (4.96) and the highest for China (7.02). Environmental scores range on average from 5.16 to 5.85 with the lowest average score for Indonesia (3.81) and the highest for the Czech Republic (6.52). Social scores range on average from 3.92 to 5.20 with the lowest average score for China (2.44) and the highest for South Korea (7.11). Governance scores range on average from 5.41 to 6.35 with the lowest average score for China (4.38) and the highest for Chile (7.12).

5. Analysis of the Impact of ESG on Risk and Return

Exhibit 5.1: Ranking of the average Economic, Environmental, Social and Governance scores for each developing country over the sample period from 2010 to 2020 (higher rank = better)

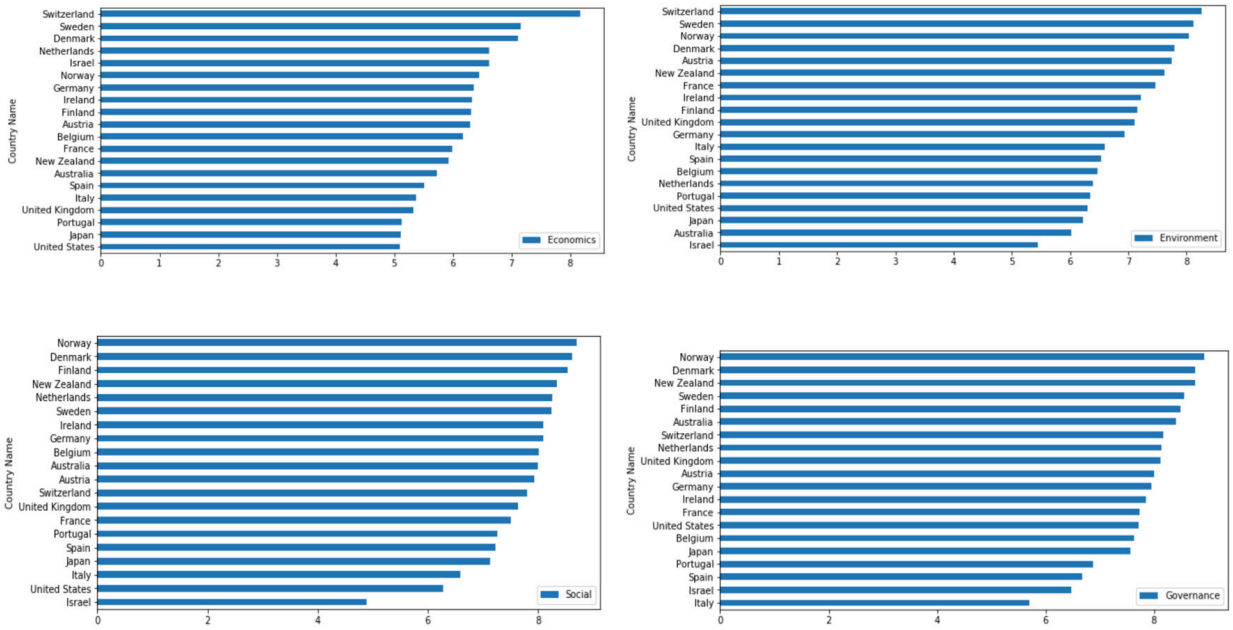
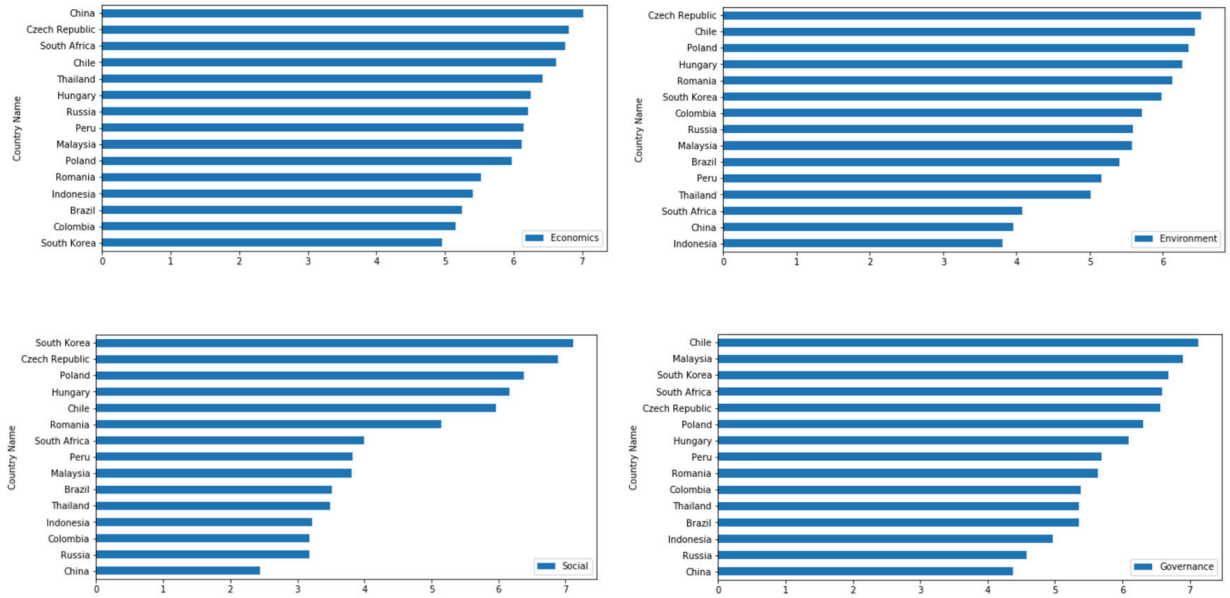


Exhibit 5.2: Ranking of the average Economic, Environmental, Social and Governance scores for each emerging country over the sample period from 2010 to 2020 (higher rank = better)



5. Analysis of the Impact of ESG on Risk and Return

Appendix A.5.15 reports the average scores and rank for developed and emerging countries over the sample study period from 2010 to 2020. There is a clear difference between good and bad performers with respect to each dimension, as shown in Exhibits 5.1 and 5.2. Among developed countries, Scandinavian countries such as Denmark, Finland, Norway and Sweden are in the top 50% of best performers for each dimension. Dispersion (standard deviation) over the period 2010–2020 ranges from 0.077 (Austria) to 0.761 (Ireland) for Economics, from 0.084 (Italy) to 0.320 (Japan) for Environment, from 0.098 (New Zealand) to 0.475 (Israel) for Social, and from 0.079 (Denmark) to 0.290 (Italy) for Governance. Among emerging countries, countries in the top 50% of best performers for the Economic dimension do not necessarily maintain the same position for the other dimensions, except the Czech Republic, Chile and Hungary. While China ranks first in Economics, it is among the two worst performers (with Indonesia) for the Environment dimension and among the two worst performers (with Russia) both for the Social and Governance dimensions. Dispersion (standard deviation) over the period 2010–2020 ranges from 0.123 (Chile) to 0.537 (Romania) for Economics, from 0.108 (Czech Republic) to 0.386 (Romania) for Environment, from 0.1196 (Romania) to 0.8806 (Colombia) for Social, and from 0.1201 (Chile) to 0.708 (Russia) for Governance.

Appendix A.5.16 shows the heterogeneity of the E, S and G dimensions over time for each region (developed countries and emerging countries).

Regarding the Economic dimension, in developed countries the average score for all countries decreases between 2010 and 2012 then increases from 2012 to 2016 and finally gradually decreases from 2016 to 2020. In emerging countries it decreases from 2010 to 2011 and then gradually increases from 2011 to 2018 before finally decreasing again at a moderate rate from 2018 to 2020.

Regarding the Environmental dimension, in developed countries we observe 3 distinct phases: the average score for all countries increases between 2010 and 2013, then sharply decreases from 2013 to 2015 and increases from 2015 to 2019 with a slight decrease from 2019 to 2020. When it comes to emerging countries, the score increases from 2010 to 2013, slightly decreases from 2013 to 2015 and finally increases from 2015 to 2020.

The average social score for all countries increases from 2010 to 2020, while in emerging countries it decreases from 2010 to 2015 before increasing without any interruption from 2015 to 2020.

Regarding Governance, in developed countries we observe 3 distinct phases: the score decreases from 2010 to 2015, then increases from 2015 to 2018 and finally decreases again from 2018 to 2020. In emerging countries it keeps increasing from 2010 to 2020 with some decrease in between in 2010, 2014–2015 and 2017.

Appendices A.5.17 and A.5.18 show the heterogeneity of the Economic, Environmental, Social and Governance dimensions simultaneously across developed and emerging countries, and over time (2010–2020).

5. Analysis of the Impact of ESG on Risk and Return

Over the period the average score for each dimension showed a similar trend for both developed and emerging countries.

5.2. ESG Scores and Risk & Performance Characteristics of Sovereign Bonds

We are now ready to analyze how differences in ESG indicators can help explain differences in the risk and performance of sovereign bonds. We draw an important distinction between the perspective of long-term buy-and-hold investors, for whom performance can be captured by bond yield spreads, and that of shorter-term investors, who will not hold the bond until maturity, and as such cannot use bond yield as a measure of expected performance because of the uncertainty regarding the selling price of the sovereign bonds held in their portfolios. In the latter case, we will instead use average annualized return as a measure of performance.

5.2.1. ESG Scores and Sovereign Bond yield Spreds

In this section, we explore the impact of cross-sectional differences in ESG scores on the performance characteristics of sovereign bonds from the perspective of a long-term investor for whom sovereign bonds are held to maturity.

In particular, we want to answer the following questions: What is the relationship between ESG scores and the premium investors demand to invest in the sovereign bond market? How can ESG performance affect sovereign bond yield spreads? Is better ESG associated with lower bond yield spreads?

We answer these questions by exploring the impact of ESG scores taken individually on bond yield spreads for different bond maturities (1-year, 5-year and 10-year) and level of country development (developed versus emerging markets).

5.2.1.1.Univariate Regression analysis

We start by conducting a univariate regression analysis to investigate the linear relationship between bond yield spreads and E, S and G scores.

The regression model is of the following form:

$$Spread_{i,t} = \beta_0 + \beta_{ESGDim} ESGDim_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

where

i = 1 to n (the number of countries) and t = 1 to T (the number of periods)

$Spread_{i,t}$: sovereign bond yield spreads of country i at time t defined as $Spread_{i,t}=Yield_{i,t}-Yield_{USA,t}$. The sovereign bond spreads can be either 1-year, 5-year or 10-year.

$ESGDim_{i,t-1}$: lagged Environmental, Social or Governance dimension from Verisk database

$\varepsilon_{i,t}$: error term

β_0:constant

In Appendices A.5.19 to A.5.24, we present scatterplots showing the relationship between the Economic, Environmental, Social and Governance scores and bond yield spreads per country over the sample period 2010–2020.

5. Analysis of the Impact of ESG on Risk and Return

In Exhibit 5.3, we present the results of the estimation of the relationship between Economic, Environmental, Social and Governance scores and bond yield spreads per country over the sample period 2010–2020.

Exhibit 5.3: OLS regression results of 1-year, 5-year and 10-year yield spread against Economic, Environmental, Social and Governance scores for 20 developed countries and 15 emerging countries over the period 2010–2020

Developed Countries			
	Bond Yield Spreads *Spread_(i,t)*		
	1Y	5Y	10Y
	Economics		
Eco_(i,t-1)	-0.007***	-0.009***	-0.008***
	(0.002)	(0.002)	(0.001)
β_0	0.037***	0.051***	0.052***
	(0.010)	(0.010)	(0.009)
Observations	190	190	190
Countries	19	19	19
R-sq	0.087	0.132	0.17
	Environment		
Env_(i,t-1)	-0.004**	-0.005***	-0.006***
	(0.002)	(0.002)	(0.002)
β_0	0.021*	0.032***	0.037***
	(0.012)	(0.012)	(0.011)
Observations	190	190	190
Countries	19	19	19
R-sq	0.025	0.043	0.069
	Social		
Soc_(i,t-1)	-0.002	-0.004**	-0.004***
	(0.001)	(0.002)	(0.001)
β_0	0.013	0.024**	0.032***
	(0.011)	(0.012)	(0.010)
Observations	190	190	190
Countries	19	19	19
R-sq	0.012	0.027	0.057
	Governance		
Gov_(i,t-1)	0.001	-0.002	-0.004***
	(0.002)	(0.002)	(0.001)
β_0	-0.010	0.015	0.029***
	(0.012)	(0.013)	(0.011)
Observations	190	190	190
Countries	19	19	19
R-sq	0.001	0.011	0.044

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

Emerging Countries			
	Bond Yield Spreads Spread_(i,t)		
	1Y	5Y	10Y
	Economics		
Eco_(i,t-1)	-0.016***	-0.017***	-0.017***
	(0.003)	(0.003)	(0.003)
β_0	0.128***	0.134***	0.129***
	(0.020)	(0.020)	(0.020)
Observations	150	150	150
Countries	15	15	15
R-sq	0.145	0.165	0.154
	Environment		
Env_(i,t-1)	-0.013***	-0.014***	-0.014***
	(0.002)	(0.002)	(0.002)
β_0	0.098***	0.106***	0.107***
	(0.014)	(0.013)	(0.013)
Observations	150	150	150
Countries	15	15	15
R-sq	0.154	0.190	0.200
	Social		
Soc_(i,t-1)	-0.010***	-0.011***	-0.011***
	(0.001)	(0.001)	(0.001)
β_0	0.073***	0.078***	0.077***
	(0.006)	(0.006)	(0.006)
Observations	150	150	150
Countries	15	15	15
R-sq	0.289	0.342	0.348
	Governance		
Gov_(i,t-1)	-0.012***	-0.013***	-0.013***
	(0.003)	(0.002)	(0.002)
β_0	0.097***	0.107***	0.106***
	(0.015)	(0.015)	(0.014)
Observations	150	150	150
Countries	15	15	15
R-sq	0.125	0.164	0.169

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

5. Analysis of the Impact of ESG on Risk and Return

The analysis shows that on each dimension, the scores are highly dispersed for both developed and emerging countries. The dispersion is higher for emerging countries than developed countries, while developed countries are more closely dispersed around the regression line.

For both developed and emerging countries, we find a negative relationship between bond yield spreads and the Economic, Environmental, Social and Governance scores, meaning that countries with a higher score on a given dimension have on average a lower bond yield spread.[10] This result suggests that borrowing costs are lower for better-ranked countries, as expected. It also suggests that investing in countries with a higher rating leads to a lower performance for the long-term investor, which is also consistent with the risk-return tradeoff that implies that a higher performance is expected from investment in countries with higher levels of financial and extra-financial risks.

Regarding developed countries, for 1-year bond maturity, the Environmental dimension is significant with a negative relationship with bond spreads, while for 5-year bond maturity both the Environmental and Social dimensions are statistically significant with a negative relationship with bond spreads as well (a country with a higher score on a given dimension has on average a lower bond yield spread). Finally, for 10-year bond spreads, all dimensions are significant with a negative relationship with bond yield spreads. Moreover, for developed countries, the relationship between bond yield spreads and Governance for 5-year and 1-year bond maturities, as well as the relationship between bond yield spreads and the Social dimension for 1-year bond maturity, seem almost nonexistent, the regression line being close to horizontal (slope almost equal to zero), meaning that differences in Governance scores do not seem to provide much explanatory power with respect to differences in bond yield spreads.

As far as emerging countries are concerned, all dimensions, regardless of bond maturity, are significant with a negative coefficient. The results also differ with respect to the steepness of the regression line. The (negative) slope of the regression line for emerging countries is greater than for developed countries. In other words, bond yield spreads for emerging countries tend to be more sensitive to differences in ESG scores than for developed countries.

5.2.1.2. Multivariate regression analysis: identifying the most important dimension

We turn to a multivariate regression analysis to explore to what extent ESG dimensions influence sovereign bond yield spreads in addition to information already contained in the economic fundamentals, as suggested by the literature on the determinants of sovereign bond yield spreads. To this end, we first investigate the linear relationship between bond yield spreads and E, S and G dimensions including the Economic dimension as a control variable.

While Section 5.2.1.1 gave us a first insight into the linear relationship between bond spreads and

10 - One notable exception is the positive link found between 1-year bond yield spread and Governance for developed countries.

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each dimension, a necessary preliminary step before conducting any regression is to compute a correlation matrix between the main variables. This also helps to identify potential multicollinearity issues to address.

Exhibit 5.4 shows that for developed countries the three non-financial/non-economic dimensions, Environmental, Social and Governance, are all positively correlated. Higher-than-average values of Environmental quality are associated with higher-than-average scores in Social and/or social-political governance. The correlation goes from 78% between Governance and Social to 59% between Governance and Environment and 64% between Social and Environment. The average correlation is not exceedingly high, which suggests that each dimension provides incremental information, and that the multivariate analysis will not suffer from severe multicollinearity problems. It should also be noted that these three dimensions are positively correlated to the Economic score with correlation coefficients of 53%, 28% and 43% for Environment, Social and Governance, respectively.

Moreover, the four dimensions are all negatively correlated with 1-year, 5-year and 10-year yield spreads, suggesting that higher values in these dimensions are associated with lower yield spreads, which is consistent with the results from the univariate regressions. The only exception is the weakly positive correlation coefficient, equal to 0.04, between Governance scores and 1-year yield spreads.

Exhibit 5.4: Correlation matrix of bond yield spreads and Economic, Environmental, Social and Governance dimensions for developed countries over the sample period 2010–2020

	1Y-Yield	5Y-Yield	10Y-Yield	Economics	Environment	Social	Governance
1Y-Yield	1						
5Y-Yield	0.93**	1					
10Y-Yield	0.86**	0.98**	1				
Economics	-0.29**	-0.36**	-0.41**	1			
Environment	-0.16**	-0.21**	-0.26**	0.53**	1		
Social	-0.11	-0.16**	-0.24**	0.28**	0.64**	1	
Governance	0.04	-0.1	-0.21**	0.43**	0.59**	0.78**	1

*Note: Developed Countries. ** significant at 5%.*

Exhibit 5.5: Correlation matrix of bond yield spreads and Economic, Environmental, Social and Governance dimensions for emerging countries over the sample period 2010–2020

	1Y-Yield	5Y-Yield	10Y-Yield	Economics	Environment	Social	Governance
1Y-Yield	1						
5Y-Yield	0.96**	1					
10Y-Yield	0.89**	0.97**	1				
Economics	-0.38**	-0.40**	-0.39**	1			
Environment	-0.39**	-0.44**	-0.45**	-0.12	1		
Social	-0.54**	-0.58**	-0.59**	0.01	0.72**	1	
Governance	-0.35**	-0.40**	-0.41**	0.06	0.49**	0.66**	1

*Note: Emerging Countries. ** significant at 5%.*

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Exhibit 5.5 shows that for emerging countries, like developed countries, the three non-financial/non-economic dimensions, Environmental, Social and Governance, are all positively correlated. The correlation goes from 66% between Governance and Social, to 49% between Governance and Environment and 72% between Social and Environment. The correlation is not perfect for developed countries, which suggests that it is useful to include these dimensions in a multivariate regression, in addition to Economics, without being exposed to high collinearity problems.

Again, the four dimensions are all negatively correlated with 1-year, 5-year and 10-year yield spreads, suggesting that higher values in these dimensions are associated with lower yield spreads. On the other hand, these three dimensions are not all positively correlated to Economics, with correlation coefficients of -12%, 1% and 6% for Environment, Social and Governance, respectively.

We now turn to the multivariate analysis of the impact of cross-sectional differences in the Environmental, Social and Governance dimensions on sovereign bond spreads. Our main analysis consists in estimating a (dynamic) fixed-effects panel regression model including ESG scores as explanatory variables. The Economic score is used as a control variable to isolate the impact of the three extra-financial dimensions on bond yield spreads.

Our dataset is a panel that includes a group of 19 developed countries (US excluded) and 15 emerging countries observed over a period of 10 years. The structure of the dataset includes a country dimension.

We performed a Hausman test, which indicates that a fixed-effects model needs to be estimated, instead of a random-effects model. Indeed, the test for the non-existence of fixed effects rejects the null hypothesis and concludes with the existence of country-specific effects.[11] Because of the persistency of the spread, we also included lagged sovereign bond spreads on the right-hand side.

The three Verisk dimensions that are used as proxies for ESG criteria are also lagged for robustness.

To estimate our model, we use the Least Square Dummy Variable Corrected (LSDVC) estimator of Bruno (2005) as in (Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens (2019). The lagged sovereign bond spreads added on the right-hand side of the model might be serially correlated and hence correlated with the error term, which makes the OLS (Ordinary Least Squares) and LSDV (Least Square Dummy Variable) estimators biased and inconsistent Baltagi & Chang (1994). The LSDVC estimator of Bruno (2005) derives an approximation for the bias of the LSDV estimator for the standard autoregressive panel data model and extends the results by Bun & Kiviet (2003), Kiviet (1999) and Kiviet (1995) to unbalanced panels.

11 - For further research, we could test for the presence of time-specific fixed effects.

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As in Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens (2019), we evaluate the performance of the LSDVC estimator of Bruno (2005) by comparing the coefficient estimate of the first lagged dependent variable with the one that would be obtained estimating our model with a simple linear regression (OLS estimation) or the within-panel transformation (LSDV estimation). The coefficient of our estimator lies between the coefficient estimates of the alternative two estimators, meaning that it is a consistent estimate.[12]

The dynamic panel regression model is of the following form[13]:

$$Spread_{i,t} = \beta_0 + Spread_{i,t-1} + \beta_{Eco}Eco_{i,t-1} + \beta_{Env}Env_{i,t-1} + \beta_{Soc}Soc_{i,t-1} + \beta_{Gov}Gov_{i,t-1} + \alpha_i + \varepsilon_{i,t} \quad (2)$$

where

i = 1 to n (the number of countries) and t = 1 to T (the number of periods)

$Spread_{i,t}$: sovereign bond yield spreads of country i at time t defined as $Spread_{i,t} = Yield_{i,t} - Yield_{USA,t}$. The sovereign bond spreads can be either 1-year, 5-year or 10-year.

$Spread_{i,t-1}$: lagged sovereign bond yield spreads of country i to account for the persistent nature of spreads

$Eco_{i,t-1}$: lagged Economic dimension obtained from Verisk database

$Env_{i,t-1}$: lagged Environmental dimension obtained from Verisk database

$Soc_{i,t-1}$: lagged Social dimension obtained from Verisk database

$Gov_{i,t-1}$: lagged Governance dimension obtained from Verisk database

α_i: (unobserved) country-specific fixed effect allowing us to take into account unobservable variables that are specific to country i and time invariant.

$\varepsilon_{i,t}$: error term

β_0:constant

The results of the panel regression model (1) are presented below in Exhibit 5.6 for developed countries and Exhibit 5.7 for emerging countries.

Our estimation results allow us to extract two key conclusions on the relationship between ESG scores and yield spreads.[14]

For developed countries, and after controlling for economic scores as well as other variables and fixed effects, we first find that differences in Environmental scores help explain differences in bond yield spreads, with a higher Environmental score associated with a lower spread. Regardless of bond maturity, the coefficient associated with the Environmental dimension is negative and

12 - As in Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens (2019), we also tested among different estimators such as the estimators of Anderson and Hsiao (1982) in difference and in level, the GMM estimators of Arellano-Bond (1991), the estimator of Bundell and Bond (1998) and the estimator LSDVC of Bruno (2005) and we compared the results obtained with the OLS and LSDV (fixed effect) regressions.

13 - We also performed cross-sectional dependence autocorrelation and heteroskedasticity tests, as well as an overidentification test and tests of endogeneity for each explanatory variable.

14 - For further research, we could further study the lag structure of the model.

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Exhibit 5.6: Model estimates of equation (2) for developed countries

Developed Countries			
	Bond Yield Spreads *Spread_(i,t)*		
	1Y	5Y	10Y
Spread_(i,t-1)	0.713***	0.686***	0.661***
	(0.065)	(0.066)	(0.067)
Eco_(i,t-1)	-0.003	-0.002	-0.003
	(0.003)	(0.004)	(0.003)
Env_(i,t-1)	-0.013**	-0.025***	-0.023***
	(0.005)	(0.006)	(0.004)
Soc_(i,t-1)	0.003	0.005*	0.003*
	(0.003)	(0.004)	(0.003)
Gov_(i,t-1)	0.013**	0.013*	0.009*
	(0.005)	(0.006)	(0.005)
Observations	190	190	190
Countries	19	19	19
Fixed effects	Yes	Yes	Yes
R-sq	0.651	0.629	0.633

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

Exhibit 5.7: Model estimates of equation (2) for emerging countries

Emerging Countries			
	Bond Yield Spreads Spread_(i,t)		
	1Y	5Y	10Y
Spread_(i,t-1)	0.710***	0.852***	0.604***
	(0.073)	(0.079)	(0.090)
Eco_(i,t-1)	-0.003	-0.003	-0.005**
	(0.004)	(0.003)	(0.003)
Env_(i,t-1)	0.001	0.002	0.002
	(0.006)	(0.005)	(0.004)
Soc_(i,t-1)	-0.007***	-0.004**	-0.001
	(0.002)	(0.002)	(0.001)
Gov_(i,t-1)	0.004	0.004	0.002
	(0.003)	(0.002)	(0.002)
Observations	150	150	150
Countries	15	15	15
Fixed effects	Yes	Yes	Yes
R-sq	0.676	0.602	0.419

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

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statistically significant. Social and Governance scores are both associated with a positive coefficient but do not appear significant, except Governance for 1-year sovereign bond maturity, which appears significant with a positive coefficient (0.013). While the results are similar across bond maturities (in terms of significance), the magnitude of the Environmental score coefficients changes with the bond maturity: -0.013 for 1-year, -0.025 for 5-year and -0.023 for 10-year bond yield spreads. The impact of the Environmental dimension on bond yield spreads is more pronounced in the medium run. Hence, from an issuer standpoint, better Environmental scores can lead to reduced borrowing costs, everything else being equal. From the investor standpoint, this result suggests that a lower yield is to be expected when investing in countries with higher environmental performance, which tells us that a negative premium is associated with this reduction in environmental risk. Interestingly, these results differ from previous studies such as (Capelle-Blancard, Crifo, Diaye, Oueghlissi, & Scholtens, 2019), who show that the Environmental dimension has no impact on bond yield spreads while Governance has the strongest negative relationship with bond yield spreads followed by the Social dimension.

For emerging countries, and after controlling for economic scores as well as other variables and fixed effects, we first find that differences in Social scores help explain differences in bond yield spreads, with a higher Social score associated with a lower spread. For 5-year and 10-year maturity bonds, the coefficient associated with the Social dimension is negative and significant. Environmental and Governance scores are associated with a positive coefficient, but do not appear significant. While the results are similar across bond maturities (in terms of significance), the magnitude of the Social score coefficients changes with the bond maturity, reaching a value of -0.007 for 1-year and -0.004 for 5-year bond yield spreads. The impact of the Social dimension on bond yield spreads is more pronounced in the short run. Hence, from an investor standpoint, a lower yield is to be expected when investing in countries with higher social performance, suggesting that a negative premium is associated with this reduction in social risk. These results are in line with Berg, Margaretic, & Pouget (2016) in terms of the negative impact of this Social dimension on bond yield spreads. However, Berg, Margaretic, & Pouget (2016) find that the link between the Social score and bond yield spread is stronger in the long term. Moreover, they also find that the Environmental dimension impacts the spread with a strong negative long-term link.

The intuition and interpretation behind the fact that the social factor shows up as the most significant factor explaining cross-sectional differences in yields and performance can be tied to both statistical and economic arguments.

From the statistical interpretation perspective, one straightforward explanation why the S dimension may have a higher explanatory power is that it is the variable that exhibits the highest degree of cross-sectional dispersion. Looking at the cross-sectional dispersion of each of the E, S and

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G dimensions, it indeed turns out that S is the most dispersed for both developed and emerging countries, with a standard deviation equal to 0.92 and 1.57, respectively. The dispersion of the S dimension for emerging countries is particularly high, meaning that the S scores are more spread out within emerging countries. It should be noted that there is higher heterogeneity in terms of social performance within emerging countries, compared to developed countries. In comparison, for the G dimension standard deviation equals 0.85 and 0.86 for developed and emerging countries, respectively, while for the E dimension the respective figures are 0.80 and 0.91.

From the economic interpretation perspective, it can be argued that if emerging countries appear more vulnerable to social risks it is because these risks may be more material in emerging countries, where governments have less resources available to manage them. The social dimension is closely linked to political stability, governance and a country's ability to raise taxes or introduce reforms. Key social factors include human rights, labor standards, education system, health care, etc. As already noted, our result regarding the S dimension for emerging countries is in line with Berg, Margaretic, & Pouget (2016), who analyze 52 emerging economies from 2000 to 2012. Their results indicate that emerging economies seem to be more vulnerable to environmental and social risks. They find that governance is not significant in explaining sovereign bond spreads while the environmental and social factors are. Moreover, a strand of the literature on sovereign bonds & ESG indicators focuses on the link between sovereign bond spreads and/or credit ratings and one particular dimension of the ESG criteria (either E, S or G). Regarding the social factor, Bundala (2013) find that the inequality-adjusted human development index and the unemployment rate respectively influence the probability of a country defaulting and dishonoring its debt obligation negatively and positively. Therefore, the study recommends using these factors as a pre-requisite when assessing a country's creditworthiness. Hoepner, Oikonomou, Scholtens, & Schröder (2016) investigate the link between the Sustainable Development Culture of a country and country risk. They show that high ratings for culture, in terms of Social, Environment and Political issues, reduce government bond yields, meaning that culture is priced by sovereign bond markets.

5.2.2. ESG Scores and risk & expected Return on Sovereign Bonds

In this section, we want to explore the impact of cross-sectional differences in each E, S and G dimension on the performance characteristics of sovereign bonds from the perspective of a short-term investor, who by definition will not hold the bonds until maturity and for whom bond yields are not sufficient statistics for expected returns. In particular, we want to answer the following questions: What is the relationship between each ESG score and sovereign bond risk and performance from an investor perspective? How can each ESG performance dimension affect sovereign bond returns? Is better ESG associated with lower sovereign bond returns and/or lower risk?

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We answer these questions exploring the impact of each ESG score on bond returns for different bond maturities (1-year, 5-year and 10-year), and level of country development (developed vs emerging markets).

5.2.2.1. ESG scores and risk & return on sovereign bonds

We want to examine how cross-sectional differences in the E, S and G dimensions can help explain differences in risk and return characteristics. To this end, for every time period (year) we sort sovereign bonds based on their Economic/Environmental/Social/Governance scores and form four quartiles. Quartile Q1 corresponds to the 25% lowest-ranked bonds, whereas quartile Q4 corresponds to the 25% best-rated bonds. The selected bonds are then equally weighted, and each quartile is rebalanced on an annual basis (note: Verisk indices are updated on an annual basis).

We also want to explore the impact of cross-sectional differences in each dimension on sovereign market risk, and for each sovereign bond quartile, in addition to annualized expected returns, we report the average value of the following indicators: volatility and Sharpe ratio, max drawdown, Kurtosis and Skewness. We perform the analysis for both developed and emerging countries, and also for different maturities (1-year, 5-year and 10-year).

In Appendices A.5.25 to A.5.30 we present the distribution of returns for each country, for 1-year, 5-year and 10-year bond maturity over the sample period 2010–2020.

Exhibit 5.8: Annualized expected returns in %, volatility in %, max drawdown in %, Sharpe ratio, skewness and kurtosis for each developed country's ESG quartiles over the period 2010–2020, as well as the difference between the quartiles with the best and poorest ESG profiles (Q4–Q1)

		Economics					Environment				
	Bond Maturity	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1
Annualized Return (%)	1Y	2.36	2.97	2.10	1.69	-0.67	2.66	1.94	2.98	1.53	-1.13
	5Y	5.82	6.81	5.38	4.92	-0.89	6.40	5.79	6.55	4.21	-2.19
	10Y	8.44	11.03	9.87	8.86	0.42	10.56	9.32	10.91	7.49	-3.07
Volatility (%)	1Y	0.07	0.09	0.08	0.08	0.01	0.08	0.08	0.08	0.09	0.01
	5Y	0.14	0.11	0.10	0.10	-0.04	0.13	0.11	0.11	0.11	-0.02
	10Y	0.19	0.15	0.15	0.14	-0.05	0.17	0.17	0.15	0.14	-0.03
Maximum Drawdown (%)	1Y	21.99	28.02	24.71	23.64	1.64	23.33	23.72	25.08	26.23	2.90
	5Y	33.04	32.05	29.47	27.50	-5.54	31.42	30.87	29.99	29.78	-1.63
	10Y	41.33	39.12	37.72	35.22	-6.11	39.34	39.63	37.64	36.78	-2.55
Sharpe Ratio	1Y	0.25	0.28	0.18	0.10	-0.15	0.22	0.22	0.28	0.09	-0.14
	5Y	0.43	0.55	0.45	0.39	-0.03	0.51	0.46	0.52	0.32	-0.18
	10Y	0.43	0.65	0.63	0.56	0.14	0.62	0.53	0.65	0.48	-0.14
Kurtosis	1Y	3.27	3.14	2.73	3.12	-0.16	3.02	2.92	3.00	3.32	0.30
	5Y	3.05	3.00	2.62	3.20	0.16	3.13	2.93	2.49	3.31	0.18
	10Y	2.97	3.46	3.35	3.94	0.97	3.49	3.59	2.80	3.85	0.36
Skewness	1Y	0.18	-0.39	-0.28	0.27	0.09	0.10	-0.29	-0.25	0.22	0.12
	5Y	0.40	-0.18	-0.10	0.60	0.20	0.23	0.12	-0.05	0.43	0.20
	10Y	0.43	0.41	0.59	1.02	0.58	0.48	0.76	0.34	0.87	0.39

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		Social					Governance				
	Bond Maturity	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1
Annualized Return (%)	1Y	1.24	0.37	0.79	1.24	0.00	2.48	2.17	1.35	3.13	0.64
	5Y	6.63	2.60	4.00	4.06	-2.58	6.74	6.01	4.04	6.14	-0.60
	10Y	11.14	6.03	8.10	7.22	-3.92	10.06	10.06	7.70	9.64	-0.43
Volatility (%)	1Y	0.07	0.08	0.08	0.09	0.02	0.08	0.07	0.08	0.09	0.01
	5Y	0.12	0.11	0.11	0.11	0.00	0.14	0.10	0.10	0.11	-0.03
	10Y	0.17	0.16	0.16	0.15	-0.02	0.20	0.14	0.14	0.15	-0.06
Maximum Drawdown (%)	1Y	20.30	24.98	25.20	27.87	7.57	23.89	21.16	24.73	28.57	4.68
	5Y	29.27	30.62	30.14	32.02	2.75	35.28	26.64	27.76	32.38	-2.90
	10Y	37.95	38.18	38.91	38.34	0.39	43.90	36.27	34.91	38.31	-5.59
Sharpe Ratio	1Y	0.22	0.14	0.24	0.23	0.01	0.27	0.20	0.09	0.26	-0.01
	5Y	0.57	0.34	0.47	0.43	-0.14	0.45	0.53	0.37	0.47	0.01
	10Y	0.61	0.51	0.61	0.54	-0.07	0.50	0.65	0.53	0.59	0.09
Kurtosis	1Y	3.16	3.15	2.95	3.01	-0.16	2.74	3.15	3.27	3.10	0.36
	5Y	3.08	3.20	2.68	2.90	-0.18	3.47	2.46	2.91	3.03	-0.43
	10Y	3.62	3.66	3.16	3.30	-0.32	4.04	3.10	3.24	3.36	-0.68
Skewness	1Y	0.24	-0.03	-0.26	-0.17	-0.41	-0.16	-0.04	0.09	-0.11	0.04
	5Y	0.52	0.23	-0.03	0.00	-0.52	0.62	-0.04	0.09	0.05	-0.57
	10Y	0.81	0.71	0.49	0.45	-0.36	1.01	0.49	0.50	0.45	-0.56

Exhibit 5.8 reports the annualized expected returns in %, the volatility in %, the max drawdown in %, the Sharpe ratio, skewness and kurtosis for each ESG quartile over the period 2010–2020, as well as the difference between the quartiles with the best and poorest ESG profiles (Q4–Q1).

Exhibits 5.9 to 5.12 show the annualized returns in % of the Economic, Environmental, Social and Governance quartiles over the period 2010–2020 for developed countries.

Exhibit 5.9: Annualised Returns in % of Economics Sorted Quartiles

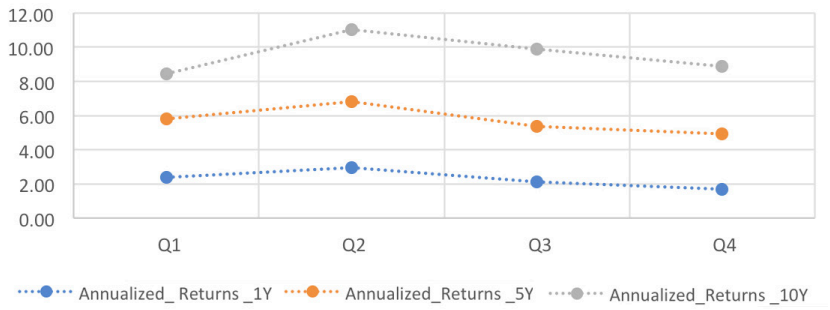

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Exhibit 5.10: Annualised Returns in % of Environment Sorted Quartiles

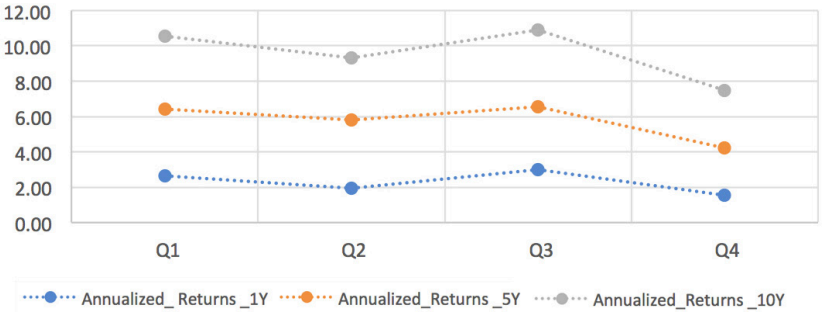

Exhibit 5.11: Annualised Returns in % of Social Sorted Quartiles

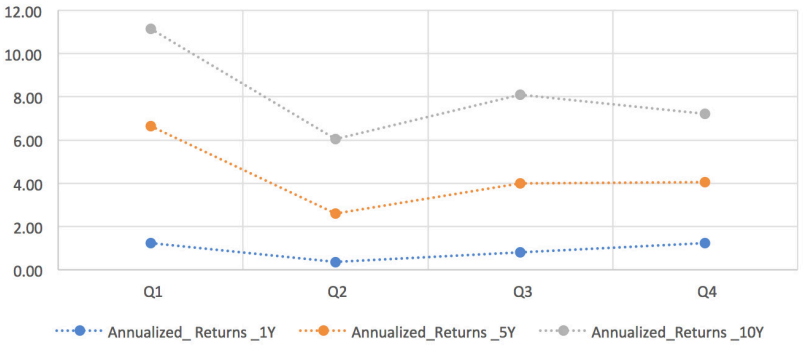

Exhibit 5.12: Annualised Returns in % of Governance Sorted Quartiles

Exhibit 5.13 reports the annualized expected returns in %, the volatility in %, the max drawdown in %, the Sharpe Ratio, skewness and kurtosis for each Economic, Environmental, Social and Governance quartile over the period 2010–2020, as well as the difference between the quartiles with the best and poorest Economic, Environmental, Social and Governance profiles (Q4–Q1).

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Exhibit 5.13: Annualized expected returns in %, volatility in %, max drawdown in %, Sharpe Ratio, skewness and kurtosis for each emerging country's ESG quartiles over the period 2010–2020, as well as the difference between the quartiles with the best and poorest ESG profiles (Q4–Q1)

		Economics					Environment				
	Bond Maturity	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1
Annualized Return (%)	1Y	10.01	8.72	5.82	4.28	-5.73	6.52	11.43	6.78	3.83	-2.69
	5Y	12.90	12.46	10.29	6.68	-6.23	9.71	15.61	10.31	6.56	-3.15
	10Y	14.64	15.71	13.59	7.97	-6.67	12.05	17.98	13.09	9.07	-2.98
Volatility (%)	1Y	0.12	0.12	0.12	0.13	0.01	0.12	0.16	0.10	0.11	-0.01
	5Y	0.12	0.12	0.12	0.13	0.01	0.11	0.14	0.11	0.13	0.02
	10Y	0.15	0.16	0.15	0.14	-0.01	0.13	0.18	0.14	0.16	0.03
Maximum Drawdown (%)	1Y	32.44	31.25	30.31	33.27	0.84	31.34	37.96	27.10	30.07	-1.28
	5Y	31.37	31.06	31.23	33.88	2.51	28.96	33.96	30.39	34.37	5.41
	10Y	35.81	35.12	35.12	37.00	1.19	33.05	36.93	33.68	40.18	7.13
Sharpe Ratio	1Y	0.63	0.63	0.38	0.25	-0.37	0.43	0.60	0.55	0.31	-0.11
	5Y	0.88	0.92	0.70	0.43	-0.44	0.75	0.95	0.77	0.47	-0.29
	10Y	0.82	0.90	0.79	0.52	-0.31	0.80	0.90	0.81	0.51	-0.29
Kurtosis	1Y	3.15	3.12	2.78	2.60	-0.55	2.65	3.53	2.73	2.79	0.15
	5Y	3.62	3.76	3.13	2.76	-0.86	3.37	4.05	2.98	2.90	-0.47
	10Y	2.55	3.41	3.49	3.28	0.73	2.75	3.46	3.23	3.27	0.52
Skewness	1Y	0.02	0.37	0.13	-0.01	-0.03	0.22	0.71	-0.05	-0.50	-0.71
	5Y	-0.70	0.11	0.11	-0.13	0.57	-0.55	0.06	0.12	-0.26	0.29
	10Y	-0.39	0.65	0.55	0.04	0.44	-0.13	0.30	0.43	0.33	0.45
		Social					Governance				
	Bond Maturity	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1	Q1 (Worst)	Q2	Q3	Q4 (Best)	Q4-Q1
Annualized Return (%)	1Y	8.21	10.42	5.83	4.06	-4.15	7.50	10.58	6.15	4.48	-3.02
	5Y	12.34	14.22	9.40	6.13	-6.20	11.66	14.54	9.07	6.95	-4.70
	10Y	14.59	16.88	12.22	8.26	-6.32	14.38	17.11	12.02	8.29	-6.09
Volatility (%)	1Y	0.15	0.13	0.12	0.09	-0.06	0.14	0.13	0.10	0.12	-0.01
	5Y	0.13	0.12	0.13	0.11	-0.03	0.12	0.13	0.12	0.13	0.00
	10Y	0.16	0.15	0.16	0.14	-0.02	0.16	0.16	0.15	0.13	-0.03
Maximum Drawdown (%)	1Y	35.66	33.32	30.81	25.55	-10.12	33.44	33.01	28.49	32.02	-1.43
	5Y	32.39	30.01	34.02	30.21	-2.18	30.47	32.16	31.98	32.62	2.15
	10Y	36.03	33.35	36.86	36.76	0.73	35.67	35.42	37.13	34.10	-1.58
Sharpe Ratio	1Y	0.46	0.46	0.49	0.35	-0.11	0.44	0.66	0.50	0.29	-0.14
	5Y	0.78	0.78	0.66	0.49	-0.29	0.83	0.95	0.68	0.48	-0.34
	10Y	0.75	0.75	0.70	0.54	-0.22	0.81	0.91	0.73	0.60	-0.21
Kurtosis	1Y	3.31	2.99	2.55	2.88	-0.43	3.26	2.98	2.65	2.83	-0.43
	5Y	3.70	3.77	2.89	2.95	-0.76	3.83	3.45	2.99	3.07	-0.76
	10Y	3.37	2.78	3.38	3.16	-0.21	3.24	3.00	3.56	2.80	-0.44
Skewness	1Y	0.66	0.44	-0.12	-0.63	-1.29	0.53	0.31	-0.31	-0.03	-0.56
	5Y	0.09	-0.44	0.10	-0.41	-0.49	-0.18	-0.20	-0.14	-0.05	0.14
	10Y	0.39	-0.18	0.54	0.13	-0.26	0.46	0.13	0.34	-0.11	-0.56

5. Analysis of the Impact of ESG on Risk and Return

Exhibits 5.14 to 5.17 show the annualized returns in % of the Economic, Environmental, Social and Governance quartiles over the period 2010–2020 for emerging countries.

Exhibit 5.14: Annualised Returns in % of Economic Sorted Quartiles

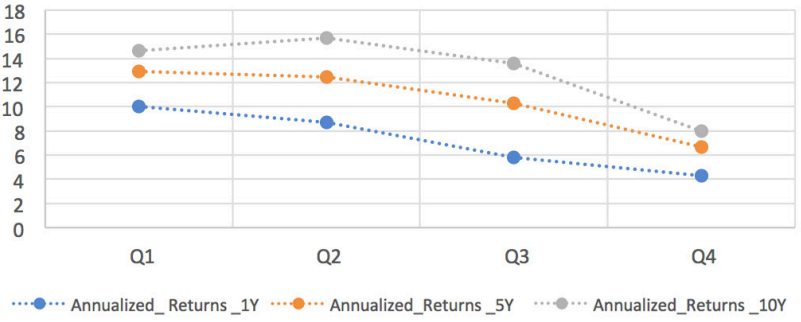


Exhibit 5.15: Annualised Returns in % of Environmental Sorted Quartiles

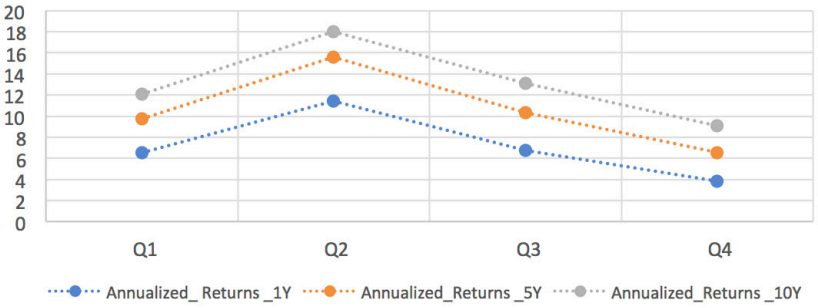


Exhibit 5.16: Annualised Returns in % of Social Sorted Quartiles

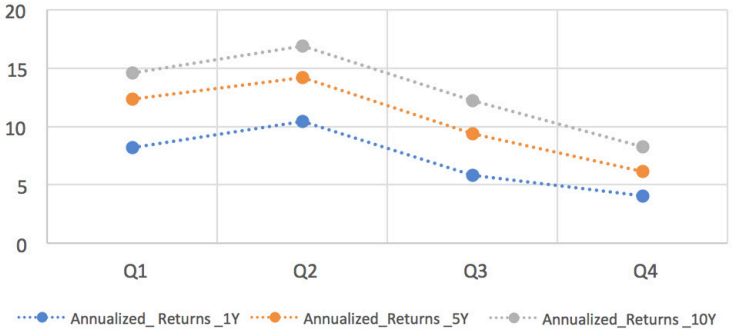
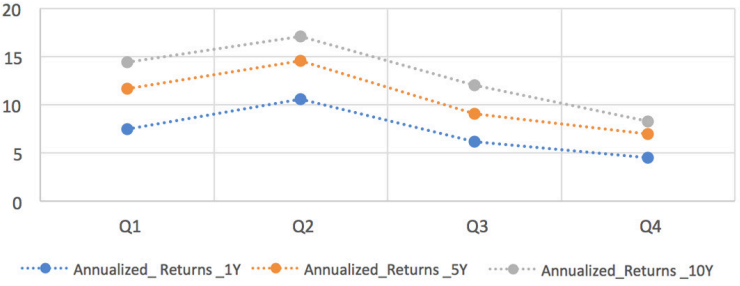


Exhibit 5.17: Annualised Returns in % of Politics Sorted Quartiles



5. Analysis of the Impact of ESG on Risk and Return

Appendices A.5.31 to A.5.38 show the cumulative returns of the Economic, Environmental, Social and Governance quartiles for developed countries over the period 2010–2020.

For both developed and emerging countries, we find that annualized returns are lower for the best ESG quartiles (Q4) than the worst ESG quartiles (Q1). Moreover, the difference is higher for emerging countries than developed countries. Regarding bond maturities, the difference between the two quartiles is higher for long-term bonds (10-year maturity bonds), an intuitive result given that the longer maturity magnifies the effect under consideration. In other words, we confirm that a negative risk premium is associated with each ESG dimension for both developed and emerging countries. This result implies that investors seeking to improve the E, S and/or G scores of their portfolio will face an opportunity cost that will translate into lower performance.

This lower performance is naturally associated with lower risk. Indeed, we find that on average bonds in the best ESG quartiles (Q4) are less volatile than those in the worst (Q1) for all maturities and for both developed and emerging countries. We also find that on average bonds in the best ESG quartiles (Q4) have a lower max drawdown than those in the worst (Q1), a result which again holds for all maturities and for both developed and emerging countries.

Combining the impact on risk and performance, we also find that on average bonds in the best ESG quartiles (Q4) have a higher Sharpe Ratio than those in the worst (Q1), a result which is robust to changes in bond maturities and regions (both developed and emerging countries).

5.2.2.2. Regression analyses controlling for economic scores

A complementary analysis is necessary to control for differences in Economic scores so as to better isolate the impact of non-financial dimensions. With only 20 developed countries and 15 emerging countries in our dataset, we opt for a regression analysis instead of a double sorted methodology to control for Economic scores. We first perform univariate regressions before moving on to multivariate regressions where Economic scores are used as control variables.

5.2.2.2.1 Univariate Regression Analysis

In this section, we want to examine whether investors can potentially benefit from cross-sectional differences in Environmental, Social and Governance dimensions.

We explore the impact of ESG scores on bond returns for different bond maturities (1-year, 5-year and 10-year), and level of country development (developed versus emerging markets).

To this end we first conduct a standard univariate regression analysis to investigate the linear relationship between bond returns and Environmental, Social and Governance dimensions.

The regression model is of the following form:

$$Ret_{i,t} = \beta_0 + \beta_{ESGDim} ESGDim_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

where

i = 1 to n (the number of countries) and t = 1 to T (the number of periods)

$ESGDim_{i,t-1}$: lagged Environmental, Social or Governance dimension from Verisk database

$\varepsilon_{i,t}$: error term

β_0:constant

5. Analysis of the Impact of ESG on Risk and Return

In Appendices A.5.39 to A.5.44, we present scatterplots showing the relationship between Economic, Environmental, Social and Governance scores and bond returns per country over the sample period 2010–2020.

In Exhibit 5.18 we present the results of the estimation of the relationship between Economic, E, S and G scores and bond returns per country over the sample period 2010–2020 for developed and emerging countries.

Exhibit 5.18: OLS regression results for 1-year, 5-year and 10-year bond returns against Economic, Environmental, Social and Governance scores for 20 developed countries and 15 emerging countries over the period 2010–2020

Developed Countries			
	Bond Returns Ret_(i,t)		
	1Y	5Y	10Y
	Economic		
Eco_(i,t-1)	-0.009	-0.021**	-0.021
	(0.007)	(0.010)	(0.014)
β_0	1.084***	1.194***	1.242***
	(0.041)	(0.063)	(0.089)
Observations	200	200	200
Countries	20	20	20
R-sq	0.008	0.020	0.011
	Environment		
Env_(i,t-1)	-0.004	-0.010	-0.012
	(0.007)	(0.011)	(0.015)
β_0	1.062***	1.139***	1.196***
	(0.048)	(0.075)	(0.104)
Observations	200	200	200
Countries	20	20	20
R-sq	0.002	0.005	0.003
	Social		
Soc_(i,t-1)	0.003	-0.004	-0.006
	(0.006)	(0.009)	(0.013)
β_0	1.009***	1.97***	1.158***
	(0.044)	(0.069)	(0.096)
Observations	200	200	200
Countries	20	20	20
R-sq	0.001	0.001	0.001
	Governance		
Gov_(i,t-1)	0.001	-0.010	-0.016
	(0.006)	(0.010)	(0.014)
β_0	1.025***	1.148***	1.233***
	(0.050)	(0.078)	(0.108)
Observations	200	200	200
Countries	20	20	20
R-sq	0.001	0.005	0.007

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

Emerging Countries			
	Bond Returns Ret_(i,t)		
	1Y	5Y	10Y
	Economics		
Eco_(i,t-1)	-0.035**	-0.04***	-0.045**
	(0.016)	(0.015)	(0.019)
β_0	1.298***	1.361***	1.419***
	(0.096)	(0.092)	(0.113)
Observations	150	150	150
Countries	15	15	15
R-sq	0.032	0.045	0.038
	Environment		
Env_(i,t-1)	-0.016	-0.017	-0.014
	(0.012)	(0.012)	(0.014)
β_0	1.173***	1.213***	1.223***
	(0.067)	(0.064)	(0.079)
Observations	150	150	150
Countries	15	15	15
R-sq	0.012	0.014	0.006
	Social		
Soc_(i,t-1)	-0.022***	-0.021***	-0.017**
	(0.007)	(0.006)	(0.008)
β_0	1.184***	1.215***	1.224***
	(0.032)	(0.031)	(0.038)
Observations	150	150	150
Countries	15	15	15
R-sq	0.066	0.068	0.031
	Governance		
Gov_(i,t-1)	-0.022*	-0.029**	-0.032**
	(0.012)	(0.012)	(0.014)
β_0	1.214***	1.289***	1.329***
	(0.072)	(0.068)	(0.084)
Observations	150	150	150
Countries	15	15	15
R-sq	0.021	0.041	0.032

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

5. Analysis of the Impact of ESG on Risk and Return

Overall, we find that for developed countries no dimensions are significant, while for emerging countries the Social dimension is significant with a negative coefficient for all bond maturities (higher Social scores are associated with lower bond returns) and Governance is significant with a negative coefficient for 5-year and 10-year bond maturities (higher Governance scores are associated with lower bond returns). These results suggest that the negative relationship that we have found through a portfolio sorting procedure between E, S and G scores with both risk and performance indicators is not of a linear nature.

5.2.2.2.2 Multivariate Regression Analysis: Identifying the Most Important Dimension

We now want to examine whether investors can potentially benefit from cross-sectional differences in Environmental, Social and Governance dimensions, controlling for Economics. To do this we turn to a multivariate regression analysis to explore to what extent ESG dimensions influence sovereign bond returns in addition to information already contained in the fundamentals.

While section 5.2.2.2.1. gave us our first insight into the linear relationship between bond returns and each dimension, a necessary preliminary step before conducting any regression is to compute a correlation matrix between the main variables. This helps to identify potential multicollinearity issues to address.

As shown in Section 5.2.1.2, for developed countries the three non-financial/non-economic dimensions, Environmental, Social and Governance, are all positively correlated but the correlation is not perfect, which suggests that we need to include these dimensions at the same time in the regressions and in addition to Economics. Moreover, these three dimensions are positively correlated to Economics with correlation coefficients of 53%, 28% and 43% for Environment, Social and Governance, respectively.

Exhibit 5.19 also shows that no dimensions are strongly linearly correlated with bond returns, regardless of maturity.

Exhibit 5.19: Correlation matrix of bond returns and Economic, Environmental, Social and Governance dimensions for developed countries over the sample period 2010–2020

	1Y-R	5Y-R	10Y-R	Economics	Environment	Social	Governance
1Y-R	1						
5Y-R	0.83**	1					
10Y-R	0.72**	0.96**	1				
Economics	-0.09	-0.14**	-0.10	1			
Environment	-0.04	-0.07	-0.06	0.53**	1		
Social	0.04	-0.03	-0.04	0.28**	0.64**	1	
Governance	0.01	-0.07	-0.08	0.43**	0.59**	0.78**	1

*Note: Developed Countries. ** significant at 5%.*

5. Analysis of the Impact of ESG on Risk and Return

Exhibit 5.20: Correlation matrix of bond yield spreads and Economic, Environmental, Social and Governance dimensions for emerging countries over the sample period 2010–2020

	1Y-R	5Y-R	10Y-R	Economics	Environment	Social	Governance
1Y-R	1						
5Y-R	0.85**	1					
10Y-R	0.59**	0.90**	1				
Economics	-0.18**	-0.21**	-0.19**	1			
Environment	-0.11	-0.12	-0.08	-0.12	1		
Social	-0.26**	-0.26**	-0.17**	0.01	0.72**	1	
Governance	-0.15	-0.20**	-0.18**	0.06	0.49**	0.66**	1

*Note: Emerging Countries. ** significant at 5%..*

As shown previously in Section 5.2.1.2, for emerging countries the three non-financial/non-economic dimensions, Environmental, Social and Governance, are all positively correlated but the correlation is not perfect, which suggests that we need to include these dimensions at the same time in the regressions and in addition to Economics. Moreover, these three dimensions are not all positively correlated to Economics with correlation coefficients of -12%, 1% and 6% for Environment, Social and Governance, respectively.

Exhibit 5.20 shows that the Economic, Social and Governance dimensions are linearly correlated with bond returns.

Our aim is to explore the financial impact of each dimension – Environment, Social and Governance – on sovereign bond returns.

Our main analysis consists in estimating a fixed-effects panel regression model including ESG dimensions as explanatory variables. Economics is used as a control variable to isolate the impact of the other three dimensions on bond returns.

Our dataset is a panel that includes a group of 20 developed countries and 15 emerging countries observed over a period of 10 years. The structure of the dataset includes both a country dimension and a time dimension.

We performed a Hausman test which indicates that a fixed-effects model needs to be estimated instead of a random effects model. Indeed, the test for the non-existence of fixed effects rejects the null hypothesis and concludes with the existence of country-specific effects.[16]

The three Verisk dimensions that are used as proxies for ESG criteria are also lagged for robustness.

16 - For further research, we could test for the presence of time-specific fixed effects.

5. Analysis of the Impact of ESG on Risk and Return

The fixed-effects panel model regression is of the following form:

$$Ret_{i,t} = \beta_0 + \beta_{Eco}Eco_{i,t-1} + \beta_{Env}Env_{i,t-1} + \beta_{Social}Soc_{i,t-1} + \beta_{Gov}Gov_{i,t-1} + \alpha_i + \mu_{i,t} \quad (4)$$

where

i = 1 to n (the number of countries) and t = 1 to T (the number of periods)

$Ret_{i,t}$: sovereign bond returns of country i at time t

$Eco_{i,t-1}$: lagged Economic dimension obtained from Verisk database

$Env_{i,t-1}$: lagged Environmental dimension obtained from Verisk database

$Soc_{i,t-1}$: lagged Social dimension obtained from Verisk database

$Gov_{i,t-1}$: lagged Governance dimension obtained from Verisk database

α_i: (unobserved) country-specific fixed effect allowing us to take into account unobservable variables that are specific to country i and time invariant

$\mu_{i,t}$: error term

β_0:constant

The results of the panel regression model (2) are presented below, in Exhibit 5.21 for developed countries and Exhibit 5.22 for emerging countries.

Exhibit 5.21: Model estimates of equation (4) for developed countries

Developed Countries			
	Bond Returns Ret_(i,t)		
	1Y	5Y	10Y
Eco_(i,t-1)	-4.22E-06	-0.045	-0.030
	(0.021)	(0.033)	(0.048)
Env_(i,t-1)	-0.110***	-0.082	-0.051
	(0.037)	(0.058)	(0.083)
Soc_(i,t-1)	-0.017	-0.049	-0.078
	(0.0245)	(0.038)	(0.055)
Gov_(i,t-1)	-0.096**	-0.139**	-0.201**
	(0.038)	(0.060)	(0.086)
β_0	2.683***	3.378***	3.822***
	(0.370)	(0.577)	(0.827)
Observations	200	200	200
Countries	20	20	20
Fixed effects	Yes	Yes	Yes
R-sq	0.118	0.102	0.074

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

Exhibit 5.22: Model estimates of equation (4) for emerging countries.

Emerging Countries			
	Bond Returns Ret_(i,t)		
	1Y	5Y	10Y
Eco_(i,t-1)	-0.061	-0.052	-0.046
	(0.041)	(0.038)	(0.049)
Env_(i,t-1)	-0.012	-0.081	-0.125*
	(0.061)	(0.057)	(0.075)
Soc_(i,t-1)	-0.082***	-0.047**	-0.017
	(0.023)	(0.021)	(0.028)
Gov_(i,t-1)	0.011	-0.022	-0.044
	(0.035)	(0.033)	(0.044)
β_0	1.835***	2.222***	2.439***
	(0.434)	(0.403)	(0.530)
Observations	150	150	150
Countries	15	15	15
Fixed effects	Yes	Yes	Yes
R-sq	0.144	0.112	0.056

*Standard Deviation in parentheses. Level of significance: *10%, **5%, ***1%.*

5. Analysis of the Impact of ESG on Risk and Return

Our estimation results allow us to reach two main conclusions. On the one hand, Environmental and Governance scores have a significant and negative impact on bond returns for developed countries after controlling for economic scores and other fixed effects. On the other hand, Social scores have a significant and negative impact on bond returns for emerging countries after controlling for economic scores and other fixed effects.

In more detail regarding developed countries, Governance is significant with a negative coefficient for all bond maturities, while Environment is significant with a negative coefficient (-0.10) only for 1-year bond maturity. While the results are similar across bond maturities (in terms of significance), the magnitude of the Governance score coefficients changes with the bond maturity: -0.10 for 1-year, -0.14 for 5-year and -0.20 for 10-year bond yield spreads. The impact of the Governance dimension on bond returns is more pronounced in the long run. Social and Economic (the control variable) scores do not appear significant.

Regarding emerging countries, the Social dimension impacts bond returns with a negative coefficient for 1-year and 5-year bond maturity. The magnitude of the Social score coefficients changes with the bond maturity: -0.08 for 1-year and -0.05 for 5-year bond yield spreads. The impact of the Social dimension on bond returns is more pronounced in the short run. Environmental, Governance and Economic (the control variable) scores do not appear significant.

6. Implications for Sovereign Bond Portfolio Management

6. Implications for Sovereign Bond Portfolio Management

The results in the previous section suggest that cross-sectional differences in E, S or G scores translate into cross-sectional differences in the risk and performance characteristics of sovereign bond portfolios. In this section we explore the implications of these findings for various investment strategies seeking to incorporate ESG constraints. In particular we are interested in measuring and minimizing the opportunity costs associated with the introduction of such constraints with respect to an otherwise comparable unconstrained sovereign bond portfolio strategy. Finally, we also analyze the benefits of ESG momentum strategies, defined as strategies designed to exploit time-series differences in ESG scores, as opposed to exploiting cross-sectional differences in these scores.

6.1. Measuring and Managing the Opportunity Costs of ESG Constraints

While ESG investing is sometimes presented as an *opportunity for higher performance*, it has to be recognized that ESG scores are strictly speaking to be regarded instead as *performance constraints*, which need to be applied at the security selection and/or portfolio construction stages. As such, the integration of ESG dimensions in an investment decision framework suggests that an opportunity cost should be incurred compared to a portfolio that would be optimally formed in the absence of ESG considerations. The main focus of this Section is to analyze how implementation choices regarding how ESG criteria are incorporated into a portfolio can have a direct impact on this opportunity cost.

6.1.1. Integrating ESG Constraints at the Selection Stage

A first approach to the introduction of ESG criteria into the investment process is to include them at the selection stage. In this context, an investor or portfolio manager may wish to increase the E, S and/or G score of a portfolio by applying a set of investment screens, designed to either exclude (negative screening) or select (positive screening) sovereign bonds from the investment universe on the basis of their ESG scores.

In other words, a negative screening, or "ESG worst-in-class exclusion", approach, involves excluding from a portfolio a number of countries (say the last decile or quartile) that perform poorly in terms of ESG scores. A drawback of this negative exclusion approach is that it tends to have a relatively modest impact on the global ESG score of the portfolio since relatively few assets are excluded. On the other hand, it allows the investor to enjoy a relatively high level of diversification. Conversely, a positive screening, or "ESG best-in-class inclusion", approach involves only including in the portfolio countries with the highest ESG scores (say the top decile or quartile). A drawback of this positive screening approach is that it can be too exclusive, and just focusing on better ESG countries can easily result in a pool of highly correlated and geographically concentrated countries, with lower associated diversification benefits. However, the impact in terms of improvement on ESG scores is expected to be greater given the focus on the relatively few sovereign bonds that have the highest ESG scores.

There is a key distinction to make between an ESG approach based on negative/positive

6. Implications for Sovereign Bond Portfolio Management

screening with a regional neutrality constraint and one without such a constraint. In the latter case, geographical biases would arise from a straightforward positive or negative screening process. For this reason, in what follows we build portfolios of 5-year maturity sovereign bonds separately for developed and emerging countries, as opposed to selecting sovereign bonds in a global universe mixing developed and emerging economies.

More precisely, for each region (developed and emerging) we sort sovereign bonds based on the four available dimensions, namely Economic, Environmental, Social and Governance, and for each one we form four quartiles. Quartile Q1 corresponds to the 25% lowest-ranked bonds, whereas quartile Q4 corresponds to the 25% best-rated bonds. Our negative screening strategy is to exclude the 25% lowest-ranked bonds (Q1). The selected bonds, corresponding to the 75% best-ranked bonds (Q2, Q3 and Q4), are then equally weighted, and the portfolios are rebalanced on an annual basis, which is consistent with the fact that Verisk scores are updated on an annual basis. Our positive screening strategy consists of selecting the 25% best-ranked bonds (Q4). The selected bonds are then equally weighted, and the portfolios are rebalanced on an annual basis. We use an equally-weighted portfolio of all quartiles, which is also rebalanced on an annual basis, as a benchmark portfolio for developed and emerging countries.

In Exhibits 6.1 to 6.3, for each sovereign bond portfolio (benchmark portfolios, negative and positive screening strategies) associated with each selection/exclusion criterion, we report the following indicators: annualized mean return, annualized volatility, Sharpe ratio, information ratio, maximum return, minimum return and maximum drawdown over the period 2010–2020. We also report the Economic, Environmental, Social and Governance scores associated with each portfolio over the period 2010–2020.

Exhibit 6.1: Benchmark results over the sample period 2010–2020 for developed and emerging countries

Benchmark								
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.46				12.60			
Annualized Volatility (%)	8.76				6.68			
Sharpe Ratio	0.85				1.89			
Max Drawdown (%)	71.66				42.20			
Benchmark Score (mean)	Eco	E	S	G	Eco	E	S	G
	6.15	7.00	7.68	7.83	6.04	5.47	4.55	5.84

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Exhibit 6.2: Results of the negative screening strategy over the sample period 2010–2020 for developed and emerging countries

Negative Screening								
	Economics							
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.20				11.54			
Annualized Volatility (%)	9.32				7.15			
Portfolio Annualized Return - Benchmark (%)	-0.25				-1.06			
Sharpe Ratio	0.77				1.61			
Tracking Error (%)	1.40				1.36			
Information Ratio	-0.18				-0.78			
Max Return (%)	9.50				7.76			
Min Return (%)	-6.74				-3.62			
Max Drawdown (%)	70.88				46.62			
	Economics	Environment	Social	Governance	**Economics**	Environment	Social	Governance
Score (mean)	**6.45**	7.15	7.88	8.04	**6.37**	5.47	4.58	5.90
Benchmark Score (mean)	**6.15**	7.00	7.68	7.83	**6.04**	5.47	4.55	5.84
Diff Score / Benchmark Score (%)	**4.92**	2.18	2.64	2.71	**5.51**	0.17	0.56	1.03

	Environment							
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.78				12.80			
Annualized Volatility (%)	9.14				7.69			
Portfolio Annualized Return - Benchmark (%)	0.32				0.20			
Sharpe Ratio	0.85				1.66			
Tracking Error (%)	1.11				1.96			
Information Ratio	0.29				0.10			
Max Return (%)	9.20				8.80			
Min Return (%)	-5.84				-4.43			
Max Drawdown (%)	63.50				50.32			
	Economics	**Environment**	Social	Governance	Economics	**Environment**	Social	Governance
Score (mean)	6.27	**7.30**	7.92	7.94	5.91	**5.92**	5.01	6.02
Benchmark Score (mean)	6.15	**7.00**	7.68	7.83	6.04	**5.47**	4.55	5.84
Diff Score / Benchmark Score (%)	1.90	**4.31**	3.19	1.44	-2.13	**8.39**	10.11	3.08

	Social							
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.48				11.92			
Annualized Volatility (%)	9.60				7.63			
Portfolio Annualized Return - Benchmark (%)	0.02				-0.68			
Sharpe Ratio	0.78				1.56			
Tracking Error (%)	1.15				1.89			
Information Ratio	0.02				-0.36			
Max Return (%)	9.42				9.34			
Min Return (%)	-6.99				-4.35			
Max Drawdown (%)	74.20				46.57			
	Economics	Environment	**Social**	Governance	Economics	Environment	**Social**	Governance
Score (mean)	6.33	7.24	**8.08**	8.16	6.03	5.71	**5.15**	6.19
Benchmark Score (mean)	6.15	7.00	**7.68**	7.83	6.04	5.47	**4.55**	5.84
Diff Score / Benchmark Score (%)	2.98	3.39	**5.24**	4.22	-0.13	4.47	**13.15**	5.94

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	Governance							
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.23				12.05			
Annualized Volatility (%)	9.05				7.96			
Portfolio Annualized Return - Benchmark (%)	-0.23				-0.55			
Sharpe Ratio	0.80				1.51			
Tracking Error (%)	1.47				1.98			
Information Ratio	-0.16				-0.28			
Max Return (%)	9.56				9.75			
Min Return (%)	-5.98				-4.60			
Max Drawdown (%)	62.59				47.15			
	Economics	Environment	Social	**Governance**	Economics	Environment	Social	**Governance**
Score (mean)	6.32	7.22	8.00	**8.22**	5.99	5.78	5.09	**6.24**
Benchmark Score (mean)	6.15	7.00	7.68	**7.83**	6.04	5.47	4.55	**5.84**
Diff Score / Benchmark Score (%)	2.74	3.14	4.14	**4.96**	-0.78	5.78	11.65	**c**

Exhibit 6.3: Results of the positive screening strategy over the sample period 2010–2020 for developed and emerging countries

Positive Screening								
	Economics							
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.77				11.37			
Annualized Volatility (%)	9.22				8.15			
Portfolio Annualized Return - Benchmark (%)	-1.68				-1.23			
Sharpe Ratio	0.63				1.40			
Tracking Error (%)	2.69				1.36			
Information Ratio	-0.63				-0.28			
Max Return (%)	10.99				9.85			
Min Return (%)	-6.26				-4.13			
Max Drawdown (%)	56.97				41.90			
	Economics	Environment	Social	Governance	**Economics**	Environment	Social	Governance
Score (mean)	**7.19**	7.47	7.78	8.16	**6.89**	4.96	4.39	5.78
Benchmark Score (mean)	**6.15**	7.00	7.68	7.83	**6.04**	5.47	4.55	5.84
Diff Score / Benchmark Score (%)	**16.93**	6.68	1.28	4.19	**13.97**	-9.18	-3.52	-0.97

	Environment							
	Developed Countries				Emerging Countries			
Annualized Return (%)	6.55				9.49			
Annualized Volatility (%)	6.71				11.05			
Portfolio Annualized Return - Benchmark (%)	-0.90				-3.11			
Sharpe Ratio	0.98				0.86			
Tracking Error (%)	6.58				1.96			
Information Ratio	-0.14				-0.56			
Max Return (%)	7.34				12.63			
Min Return (%)	-3.73				-7.83			
Max Drawdown (%)	50.78				61.96			
	Economics	**Environment**	Social	Governance	Economics	**Environment**	Social	Governance
Score (mean)	6.98	**8.00**	8.26	8.49	6.49	**6.46**	6.27	6.55
Benchmark Score (mean)	6.15	**7.00**	7.68	7.83	6.04	**5.47**	4.55	5.84
Diff Score / Benchmark Score (%)	13.41	**14.28**	7.58	8.51	7.38	**18.21**	37.76	12.12

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	Social							
	Developed Countries				Emerging Countries			
Annualized Return (%)	8.19				8.73			
Annualized Volatility (%)	10.00				10.85			
Portfolio Annualized Return - Benchmark (%)	0.73				-3.87			
Sharpe Ratio	0.82				0.80			
Tracking Error (%)	2.67				1.89			
Information Ratio	0.27				-0.74			
Max Return (%)	10.59				11.17			
Min Return (%)	-6.98				-7.25			
Max Drawdown (%)	65.95				64.94			
	Economics	Environment	**Social**	Governance	Economics	Environment	**Social**	Governance
Score (mean)	6.55	7.57	**8.52**	8.64	5.96	6.27	**6.83**	6.60
Benchmark Score (mean)	6.15	7.00	**7.68**	7.83	6.04	5.47	**4.55**	5.84
Diff Score / Benchmark Score (%)	6.41	8.11	**10.89**	10.35	-1.33	14.72	**50.03**	13.03

	Governance							
	Developed Countries				Emerging Countries			
Annualized Return (%)	8.58				10.31			
Annualized Volatility (%)	10.39				9.02			
Portfolio Annualized Return - Benchmark (%)	1.12				-2.29			
Sharpe Ratio	0.83				1.14			
Tracking Error (%)	3.39				1.98			
Information Ratio	0.33				-0.49			
Max Return (%)	10.82				12.16			
Min Return (%)	-6.45				-4.70			
Max Drawdown (%)	59.62				38.70			
	Economics	Environment	Social	**Governance**	Economics	Environment	Social	**Governance**
Score (mean)	6.60	7.67	8.46	**8.70**	6.43	5.72	5.05	**7.00**
Benchmark Score (mean)	6.15	7.00	7.68	**7.83**	6.04	5.47	4.55	**5.84**
Diff Score / Benchmark Score (%)	7.21	9.60	10.11	**11.12**	6.42	4.65	10.93	**19.86**

Starting with the negative screening strategy, we find that for each dimension the annualized performance of the ESG e nhanced portfolio remains close to or slightly lower than the annualized return of the benchmark portfolio for both developed and emerging countries. On the other hand, the annualized volatility is systematically higher than that of the benchmark portfolios, reflecting a lower level of diversification without a strong corresponding impact on ESG scores (see below). For each dimension, the Sharpe ratio for both developed and emerging countries is equal to or slightly lower than their benchmarks.

Moreover, for each dimension we confirm that, as expected, the E, S and G scores are systematically higher for the negative screening

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strategy, compared to their benchmarks. Excluding the 25% worst-ranked bond results only has a relatively modest impact in terms of Environmental, Social or Governance criteria. For both developed and emerging countries, among these criteria the highest increase is for the Social dimension (+5.24% and +13.15%, respectively) and the lowest increase is for the Environmental dimension for developed countries (+4.31%) and the Governance dimension for emerging countries (+6.76%).

> ...we confirm that the scores are systematically higher than the benchmark portfolios...

These results imply that increasing the sustainability (Environmental, Social and Governance criteria taken separately) of a portfolio using negative screening does not do much harm to returns and increases volatility by 0.5% on average for developed countries and 0.9% for emerging countries. However, the increase in the Environmental, Social and Governance scores remains quite small, up to 4.8% on average for developed countries and 8.4% on average for emerging countries.

Regarding the positive screening strategy, for developed countries the annualized return and volatility are both lower for the Environmental dimension while they are both higher for the Social and Governance dimensions, compared to the benchmark. For emerging countries, all portfolios have lower annualized returns and higher annualized volatility than the benchmark portfolio.

For each dimension, we confirm that the scores are systematically higher than the benchmark portfolios, and also with respect to the less aggressive negative screening strategy, which makes sense since these portfolios only include the 25% best-ranked bonds. For developed countries the highest increase in ESG scores is for the Environmental dimension (+14.28%), and for emerging countries the highest increase is for the Social dimension (+50%). For developed countries the lowest increase is for the Governance dimension (+11.12%), and for emerging countries it is for Environment (+18.21%).

These results allow us to draw two conclusions: first, for developed countries, increasing the sustainability of a portfolio using positive screening comes at a cost for the Environmental dimension while it slightly enhances returns and increases volatility for the Social and Governance dimensions. Second, for emerging countries, increasing the sustainability of a portfolio using positive screening comes at a cost for all dimensions since it leads to a lower annualized return and higher volatility. The higher the increase in the score (the more sustainable a portfolio is, based on our different criteria taken individually), the higher the cost.

We also find that for developed countries, increasing the E, S or G score of a portfolio using a negative or positive screening strategy also improve the scores for the other (non-targeted)

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E, S or G dimensions of the portfolio, as well as Economics, and these scores are systematically higher than the E, S and G scores of the benchmark portfolio. This result is interesting since it suggests that there is no conflict between the various dimensions of ESG. An investor with a core focus on improving the portfolio along the E, S or G dimension can be assumed to enjoy a benefit in the other two dimensions, even if they are not explicitly targeted.

When it comes to emerging countries, increasing the E, S or G score of a portfolio using a negative screening strategy also improves the scores for the other (non-targeted) E, S and G dimensions, and these scores are systematically higher than the E, S and G scores of the benchmark portfolio, except for the Economic score, which slightly decreases. Regarding the positive screening strategy, increasing the E, S and G scores also increases the scores of the other (non-targeted) E, S and G dimension scores, as well as Economics (except for the S dimension), and these scores are systematically higher than the E, S and G scores of the benchmark portfolio. The positive impact of the different scores is greater for the positive screening strategy.

6.1.2. Integrating ESG Constraints at the Optimization Stage

In contrast to including ESG criteria at the selection stage, one may also attempt to incorporate ESG constraints at the allocation stage.[17] In this context, an investor or portfolio manager may wish to increase the E, S and/or G score of a portfolio by introducing a minimum score target as a constraint in a formal portfolio optimization process. In what follows, we make a key distinction between an absolute performance focus, where the optimization objective relates to the risk or risk-adjusted performance of the portfolio subject to ESG constraints, and a relative performance focus, where the optimization objective relates to the tracking error of the portfolio with respect to the benchmark, again subject to ESG constraints.

6.1.2.1. Integrating ESG Constraints at the Optimization Stage: Focusing on Absolute Performance

In this Section, we explore how the findings in Section 5 can be used to inform portfolio construction decisions so as to efficiently incorporate ESG criteria into sovereign bond investment decisions. More precisely, we investigate the impact of integrating E, S and G criteria as part of two different optimization approaches, namely the maximum Sharpe ratio (MSR) portfolio and the global minimum variance (GMV) portfolio. In what follows, we perform an in-sample analysis since our main motivation is not to provide a horse race out-of-sample analysis of competing optimization strategies, which would not lead to robust conclusions given the relatively short sample history, but instead to measure the opportunity cost involved in the introduction of ESG constraints. In other words, we are interested in measuring the reduction in Sharpe ratio or the increase in variance of the ESG-constrained portfolio with respect to the corresponding unconstrained portfolio.

6.1.2.1.1. Measuring the Opportunity Cost of ESG Constraints

As before, we build separate portfolios of 5-year maturity sovereign bonds for developed and

17 - Obviously, incorporating ESG constraints at the selection and allocation stages are not mutually exclusive approaches. In this paper, we analyze these approaches separately so as to better identify the impact of ESG integration in selection and optimization procedures taken in isolation.

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emerging countries. For each region, we first build the maximum Sharpe Ratio and the minimum variance portfolios with no Environmental, Social or Governance constraints. For each portfolio, in addition to the constraint that the sum of the weights allocated to the assets must be equal to 1, we add a minimum weight constraint so that the minimum weight of each asset must be greater than or equal to $\frac{1}{2N}$, with N the total number of assets in a portfolio (20 for developed countries and 15 for emerging countries). This is meant to avoid corner solutions that are typical of straightforward optimization procedures. We then calculate the E, S and G scores of each of the portfolios at the initial date (2010) as the weighted average of each country scores.

According to modern portfolio theory (Markowitz, 1952), all mean-variance investors rationally seek to maximize the Sharpe ratio (MSR), subject to the constraint that the portfolio is fully invested in the N assets. The maximum Sharpe ratio portfolio is defined by the following program :

$$\max_w \lambda(w) = \frac{w\prime\mu}{\sqrt{w\prime\sum w}}, \text{ subject to } \begin{cases} \mathbf{1}'_N w = 1 \\ w \geq \frac{1}{2N} \end{cases}$$

where μ is the vector of expected returns and Σ is the covariance matrix.

The global minimum variance (GMV) portfolio is defined by the following program:

$$\min_w \sigma^2(w) = w' \sum w, \text{ subject to } \begin{cases} \mathbf{1}'_N w = 1 \\ w \geq \frac{1}{2N} \end{cases}$$

We want to improve the E, S and G scores of the minimum variance and maximum Sharpe ratio portfolios. To this end, in the second step we integrate E, S and G constraints into the optimization process. The level of E, S and G constraints is set in terms of a given improvement with respect to the E, S and G scores of the previously built minimum variance and maximum Sharpe ratio portfolios with no E, S or G constraints.

We denote the reference scores by $Score_{MSR}$ and $Score_{GMV}$ and the percentage increase from a reference score by P%. For each dimension, we test different target levels for P (from 5% to 60%). For each score dimension, the maximum percentage increase depends on the range of scores within the underlying universe as well as the weight and minimum weight constraints. We report the results for the maximum increase we obtained for each dimension, for both strategies.

The maximum Sharpe ratio portfolio with E, S or G constraints is defined by the following program:

$$\max_w \lambda(w) = \frac{w\prime\mu}{\sqrt{w\prime\sum w}},$$
$$\text{subject to } \begin{cases} \mathbf{1}'_N w = 1 \\ w \geq \frac{1}{2N} \\ Score \geq Score_{MSR} \times (1 + P\%) \end{cases}$$

The minimum variance portfolio with E, S or G constraints is defined by the following program:

$$\min_w \sigma^2(w),$$
$$\text{subject to } \begin{cases} \mathbf{1}'_N w = 1 \\ w \geq \frac{1}{2N} \\ Score \geq Score_{GMV} \times (1 + P\%) \end{cases}$$

In Exhibits 6.4 and 6.5, for each dimension we report the following indicators for the maximum Sharpe ratio and the minimum

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variance strategies, respectively: annualized mean, annualized volatility, Sharpe ratio, information ratio, maximum return, minimum return and maximum drawdown over the period 2010–2020. We also report the Economic, Environmental, Social and Governance scores associated with each portfolio at the initial date (2010).[18]

Exhibit 6.4: Results of the maximum Sharpe ratio strategy over the sample period 2010–2020 for developed and emerging countries

Maximum Sharpe Ratio								
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.87				16.95			
Annualized Volatility (%)	5.17				5.01			
Sharpe Ratio	1.14				3.39			
Max Return (%)	4.94				5.45			
Min Return (%)	-3.05				-2.60			
Max Drawdown (%)	61.73				47.74			
Maximum Sharpe Ratio Score (mean)	Economics	Environment	Social	Governance	Economics	Environment	Social	Governance
	5.60	6.52	6.94	7.91	5.82	4.89	3.70	5.35
Benchmark Score (mean)	6.15	7.00	7.68	7.83	6.04	5.47	4.55	5.84

Exhibit 6.5: Results of the minimum variance strategy over the sample period 2010–2020 for developed and emerging countries

Minimum Variance								
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.74				13.01			
Annualized Volatility (%)	5.05				4.47			
Sharpe Ratio	1.14				2.91			
Max Return (%)	4.76				5.30			
Min Return (%)	-3.02				-2.07			
Max Drawdown (%)	63.54				39.00			
Mininmum Variance Score (mean)	Economics	Environment	Social	Governance	Economics	Environment	Social	Governance
	5.60	6.52	6.92	7.93	6.07	4.96	3.85	5.45
Benchmark Score (mean)	6.15	7.00	7.68	7.83	6.04	5.47	4.55	5.84

In Exhibits 6.6 and 6.7, we report for each dimension the following indicators for the maximum Sharpe ratio and the minimum variance portfolios with E, S and G constraints: annualized mean, annualized volatility, Sharpe ratio, information ratio, maximum return, minimum return and maximum drawdown, over the period 2010–2020. We also report the Economic, Environmental, Social and Governance scores associated with each portfolio at the initial date (2010).

18 - In this analysis we compare the E, S and G scores of each portfolio based on the E, S and G scores of each country at the initial date (2010).

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Exhibit 6.6: Results of the maximum Sharpe ratio strategy with Environmental, Social and Governance constraints over the sample period 2010–2020 for developed and emerging countries

Maximum Sharpe Ratio + E/S/G Constraints								
	Economics							
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.30				9.92			
Annualized Volatility (%)	8.99				6.22			
Portfolio Annualized Return - Benchmark (%)	-2.16				-2.68			
Sharpe Ratio	0.59				1.59			
Tracking Error (%)	2.81				5.01			
Information Ratio	-0.77				-0.54			
Max Return (%)	11.62				5.06			
Min Return (%)	-5.63				-3.30			
Max Drawdown (%)	48.45				65.22			
Diff Ret / Max SR (%)	-9.82				-41.50			
Diff Vol / Max SR (%)	74.00				24.21			
Diff SR / Max SR (%)	-48.17				-52.90			
Diff MDD / Max SR (%)	-21.52				36.62			
	Economics (+25%)	Environment	Social	Governance	**Economics (+15%)**	Environment	Social	Governance
Score (mean)	**7.00**	7.40	7.55	8.01	**6.70**	4.52	3.44	5.19
Maximum Sharpe Ratio Score (mean)	**5.60**	6.52	6.94	7.91	**5.82**	4.89	3.70	5.35
Benchmark Score (mean)	**6.15**	7.00	7.68	7.83	**6.04**	5.47	4.55	5.84
Diff Score / Max Sharpe Ratio Score (%)	25.02	13.59	8.82	1.21	15.00	-7.68	-7.16	-3.15
Diff Score / Benchmark Score (%)	13.72	5.74	-1.69	2.32	10.86	-17.34	-24.52	-11.20

	Environment							
	Developed Countries				Emerging Countries			
Annualized Return (%)	9.37				12.68			
Annualized Volatility (%)	9.80				7.52			
Portfolio Annualized Return - Benchmark (%)	1.91				0.08			
Sharpe Ratio	0.96				1.69			
Tracking Error (%)	3.06				2.15			
Information Ratio	0.62				0.04			
Max Return (%)	9.14				9.32			
Min Return (%)	-5.89				-4.53			
Max Drawdown (%)	64.41				48.58			
Diff Ret / Max SR (%)	59.49				74.82			
Diff Vol / Max SR (%)	89.75				50.11			
Diff SR / Max SR (%)	-15.95				-50.16			
Diff MDD / Max SR (%)	4.33				1.77			
	Economics	**Environment (+10%)**	Social	Governance	Economics	**Environment (+15%)**	Social	Governance
Score (mean)	6.08	**7.17**	7.94	8.27	6.16	**5.63**	4.98	6.04
Maximum Sharpe Ratio Score (mean)	5.60	**6.52**	6.94	7.91	5.82	**4.89**	3.70	5.35
Benchmark Score (mean)	6.15	**7.00**	7.68	7.83	6.04	**5.47**	4.55	5.84
Diff Score / Max Sharpe Ratio Score (%)	8.61	10.01	14.50	4.49	5.82	15.00	34.58	12.79
Diff Score / Benchmark Score (%)	-1.20	2.41	3.44	5.64	2.01	2.96	9.42	3.41

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	Social							
	Developed Countries				Emerging Countries			
Annualized Return (%)	9.54				10.10			
Annualized Volatility (%)	9.96				7.58			
Portfolio Annualized Return - Benchmark (%)	2.08				-2.50			
Sharpe Ratio	0.96				1.33			
Tracking Error (%)	3.01				2.53			
Information Ratio	0.69				-0.99			
Max Return (%)	9.49				9.47			
Min Return (%)	-6.19				-3.77			
Max Drawdown (%)	65.22				39.82			
Diff Ret / Max SR (%)	62.40				59.60			
Diff Vol / Max SR (%)	92.84				51.47			
Diff SR / Max SR (%)	-15.78				-60.65			
Diff MDD / Max SR (%)	5.65				-16.59			
	Economics	Environment	**Social (15%)**	Governance	Economics	Environment	**Social (+55%)**	Governance
Score (mean)	6.07	7.09	**7.96**	8.26	5.68	5.45	**5.74**	6.27
Maximum Sharpe Ratio Score (mean)	5.60	6.52	**6.94**	7.91	5.82	4.89	**3.70**	5.35
Benchmark Score (mean)	6.15	7.00	**7.68**	7.83	6.04	5.47	**4.55**	5.84
Diff Score / Max Sharpe Ratio Score (%)	8.47	8.71	14.76	4.41	-2.51	11.31	55.00	17.05
Diff Score / Benchmark Score (%)	-1.32	1.20	3.67	5.56	-6.02	-0.34	26.02	7.32

	Governance							
	Developed Countries				Emerging Countries			
Annualized Return (%)	8.46				16.19			
Annualized Volatility (%)	8.84				7.61			
Portfolio Annualized Return - Benchmark (%)	1.00				3.59			
Sharpe Ratio	0.96				2.13			
Tracking Error (%)	2.68				2.99			
Information Ratio	0.37				1.20			
Max Return (%)	9.03				9.25			
Min Return (%)	-4.94				-3.74			
Max Drawdown (%)	54.69				40.49			
Diff Ret / Max SR (%)	44.02				95.54			
Diff Vol / Max SR (%)	71.03				52.10			
Diff SR / Max SR (%)	-15.79				-37.19			
Diff MDD / Max SR (%)	-11.41				-15.18			
	Economics	Environment	Social	**Governance (+5%)**	Economics	Environment	Social	**Governance (+15%)**
Score (mean)	6.02	7.10	7.80	**8.33**	6.26	4.78	4.23	**6.16**
Maximum Sharpe Ratio Score (mean)	5.60	6.52	6.94	**7.91**	5.82	4.89	3.70	**5.35**
Benchmark Score (mean)	6.15	7.00	7.68	**7.83**	6.04	5.47	4.55	**5.84**
Diff Score / Max Sharpe Ratio Score (%)	7.64	8.95	12.46	5.22	7.48	-2.24	14.33	15.00
Diff Score / Benchmark Score (%)	-2.09	1.42	1.60	6.37	3.61	-12.48	-7.05	5.43

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Exhibit 6.7: Results of the minimum variance strategy with Environmental, Social and Governance constraints over the sample period 2010–2020 for developed and emerging countries

Minimum Variance + E/S/G Constraints								
	Economics							
	Developed Countries				Emerging Countries			
Annualized Return (%)	4.83				9.64			
Annualized Volatility (%)	8.76				6.10			
Portfolio Annualized Return - Benchmark (%)	-2.63				-2.96			
Sharpe Ratio	0.55				1.58			
Tracking Error (%)	3.28				5.00			
Information Ratio	-0.80				0.67			
Max Return (%)	11.81				4.94			
Min Return (%)	-5.59				-3.22			
Max Drawdown (%)	47.30				65.12			
Diff Ret / Min Var (%)	-15.77				-25.89			
Diff Vol / Min Var (%)	73.37				36.50			
Diff SR / Min Var (%)	-51.42				-45.71			
Diff MDD / Min Var (%)	-25.55				66.97			
	Economics (+25%)	Environment	Social	Governance	**Economics (+10%)**	Environment	Social	Governance
Score (mean)	**7.00**	7.35	7.45	7.93	**6.68**	4.56	3.44	5.17
Minimum Variance Score (mean)	**5.60**	6.52	6.92	7.93	**6.07**	4.96	3.85	5.45
Benchmark Score (mean)	**6.15**	7.00	7.68	7.83	**6.04**	5.47	4.55	5.84
Diff Score / Min Variance Score (%)	25.00	12.78	7.57	0.02	10.00	-8.06	-10.76	-5.01
Diff Score / Benchmark Score (%)	13.72	5.00	-3.02	1.32	10.59	-16.63	-24.47	-11.44

	Environment							
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.03				11.38			
Annualized Volatility (%)	7.71				8.28			
Portfolio Annualized Return - Benchmark (%)	-2.43				-1.22			
Sharpe Ratio	0.65				1.37			
Tracking Error (%)	2.78				5.53			
Information Ratio	-0.87				-0.48			
Max Return (%)	10.02				9.88			
Min Return (%)	-4.64				-4.71			
Max Drawdown (%)	46.35				47.71			
Diff Ret / Min Var (%)	-12.33				-12.51			
Diff Vol / Min Var (%)	52.55				85.34			
Diff SR / Min Var (%)	-42.53				-52.80			
Diff MDD / Min Var (%)	-27.05				22.33			
	Economics	**Environment (+10%)**	Social	Governance	Economics	**Environment (+15%)**	Social	Governance
Score (mean)	6.66	**7.17**	7.34	7.95	6.23	**5.70**	5.23	6.11
Minimum Variance Score (mean)	5.60	**6.52**	6.92	7.93	6.07	**4.96**	3.85	5.45
Benchmark Score (mean)	6.15	**7.00**	7.68	7.83	6.04	**5.47**	4.55	5.84
Diff Score / Min Variance Score (%)	19.06	10.00	5.99	0.21	2.64	15.00	35.63	12.21
Diff Score / Benchmark Score (%)	8.32	2.41	-4.45	1.51	3.19	4.29	14.79	4.62

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	Social							
	Developed Countries				Emerging Countries			
Annualized Return (%)	8.29				9.22			
Annualized Volatility (%)	9.49				7.53			
Portfolio Annualized Return - Benchmark (%)	0.83				-3.38			
Sharpe Ratio	0.87				1.22			
Tracking Error (%)	2.07				2.81			
Information Ratio	0.40				-1.20			
Max Return (%)	9.46				9.48			
Min Return (%)	-5.86				-4.27			
Max Drawdown (%)	61.94				45.07			
Diff Ret / Min Var (%)	44.47				-29.13			
Diff Vol / Min Var (%)	87.83				68.47			
Diff SR / Min Var (%)	-23.08				-57.94			
Diff MDD / Min Var (%)	-2.52				15.56			
	Economics	Environment	**Social (15%)**	Governance	Economics	Environment	**Social (+50%)**	Governance
Score (mean)	6.19	7.14	**7.96**	8.37	5.67	5.42	**5.78**	6.29
Minimum Variance Score (mean)	5.60	6.52	**6.92**	7.93	6.07	4.96	**3.85**	5.45
Benchmark Score (mean)	6.15	7.00	**7.68**	7.83	6.04	5.47	**4.55**	5.84
Diff Score / Min Variance Score (%)	10.59	9.52	15.00	5.60	-6.69	9.43	50.00	15.52
Diff Score / Benchmark Score (%)	0.62	1.96	3.67	6.98	-6.19	-0.76	26.96	7.71

	Governance							
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.80				9.78			
Annualized Volatility (%)	8.56				6.68			
Portfolio Annualized Return - Benchmark (%)	0.34				-2.82			
Sharpe Ratio	0.91				1.46			
Tracking Error (%)	2.20				2.41			
Information Ratio	0.15				-1.17			
Max Return (%)	9.33				8.26			
Min Return (%)	-4.80				-4.29			
Max Drawdown (%)	51.45				51.87			
Diff Ret / Min Var (%)	35.94				-24.78			
Diff Vol / Min Var (%)	69.38				49.55			
Diff SR / Min Var (%)	-19.74				-49.71			
Diff MDD / Min Var (%)	-19.03				33.00			
	Economics	Environment	Social	**Governance (+5%)**	Economics	Environment	Social	**Governance (+15%)**
Score (mean)	5.98	7.01	7.68	**8.33**	6.02	5.32	4.83	**6.26**
Minimum Variance Score (mean)	5.60	6.52	6.92	**7.93**	6.07	4.96	3.85	**5.45**
Benchmark Score (mean)	6.15	7.00	7.68	**7.83**	6.04	5.47	4.55	**5.84**
Diff Score / Min Variance Score (%)	6.79	7.58	10.98	5.00	-0.81	7.44	25.25	15.00
Diff Score / Benchmark Score (%)	-2.84	0.16	0.05	6.37	-0.28	-2.57	6.01	7.22

6. Implications for Sovereign Bond Portfolio Management

Regarding the maximum Sharpe ratio strategies with E, S and G constraints, for developed countries we managed to increase the Environmental score by 10%, the Social score by 15% and the Governance score by 5%. The annualized returns and volatility of these portfolios are higher than those of the portfolio with no E/S/G constraint as well as the benchmark portfolio. Overall, the Sharpe ratio of these portfolios is about 15% lower than that of the portfolio with no E, S and G constraints. There is thus a tradeoff between increasing E, S and G scores maximizing the Sharpe ratio, and the cost to pay (reduction in Sharpe ratio) is generally higher than the associated benefits in terms of improvement in ESG scores.

For emerging countries we managed to increase the Environmental score by 15%, the Social score by 55% and the Governance score by 15%. The annualized returns of these portfolios are lower than for the portfolio with no E, S and G constraints and the benchmark (except for the Governance dimension), while the annualized volatility is higher. Respectively for the Environmental, Social and Governance dimensions, the Sharpe ratio of these portfolios is 52.90%, 60.65% and 37.19% lower than that of the portfolio with no E, S and G constraints. There is again a clear tradeoff between increasing E, S and G scores and generating a high Sharpe ratio. In the case of emerging countries, increasing the E, S and G scores of a maximum Sharpe ratio portfolio also comes with an opportunity cost in terms of performance.

Regarding the minimum variance strategy with E, S and G constraints, for developed countries we managed to increase the Environmental score by 10%, the Social score by 15% and the Governance score by 5%. The annualized performance for the Environmental dimension is less than for the portfolio with no E constraints as well as the benchmark, while in both cases it is higher for the Social and Governance dimensions. For the E, S and G dimensions respectively, the volatility is 52.55%, 87.83% and 69.38% higher and the Sharpe ratio is 42.53%, 23.08% and 18.74% lower, compared to the portfolio with no E, S and G constraints. Here again, there is a tradeoff between increasing E, S and G scores and generating a low variance for the portfolio.

For emerging countries, we managed to increase the Environmental score by 15%, the Social score by 50% and the Governance score by 15%. The annualized returns of these portfolios are lower than for the portfolio with no E, S and G constraints and the benchmark, while the annualized volatility is higher. For the E, S and G dimensions respectively, the volatility is 85.34%, 68.47% and 49.55% higher and the Sharpe ratio is 52.80%, 57.90% and 49.70% lower, compared to the portfolio with no E, S and G constraints. There is a clear tradeoff between increasing E, S and G scores while maintaining a focus on minimizing the portfolio variance. In the case of emerging countries, increasing the E, S and G scores of a minimum variance portfolio also comes with an opportunity cost in terms of performance, as expected.

Interestingly, our results show that for developed countries increasing the E, S or G score of a portfolio by adding an E, S or G constraint to a

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maximum Sharpe ratio or a minimum variance portfolio strategy also improves the scores for the other (non-targeted) E, S or G dimensions of the same portfolio, as well as Economics. The (non-targeted) E, S and G scores obtained are indeed systematically higher than the E, S and G scores of the maximum Sharpe ratio and minimum variance benchmark portfolios with no E, S and G constraints.

When it comes to emerging countries, increasing the E score of a portfolio by adding an E constraint to a maximum Sharpe ratio portfolio strategy not only increases the E score but also the Economic, S and G scores of the same portfolio, while increasing the S or G score of a portfolio by adding an S or G constraint decreases the Economic and Environmental scores of the same portfolio, respectively, while improving the scores of the other dimensions. Adding an Economic constraint on the other hand, to improve the score of the Economic dimension of the portfolio, systematically decreases the E, S and G scores of the same portfolio. This result suggests that the focus on the Economic dimension is not well-aligned in emerging markets with a focus on the non-economic dimensions. Regarding the minimum variance strategy for emerging countries, the conclusions are the same except that increasing the G score of the portfolio by adding a G constraint slightly decreases the Economic score of the portfolio while improving the score of the other dimensions.

6.1.2.1.2 Comparing the Opportunity Cost of ESG Constraints with an Optimization Versus Selection Approach

Increasing the E, S and G scores of a maximum Sharpe ratio or a minimum variance strategy portfolio by adding an E, S and G constraint equal to the maximum percentage increase achievable does not allow us to draw a direct comparison with the improvement of ESG scores obtained with a selection approach. Besides, setting the improvement target at their highest level is likely to hamper the optimization process since exceedingly high levels of E, S and G constraints will tend to leave little room for optimization. In this context, and in an attempt to compare the integration of ESG constraints via selection versus optimization strategies, we set the E, S and G constraint in the optimization process so that the E, S and G scores are equal to the scores obtained with the negative screening strategy in Section 6.1.1.

More precisely, we build maximum Sharpe ratio and minimum variance portfolios with the following constraints (in addition to the constraint that the sum of the weights allocated to the assets must be equal to 1, and that the minimum weight of each asset must be greater than or equal to $\frac{1}{2N}$, where N is the total number of assets in a portfolio): for developed countries our target level for the Economic, Environmental, Social and Governance scores is set at 6.45, 7.30, 8.08 and 8.22, respectively, and for emerging countries at 6.37, 5.92, 5.15 and 6.24, respectively.

In Exhibits 6.8 and 6.9, for each dimension we report the following indicators for the maximum

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Sharpe ratio and the minimum variance portfolios with E, S and G constraints: annualized mean, annualized volatility, Sharpe ratio, information ratio, maximum return, minimum return and maximum drawdown over the period 2010–2020. We also report the Economic, Environmental, Social and Governance scores associated with each portfolio at the initial date (2010).

Exhibit 6.8: Results of the maximum Sharpe ratio strategy with Environmental, Social and Governance constraints over the sample period 2010–2020 for developed and emerging countries

	Maximum Sharpe Ratio + E/S/G Constraints							
	Economics							
	Developed Countries				Emerging Countries			
Annualized Return (%)	8.07				13.44			
Annualized Volatility (%)	9.44				5.13			
Portfolio Annualized Return - Benchmark (%)	0.61				0.84			
Sharpe Ratio	0.86				2.62			
Tracking Error (%)	2.21				3.83			
Information Ratio	0.28				0.22			
Max Return (%)	9.26				4.95			
Min Return (%)	-6.43				-2.98			
Max Drawdown (%)	69.46				60.20			
Diff Ret / Max SR (%)	37.45				-20.72			
Diff Vol / Max SR (%)	82.66				2.41			
Diff SR / Max SR (%)	-24.75				-22.59			
Diff MDD / Max SR (%)	12.52				26.11			
Diff Ret / Negative Screening (%)	12.07				16.43			
Diff Vol / Negative Screening (%)	1.23				-28.29			
Diff SR / Negative Screening (%)	10.71				62.37			
Diff MDD / Negative Screening (%)	-2.00				29.12			
	Economics	Environment	Social	Governance	**Economics**	Environment	Social	Governance
Score (mean)	**6.45**	7.17	7.72	8.18	**6.37**	4.74	3.58	5.35
Maximum Sharpe Ratio Score (mean)	**5.60**	6.52	6.94	7.91	**5.82**	4.89	3.70	5.35
Negative Screening Score (mean)	**6.45**	7.15	7.88	8.04	**6.37**	5.47	4.58	5.90
Benchmark Score (mean)	**6.15**	7.00	7.68	7.83	**6.04**	5.47	4.55	5.84
Diff Score / Max Sharpe Ratio Score (%)	15.34	10.05	11.35	3.34	9.45	-3.04	-3.40	-0.15
Diff Score / Negative Screening Score (%)	0.00	0.27	-2.00	1.71	0.00	-13.33	-21.90	-9.39
Diff Score / Benchmark Score (%)	4.92	2.45	0.59	4.47	5.51	-13.19	-21.47	-8.46

	Environment	
	Developed Countries	Emerging Countries
Annualized Return (%)	9.46	10.08
Annualized Volatility (%)	10.26	9.52
Portfolio Annualized Return - Benchmark (%)	2.01	-2.52
Sharpe Ratio	0.92	1.06
Tracking Error (%)	3.77	4.04
Information Ratio	0.53	-0.62
Max Return (%)	9.89	10.05
Min Return (%)	-5.91	-6.37

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Max Drawdown (%)	59.78				63.42			
Diff Ret / Max SR (%)	61.14				-40.54			
Diff Vol / Max SR (%)	98.69				90.19			
Diff SR / Max SR (%)	-18.90				-68.74			
Diff MDD / Max SR (%)	-3.17				32.86			
Diff Ret / Negative Screening (%)	21.62				-21.24			
Diff Vol / Negative Screening (%)	12.29				23.74			
Diff SR / Negative Screening (%)	8.31				-36.35			
Diff MDD / Negative Screening (%)	-5.86				26.04			
	Economics	**Environment**	Social	Governance	Economics	**Environment**	Social	Governance
Score (mean)	6.18	**7.30**	8.08	8.41	6.27	**5.76**	5.52	6.00
Maximum Sharpe Ratio Score (mean)	5.60	**6.52**	6.94	7.91	5.82	**4.89**	3.70	5.35
Negative Screening Score (mean)	6.27	**7.30**	7.92	7.94	5.91	**5.92**	5.01	6.02
Benchmark Score (mean)	6.15	**7.00**	7.68	7.83	6.04	**5.47**	4.55	5.84
Diff Score / Max Sharpe Ratio Score (%)	10.38	12.05	16.48	6.27	7.63	**17.80**	48.95	11.97
Diff Score / Negative Screening Score (%)	-1.46	0.00	1.97	5.91	6.01	-2.69	9.98	-0.41
Diff Score / Benchmark Score (%)	0.41	4.31	5.23	7.44	3.76	5.47	21.10	2.66

	Social							
	Developed Countries				Emerging Countries			
Annualized Return (%)	9.46				12.80			
Annualized Volatility (%)	10.27				6.44			
Portfolio Annualized Return - Benchmark (%)	2.01				0.20			
Sharpe Ratio	0.92				1.99			
Tracking Error (%)	3.78				2.71			
Information Ratio	0.53				0.07			
Max Return (%)	9.90				8.15			
Min Return (%)	-5.92				-3.61			
Max Drawdown (%)	59.75				44.27			
Diff Ret / Max SR (%)	61.12				-24.48			
Diff Vol / Max SR (%)	98.74				28.65			
Diff SR / Max SR (%)	-18.92				-41.30			
Diff MDD / Max SR (%)	-3.21				-7.26			
Diff Ret / Negative Screening (%)	26.50				7.40			
Diff Vol / Negative Screening (%)	6.98				-15.58			
Diff SR / Negative Screening (%)	18.24				27.22			
Diff MDD / Negative Screening (%)	-19.47				-4.93			
	Economics	Environment	**Social**	Governance	Economics	Environment	**Social**	Governance
Score (mean)	6.18	7.30	**8.08**	8.41	5.68	5.38	**5.15**	6.04
Maximum Sharpe Ratio Score (mean)	5.60	6.52	**6.94**	7.91	5.82	4.89	**3.70**	5.35
Negative Screening Score (mean)	6.33	7.24	**8.08**	8.16	6.03	5.71	**5.15**	6.19
Benchmark Score (mean)	6.15	7.00	**7.68**	7.83	6.04	5.47	**4.55**	5.84
Diff Score / Max Sharpe Ratio Score (%)	10.40	12.06	16.49	6.29	-2.47	9.85	39.17	12.77
Diff Score / Negative Screening Score (%)	-2.48	0.89	0.00	3.10	-5.86	-5.85	0.00	-2.41
Diff Score / Benchmark Score (%)	0.42	4.32	5.24	7.45	-5.98	-1.65	13.15	3.39

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	Governance							
	Developed Countries				Emerging Countries			
Annualized Return (%)	7.70				16.49			
Annualized Volatility (%)	7.68				8.45			
Portfolio Annualized Return - Benchmark (%)	0.24				3.89			
Sharpe Ratio	1.00				1.95			
Tracking Error (%)	2.52				3.74			
Information Ratio	0.09				1.04			
Max Return (%)	7.64				9.97			
Min Return (%)	-4.43				-3.92			
Max Drawdown (%)	58.02				39.34			
Diff Ret / Max SR (%)	31.02				-2.70			
Diff Vol / Max SR (%)	48.74				68.77			
Diff SR / Max SR (%)	-11.91				-42.35			
Diff MDD / Max SR (%)	-6.02				-17.59			
Diff Ret / Negative Screening (%)	6.50				36.83			
Diff Vol / Negative Screening (%)	-15.07				6.08			
Diff SR / Negative Screening (%)	25.41				28.98			
Diff MDD / Negative Screening (%)	-7.30				-16.57			
	Economics	Environment	Social	**Governance**	Economics	Environment	Social	**Governance**
Score (mean)	5.91	6.95	7.56	**8.22**	6.33	4.67	4.29	**6.24**
Maximum Sharpe Ratio Score (mean)	5.60	6.52	6.94	**7.91**	5.82	4.89	3.70	**5.35**
Negative Screening Score (mean)	6.32	7.22	8.00	**8.22**	5.99	5.78	5.09	**6.24**
Benchmark Score (mean)	6.15	7.00	7.68	**7.83**	6.04	5.47	4.55	**5.84**
Diff Score / Max Sharpe Ratio Score (%)	5.57	6.64	8.94	3.83	8.69	-4.54	15.86	16.44
Diff Score / Negative Screening Score (%)	-6.53	-3.75	-5.50	0.00	5.60	-19.20	-15.64	0.00
Diff Score / Benchmark Score (%)	-3.97	-0.73	-1.58	4.96	4.77	-14.53	-5.81	6.76

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Exhibit 6.9: Results of the minimum variance strategy with Environmental, Social and Governance constraints over the sample period 2010–2020 for developed and emerging countries

Minimum Variance + E/S/G Constraints								
	Economics							
	Developed Countries				Emerging Countries			
Annualized Return (%)	5.17				11.04			
Annualized Volatility (%)	7.08				4.85			
Portfolio Annualized Return - Benchmark (%)	-2.29				-1.56			
Sharpe Ratio	0.73				2.28			
Tracking Error (%)	2.71				3.42			
Information Ratio	-0.84				-0.46			
Max Return (%)	8.88				4.90			
Min Return (%)	-4.18				-2.39			
Max Drawdown (%)	47.04				48.79			
Diff Ret / Min Var (%)	-9.92				-15.09			
Diff Vol / Min Var (%)	40.19				8.49			
Diff SR / Min Var (%)	-35.74				-21.74			
Diff MDD / Min Var (%)	-25.96				25.09			
Diff Ret / Negative Screening (%)	-28.27				-4.31			
Diff Vol / Negative Screening (%)	-24.02				-32.17			
Diff SR / Negative Screening (%)	-5.59				41.07			
Diff MDD / Negative Screening (%)	-33.63				4.64			
	Economics	Environment	Social	Governance	Economics	Environment	Social	Governance
Score (mean)	**6.45**	7.04	7.26	7.94	6.37	4.86	3.71	5.37
Minimum Variance Score (mean)	**5.60**	6.52	6.92	7.93	6.07	4.96	3.85	5.45
Negative Screening Score (mean)	**6.45**	7.15	7.88	8.04	6.37	5.47	4.58	5.90
Benchmark Score (mean)	**6.15**	7.00	7.68	7.83	6.04	5.47	4.55	5.84
Diff Score / Min Variance Score (%)	4.94	2.59	1.55	0.05	5.51	-2.44	-4.52	-1.69
Diff Score / Negative Screening Score (%)	0.00	-1.55	-7.94	-1.21	0.00	-11.18	-19.08	-8.98
Diff Score / Benchmark Score (%)	-4.54	-4.50	-8.46	1.36	6.07	-11.53	-19.18	-8.34

	Environment	
	Developed Countries	Emerging Countries
Annualized Return (%)	4.88	13.80
Annualized Volatility (%)	8.39	5.56
Portfolio Annualized Return - Benchmark (%)	-2.57	1.19
Sharpe Ratio	0.58	2.48
Tracking Error (%)	3.08	4.04
Information Ratio	-0.84	-0.62
Max Return (%)	11.20	10.05

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Min Return (%)	-5.25				-6.37			
Max Drawdown (%)	46.91				63.42			
Diff Ret / Min Var (%)	-14.84				6.07			
Diff Vol / Min Var (%)	66.01				24.50			
Diff SR / Min Var (%)	-48.70				-14.81			
Diff MDD / Min Var (%)	-26.17				62.62			
Diff Ret / Negative Screening (%)	-37.23				7.81			
Diff Vol / Negative Screening (%)	-8.25				-27.68			
Diff SR / Negative Screening (%)	-31.58				49.07			
Diff MDD / Negative Screening (%)	-26.12				26.04			
	Economics	Environment	Social	Governance	Economics	Environment	Social	Governance
Score (mean)	6.88	**7.30**	7.42	7.95	6.27	**5.76**	5.52	6.00
Minimum Variance Score (mean)	5.60	**6.52**	6.92	7.93	6.07	**4.96**	3.85	5.45
Negative Screening Score (mean)	6.27	**7.30**	7.92	7.94	5.91	**5.92**	5.01	6.02
Benchmark Score (mean)	6.15	**7.00**	7.68	7.83	6.04	**5.47**	4.55	5.84
Diff Score / Min Variance Score (%)	8.23	4.32	2.58	0.09	-0.71	8.39	12.58	5.94
Diff Score / Negative Screening Score (%)	9.76	0.00	-6.34	0.11	6.01	-2.69	9.98	-0.41
Diff Score / Benchmark Score (%)	-1.55	-2.89	-7.52	1.39	-0.18	-1.71	-4.72	-1.23

	Social	
	Developed Countries	Emerging Countries
Annualized Return (%)	9.16	10.45
Annualized Volatility (%)	10.15	6.18
Portfolio Annualized Return - Benchmark (%)	1.70	-2.15
Sharpe Ratio	0.90	1.69
Tracking Error (%)	3.50	2.09
Information Ratio	0.49	-1.03
Max Return (%)	9.96	8.12
Min Return (%)	-5.89	-3.25
Max Drawdown (%)	59.16	40.02
Diff Ret / Min Var (%)	59.73	-19.64
Diff Vol / Min Var (%)	101.02	38.35
Diff SR / Min Var (%)	-20.54	-41.92
Diff MDD / Min Var (%)	-6.89	2.61
Diff Ret / Negative Screening (%)	22.46	-12.31
Diff Vol / Negative Screening (%)	5.82	-18.94
Diff SR / Negative Screening (%)	15.73	8.18
Diff MDD / Negative Screening (%)	-20.27	-14.06

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	Economics	Environment	**Social**	Governance	Economics	Environment	**Social**	Governance
Score (mean)	6.21	7.29	**8.08**	8.43	5.79	5.33	**5.15**	6.04
Minimum Variance Score (mean)	5.60	6.52	**6.92**	7.93	6.07	4.96	**3.85**	5.45
Negative Screening Score (mean)	6.33	7.24	**8.08**	8.16	6.03	5.71	**5.15**	6.19
Benchmark Score (mean)	6.15	7.00	**7.68**	7.83	6.04	5.47	**4.55**	5.84
Diff Score / Min Variance Score (%)	3.54	3.59	5.24	1.96	-2.26	4.61	13.15	4.73
Diff Score / Negative Screening Score (%)	-1.98	0.67	0.00	3.31	-4.10	-6.58	0.00	-2.46
Diff Score / Benchmark Score (%)	-5.81	-3.57	-5.13	3.29	-1.74	-5.13	-4.23	-2.35

	Governance	
	Developed Countries	Emerging Countries
Annualized Return (%)	7.25	10.02
Annualized Volatility (%)	7.50	6.47
Portfolio Annualized Return - Benchmark (%)	-0.21	-2.58
Sharpe Ratio	0.97	1.55
Tracking Error (%)	2.43	2.73
Information Ratio	-0.09	-0.94
Max Return (%)	7.99	7.75
Min Return (%)	-4.09	-4.25
Max Drawdown (%)	51.16	54.80
Diff Ret / Min Var (%)	26.38	-22.96
Diff Vol / Min Var (%)	48.49	44.81
Diff SR / Min Var (%)	-14.89	-46.80
Diff MDD / Min Var (%)	-19.47	40.52
Diff Ret / Negative Screening (%)	0.33	-16.87
Diff Vol / Negative Screening (%)	-17.09	-18.73
Diff SR / Negative Screening (%)	21.00	2.28
Diff MDD / Negative Screening (%)	-18.25	16.24

	Economics	Environment	Social	**Governance**	Economics	Environment	Social	**Governance**
Score (mean)	5.85	6.87	7.47	8.22	6.16	5.28	4.46	6.24
Minimum Variance Score (mean)	5.60	6.52	6.92	7.93	6.07	4.96	3.85	5.45
Negative Screening Score (mean)	6.32	7.22	8.00	8.22	5.99	5.78	5.09	6.24
Benchmark Score (mean)	6.15	7.00	7.68	7.83	6.04	5.47	4.55	5.84
Diff Score / Min Variance Score (%)	6.74	7.53	10.89	4.96	-0.80	5.41	6.97	6.76
Diff Score / Negative Screening Score (%)	-7.42	-4.81	-6.59	0.00	2.73	-8.60	-12.37	0.00
Diff Score / Benchmark Score (%)	-2.90	0.10	-0.03	6.33	-0.27	-4.41	-9.47	-0.46

6. Implications for Sovereign Bond Portfolio Management

Regarding the maximum Sharpe ratio and minimum variance strategies with E, S and G constraints, for developed and emerging countries we managed to obtain the same E, S and G scores as for the negative screening strategy except for E in the case of emerging countries, where the score achievable is 2.68% lower than its target for both strategies. This is due to the presence of strictly positive minimum weight constraints which can be binding in some cases.

We are now able to compare the performance of portfolios whose E, S and G score improvement results from a selection approach versus an optimization approach. For developed countries, for the same E, S and G scores, respectively 7.30, 8.08 and 8.22, the maximum Sharpe ratio strategy performs better than the negative screening strategy not only in terms of risk-adjusted performance, as expected, but also in terms of raw performance. For the same E score, the maximum Sharpe ratio strategy has a 21.62% higher annualized return and an 8.31% higher Sharpe ratio. For the same S score, the strategy has a 26.50% higher annualized return and a 18.24% higher Sharpe ratio. For the same G score, the strategy has a 6.50% higher annualized return and a 25.41% higher Sharpe ratio.
For emerging countries, for the same S and G scores respectively equal to 5.15 and 6.24, the maximum Sharpe ratio strategy also performs better than the negative screening strategy in terms of both return and risk-adjusted performance. For the same S score, the MSR strategy has a 7.40% higher annualized return and a 27.22% higher Sharpe ratio. For the same G score, the MSR strategy has a 36.83% higher annualized return and a 28.98% higher Sharpe ratio.

Interestingly, for developed countries, for the same E or S score, the scores of the non-targeted dimensions are higher for the maximum Sharpe ratio strategy (except Economics). For the same G score, the scores of the non-targeted dimensions are lower for the maximum Sharpe ratio strategy (except Economics). For emerging countries, for the same S or G score, the scores of the non-targeted dimensions are lower for the maximum Sharpe ratio strategy.

Regarding the minimum variance strategy, for developed countries, for the same S and G score, respectively equal to 8.08 and 8.22, the minimum variance strategy performs better than the negative screening strategy not only in terms of volatility, as expected, but also in terms of performance and risk-adjusted performance. For the same S score, the GMV strategy has a 22.46% higher annualized return and a 15.73% higher Sharpe ratio. For the same G score, the strategy has a 0.33% higher annualized return and a 21.00% higher Sharpe ratio. Regarding the E dimension, for the same E score equal to 7.30, the minimum variance strategy underperforms the negative screening strategy with a 31.23% lower annualized return and a 31.58% lower Sharpe ratio.

For emerging countries, for the same S or G scores respectively equal to 5.15 and 6.24, the GMV strategy underperforms the negative screening strategy in terms of raw performance but outperforms it in terms of risk-adjusted

6. Implications for Sovereign Bond Portfolio Management

performance. For the same S score, the GMV strategy has a 12.31% lower annualized return and an 8.18% higher Sharpe ratio. For the same G score, the GMV strategy has a 16.87% lower annualized return and a 2.28% higher Sharpe ratio.

Interestingly, for developed countries, for the same E score, the S score (non-targeted) is lower, and the G score (non-targeted) is higher for the GMV strategy compared to the negative screening strategy (the Economic score is also higher). For the same S score, the non-targeted scores are higher for the GMV strategy (except Economics), while for the same G score the non-targeted scores are lower for the GMV strategy.

Overall, our results show that optimization approaches can be useful for integrating ESG constraints while minimizing the opportunity cost measured either in terms of lower performance or higher volatility.

6.1.2.2. Integrating ESG Constraints at the Optimization Stage: Focusing on Relative Performance

In this section, we investigate the impact of integrating E, S and G criteria into the optimization approach of minimizing the tracking error of a portfolio with respect to the benchmark. We are interested in measuring the tradeoff between the increase in tracking error and improvement in the E, S or G score, keeping in mind that this increase can be regarded as an opportunity cost for a benchmark-driven investor.

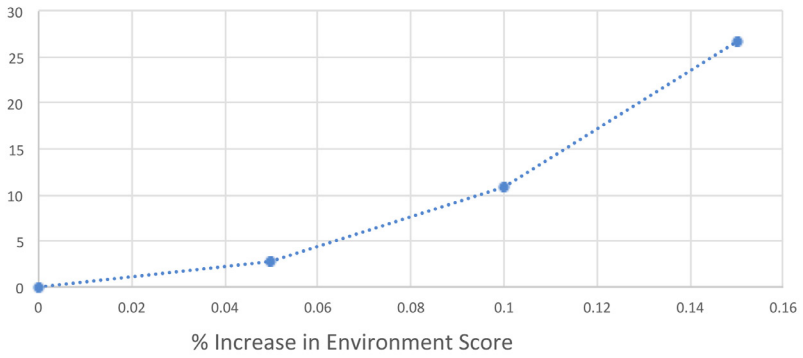
Starting from a percentage increase in ESG scores equal to zero, we progressively increase the score of the optimized portfolio by 5%, until we reach the maximum increase achievable for each dimension, considering the portfolio universe and the weight constraint.

For developed countries, the maximum percentage increases we obtained in Environmental, Social and Governance scores were +15%, +15% and + 10%, respectively. For emerging countries, these increases were +20%, +60% and + 20%, respectively.

In Exhibits 6.10 and 6.11 we report the relationship between the percentage increase in ESG scores and the tracking error for each dimension and each region, developed and emerging countries, respectively.

In Appendices A.6.1 and A.6.2 we report the tracking errors in bps obtained for the unconstrained and ESG-constrained optimized portfolios.

Exhibit 6.10: Tracking Error (bps) of ESG-constrained portfolios over the sample period 2010–2020 for developed countries



6. Implications for Sovereign Bond Portfolio Management

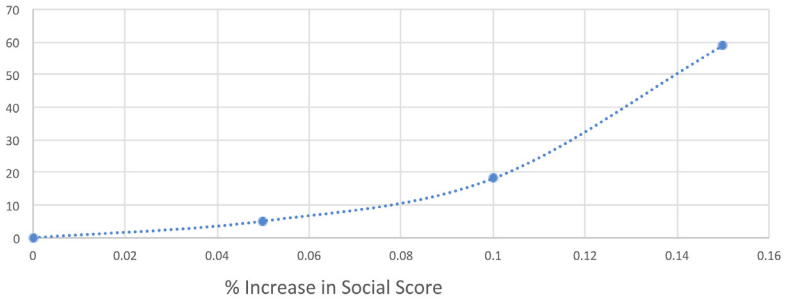
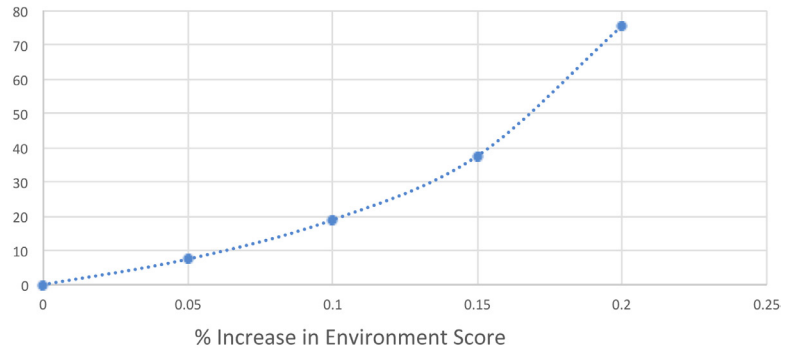
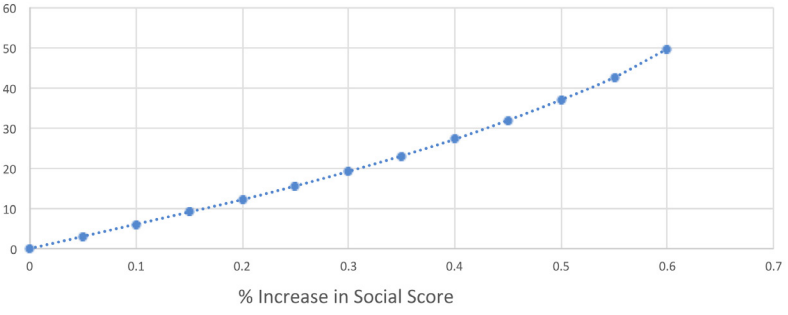
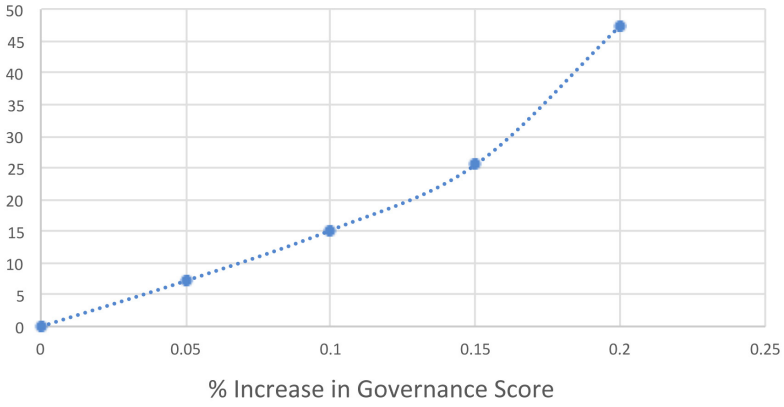


Exhibit 6.11: Tracking Error (bps) of ESG-constrained portfolios over the sample period 2010–2020 for emerging countries





6. Implications for Sovereign Bond Portfolio Management



We observe that an increase in the E, S or G constraint systematically increases the tracking error of the associated optimized portfolio. For developed countries, when adding an E, S or G constraint of +5%, investors must accept a tracking error of 2.73 bps, 5.11 bps and 3.64 bps for each dimension respectively. For emerging countries, adding an E, S or G constraint of +5% leads to a tracking error of 7.48 bps, 3.03 bps and 7.18 bps. The relationship between tracking error and improvement in ESG scores tends to be steeper beyond a certain threshold, suggesting that a small improvement comes at a lower cost in terms of tracking error compared to an otherwise comparable improvement starting at a higher level.

6.2. Exploring the Benefits of ESG momentum strategies

In this section, our ambition is to explore the benefits of using information about differences over time in ESG cores, as opposed to cross-sectional differences in ESG scores. More specifically, our ambition is to build portfolios of "improving countries", rather than of countries that are already leaders from an ESG perspective. We define Environment, Social and Government *momentum scores* by the year-on-year change in each dimension and we consider the following strategy for Economic, Environmental, Social and Governance dimensions. Every year we sort sovereign bonds based on these momentum scores, i.e. based on improvement/deterioration in their Economic, Environmental, Social and Governance scores. We then form an ESG momentum portfolio that is long the 15% best-ranked countries, i.e. countries showing the highest improvement, and short the 15% worst-ranked countries, i.e. those showing the lowest improvement. The selected bonds for both strategies are then equally weighted, and each portfolio is rebalanced on an annual basis. Appendices A.6.3 and A.6.4 show the distribution of annual variation in scores, or momentum scores, for each dimension from 2011 to 2020 for developed and emerging countries, respectively. It appears that the distribution of these momentum scores for each dimension is close to a bell shape for both developed and emerging countries. In parallel, Appendices A.6.5 and A.6.6 report the average, standard deviation, maximum and minimum value for the ESG momentum score (change

6. Implications for Sovereign Bond Portfolio Management

in ESG score) for Economic, Environmental, Social and Governance dimensions in 2012–2020, for developed and emerging countries, respectively. For developed countries, changes in Environmental and Social scores have a slightly positive mean (0.04 and 0.05, respectively) while the mean change is zero for the Governance dimensions. For emerging countries, changes in the scores for all dimensions have a slightly positive mean (0.05, 0.06 and 0.02 for E, S and G, respectively). For all dimensions, the standard deviation is higher for emerging countries than developed countries. For both regions, among the different dimensions, standard deviation is higher for the Social dimension.

In Exhibits 6.12 and 6.13, for each dimension we report the average return, maximum and minimum return for the corresponding ESG momentum strategy, for developed and emerging countries, respectively. For more details, Appendices A.6.7 to A.6.12 show the yearly return of the strategies for 1Y, 5Y and 10Y bonds based on Economic, Environmental, Social and Governance dimensions from 2011 to 2020 for developed and emerging countries, respectively.

We find that, for developed countries, regardless of bond maturity, the top 15% of bonds exhibiting positive changes in Environmental and Governance scores outperformed the bottom 15% on average over the period 2010–2020. Moreover, the long-short ESG momentum strategy based on the Environmental dimension offers attractive levels of performance, substantially higher than the strategy based on changes in Governance scores. The difference between the two strategies increases with bond maturity: 6.87% vs. 5.35% for 1-year bond maturity, 14.54% vs. 6.75% for 5-year bond maturity and 20.24% vs. 8.13% for 10-year bond maturity. The average return for the long-short

Exhibit 6.12: Long-short ESG momentum strategy based on Economic, Environmental, Social and Governance dimensions for developed countries

Developed Countries				
	Long-Short Strategy 2010-2020			
	Economics	Environment	Social	Governance
1-Year Maturity Bonds				
Average Return (%)	-7.99	6.87	-2.08	5.35
Maximum Return (%)	13.07	29.11	13.65	22.09
Minimum Return (%)	-41.21	-17.63	-13.28	-9.96
5-Year Maturity Bonds				
Average Return (%)	1.13	14.54	-2.48	6.75
Maximum Return (%)	53.06	34.29	30.93	23.70
Minimum Return (%)	-38.47	-16.63	-27.35	-18.80
10-Year Maturity Bonds				
Average Return (%)	14.55	20.24	-4.53	8.13
Maximum Return (%)	102.92	39.02	32.26	48.77
Minimum Return (%)	-39.33	-13.86	-49.68	-28.91

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Exhibit 6.13: Long-short ESG momentum strategy based on Economic, Environmental, Social and Governance dimensions for emerging countries

	Emerging Countries			
	Long-Short Strategy 2010-2020			
	Economics	Environment	Social	Governance
	1-Year Maturity Bonds			
Average Return (%)	-7.78	-4.57	4.45	12.01
Maximum Return (%)	63.08	31.61	50.82	52.43
Minimum Return (%)	-65.62	-44.67	-44.72	-14.34
	5-Year Maturity Bonds			
Average Return (%)	9.66	-4.55	21.14	4.87
Maximum Return (%)	73.70	32.29	64.12	24.96
Minimum Return (%)	-62.10	-40.60	-17.03	-29.61
	10-Year Maturity Bonds			
Average Return (%)	22.52	-4.46	37.30	-2.28
Maximum Return (%)	66.44	22.18	92.09	50.26
Minimum Return (%)	-57.43	-34.28	-23.52	-69.82

strategy based on the Environmental dimension increases much faster across bond maturities than for the long-short strategy based on the Governance dimension. On the other hand, we find that the top 15% of bonds exhibiting the highest change in scores on the Social dimension underperformed the bottom 15%. The average return remains almost the same for 1-year and 5-year bond maturity, -2.08% and -2.48% respectively, and increases up to 4.53% for 10-year bond maturity.

For emerging countries, regardless of bonds maturity, the top 15% of bonds exhibiting positive changes in Social scores outperformed the bottom 15%. Regarding Governance, the top 15% of bonds exhibiting the highest score differences outperformed the bottom 15% for 1-year and 5-year bond maturity only. For 5-year bond maturity, the long-short strategy based on the Social dimension offers the highest average return (21.14%) compared to the one based on Governance (4.87%). Regarding Environment, the top 15% of bonds exhibiting positive signals underperformed the bottom 15% for all bond maturities. The average return for the long-short strategy based on the Environmental dimension from 2011 to 2020 remains almost the same across bond maturities, on average -4.5%.

Overall, these results suggest that additional value can be added by implementing portfolio decisions informed not only by cross-sectional differences in ESG scores, but also by variations in these scores over time, suggesting the presence of some form of under-reaction to news related to changes in ESG scores.

7. Conclusions and Suggestions for Further Research

7. Conclusions and Suggestions for Further Research

The integration of ESG constraints into investment decisions ex-ante involves an opportunity cost with respect to the outcome that would be optimally achieved in the absence of ESG considerations. This cost can be measured in terms of a possible increase in risk and reduction in performance (particularly meaningful for the benchmark-free investor) and/or in terms of an increase in tracking error with respect to the benchmark (particularly meaningful for the benchmark-driven investor).

The main contribution of our analysis is that it demonstrates that several competing implementation choices exist with respect to how ESG constraints are incorporated into a sovereign bond portfolio construction context, and different choices have different impacts on these opportunity costs.

We begin by analyzing the impact of cross-sectional and/or time-series differences in E, S and G scores on key risk and return indicators for sovereign bonds in both developed and emerging markets. We find that for developed countries, and after controlling for economic scores and other fixed effects, a higher Environmental score is associated with a lower spread, while the impact of other dimensions is less pronounced. From an issuer standpoint, this result suggests that better Environmental scores can lead to reduced borrowing costs, everything else being equal. From the investor standpoint, this result suggests that a lower yield is to be expected when investing in countries with higher environmental performance, which tells us that a negative premium is associated with this reduction in environmental risk. On the other hand, for emerging countries, after controlling for economic scores and other fixed effects, we find that a higher Social score is associated with a lower spread, while the impact of other dimensions is less pronounced. Hence, from an investor standpoint, a lower yield is to be expected when investing in countries with higher social performance, suggesting that a negative premium is associated with this reduction in social risk.

In the second step, we explore the portfolio implications of these findings, analyzing how to minimize the efficiency loss involved in the introduction of ESG constraints to a robust sovereign bond portfolio construction process. We confirm that negative screening leads to more diversified portfolios and a lower level of tracking error, but also lower levels of improvement in ESG scores compared to positive screening. We also find that a dedicated focus on absolute or relative risk reduction at the selection stage allows investors to reduce opportunity costs along the dimension that is most important to them. We finally provide evidence that ESG momentum strategies in sovereign bond markets can reduce some of the aforementioned opportunity costs. Overall our results suggest that sound risk management practices are critically important in allowing investors to incorporate ESG considerations into investment decisions at an acceptable cost in terms of dollar or risk budgets.

Appendices

Appendices

A.4.1: Verisk Risk Indices (2010–2020)

Verisk Risk Indices 2010 - 2020			
Dataset	Tier 1	Tier 2	Index name
Economics	Business	Market Access	Digital Inclusion
		Workforce	Human Capital
	Economy	Access to Foreign Capital	Foreign Direct Investment
			Foreign Portfolio Investment
			International Investment Position
		Commodity Exports	Dependence on Commodity Exports
			Dependence on Fossil Fuel Exports
		Domestic Economy	Economic Growth
			External Balance
			Inflation
			Investment
		External Debt Burden	Import Cover
		Government Finances	Borrowing Costs
			Fiscal Balance
			Public Debt
Environment	Climate Change and Environment	Ecosystem Services	Environmental Pressure
			Water Quality
			Water Stress
		Emissions and Waste	CO2 Emissions from Energy Use
			CO2 Emissions from Land Use Change and Forestry
			Waste Management
		Societal Response	Low Carbon Economy
Human Rights & Development	Development	Health Threats	Obesity Risk
		Human Development	Education
			Healthcare Capacity
			Poverty
	Human Rights	Civil and Political Rights	Freedom of Opinion and Expression
			Minority Rights
			Women's and Girls' Rights
		Human Security	Arbitrary Arrest and Detention
			Extrajudicial or Unlawful Killings
			Kidnappings
			Security Forces and Human Rights
			Torture and other Ill-Treatment
		Labour Rights and Protection	Child Labour
			Forced Labour
			Freedom of Association and Collective Bargaining
			Trafficking in Persons

Appendices

Politics	Dynamic	Terrorism	Terrorism Intensity
	Structural	Energy, Food and Water Security	Energy Security
			Food Security
			Water Security
		Governance Environment	Corruption
			Democratic Governance
			Government Effectiveness
			Judicial Effectiveness
			Judicial Independence
		Regulatory Environment	Contract Enforcement Process
			Corporate Governance
			Efficacy of Corporate Boards
			Efficacy of the Regulatory System
			Ethical Behaviour of Firms
			Investor Protection
			Regulatory Burden: Cost
			Regulatory Burden: Number of Procedures
			Regulatory Burden: Time
			Regulatory Framework
			Strength of Auditing and Reporting Standards

A.4.2: Market classification

Market Classification					
Developed - 20 countries			Emerging** - 15 countries		
Europe & Middle East	America	Pacific	America	Europe & Middle East & Africa	Asia
UK	US	Australia	Brazil	Czech Republic	China
Austria		Japan	Chile	Hungary	Indonesia
Belgium		NZ	Colombia	Poland	Korea
Denmark			Peru	Russia	Malaysia
Finland				Romania*	Thailand
France				South Africa	
Germany					
Ireland					
Israel					
Italy					
Netherlands					
Norway					
Portugal					
Spain					
Sweden					
Switzerland					

* In the 2019 MSCI Country Classification Romania is a frontier country. In 2019 Romania has been promoted by FTSE Russel as "Secondary Emerging Country". While our classification is mostly inspired by 2019 MSCI Country Classification we decided to classify Romania as an emerging Country.

** In the 2019 MSCI Country Classification Greece is classified as an emerging country. We did not include greece in the list.

Appendices

A.5.1: Descriptive statistics of 1-year, 5-year and 10-year sovereign yields in (bp) for 20 developed countries over the sample study period from 2010 to 2020

Developed Countries							
Yield - 1Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
United Kingdom	0.48	0.20	0.05	0.35	0.50	0.64	0.96
Austria	-0.03	0.57	-0.85	-0.56	-0.04	0.29	1.64
Belgium	0.07	0.74	-0.80	-0.59	-0.04	0.59	3.61
Denmark	0.42	0.77	-0.55	-0.20	0.28	0.90	2.80
Finland	-0.07	0.59	-0.86	-0.60	-0.08	0.15	1.63
France	-0.02	0.58	-0.82	-0.57	-0.02	0.31	1.57
Germany	-0.11	0.58	-0.97	-0.66	-0.07	0.15	1.55
Ireland	1.13	2.56	-0.76	-0.49	0.00	1.49	17.51
Israel	1.04	1.05	-0.55	0.15	0.39	1.94	3.66
Italy	0.81	1.17	-0.44	-0.07	0.48	1.32	7.19
Netherlands	-0.10	0.58	-0.91	-0.64	-0.08	0.15	1.50
Norway	1.72	0.69	0.49	1.09	1.68	2.32	3.21
Portugal	1.74	3.22	-0.65	-0.23	0.28	2.31	18.24
Spain	0.75	1.28	-0.60	-0.32	0.22	1.48	5.92
Sweden	0.60	0.98	-0.56	-0.31	0.27	1.27	2.91
Switzerland	-0.23	0.47	-1.00	-0.67	0.02	0.11	0.85
Australia	2.87	1.30	0.23	1.98	2.62	4.00	5.39
Japan	0.18	0.18	-0.16	0.02	0.15	0.34	0.69
New Zealand	2.98	1.00	0.29	2.07	3.38	3.82	4.82
United States	0.95	0.77	0.25	0.40	0.57	1.38	2.93
Yield - 5Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
United Kingdom	1.32	0.76	0.07	0.78	1.10	1.81	3.30
Austria	0.77	1.13	-0.78	-0.16	0.29	1.80	3.51
Belgium	0.98	1.35	-0.72	-0.14	0.33	2.25	5.63
Denmark	1.15	1.03	-0.42	0.40	0.78	1.67	3.58
Finland	0.68	1.02	-0.77	-0.15	0.30	1.40	3.23
France	0.78	1.07	-0.78	-0.11	0.32	1.77	3.17
Germany	0.48	1.00	-1.01	-0.33	0.15	0.92	2.98
Ireland	2.40	3.16	-0.54	0.08	0.64	3.64	17.70
Israel	2.14	1.35	0.04	1.00	1.40	3.59	5.51
Italy	2.23	1.52	0.24	0.89	1.91	3.26	7.65
Netherlands	0.66	1.05	-0.85	-0.22	0.29	1.38	3.23
Norway	2.34	0.96	0.66	1.52	2.01	3.12	4.35
Portugal	3.91	4.16	-0.32	1.03	2.39	5.31	21.31

Spain	2.00	1.80	-0.40	0.43	1.08	3.50	7.56
Sweden	1.30	1.06	-0.16	0.39	0.77	2.16	3.74
Switzerland	0.27	0.74	-0.92	-0.33	0.18	0.69	2.00
Australia	3.38	1.47	0.53	2.45	3.18	4.41	6.28
Japan	0.28	0.26	-0.21	0.09	0.26	0.46	0.96
New Zealand	3.45	1.21	0.46	2.68	3.30	4.49	5.98
United States	1.81	0.63	0.43	1.34	1.74	2.23	3.50
Yield - 10Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
United Kingdom	2.16	1.05	0.16	1.38	1.93	2.88	4.56
Austria	1.64	1.33	-0.46	0.55	1.13	2.91	4.65
Belgium	1.90	1.48	-0.36	0.69	1.28	3.38	5.79
Denmark	1.80	1.10	-0.22	1.03	1.48	2.47	4.16
Finland	1.53	1.24	-0.46	0.54	1.12	2.48	4.29
France	1.72	1.27	-0.41	0.69	1.28	2.88	4.26
Germany	1.26	1.20	-0.86	0.34	0.91	2.00	3.95
Ireland	3.31	2.91	-0.18	0.94	1.89	5.20	12.46
Israel	3.25	1.43	0.44	2.04	2.58	4.66	6.46
Italy	3.33	1.51	0.89	2.04	3.00	4.50	7.40
Netherlands	1.47	1.26	-0.64	0.45	1.07	2.37	4.27
Norway	2.82	1.04	0.89	1.92	2.39	3.60	4.87
Portugal	4.74	3.31	0.11	2.48	3.93	6.40	16.88
Spain	3.09	1.89	0.02	1.55	2.32	4.74	7.60
Sweden	1.92	1.01	0.09	1.14	1.63	2.68	4.07
Switzerland	0.87	0.89	-0.67	0.16	0.73	1.51	2.91
Australia	3.83	1.48	0.83	2.86	3.70	4.85	6.56
Japan	0.64	0.45	-0.14	0.26	0.63	0.99	1.61
New Zealand	4.02	1.32	0.87	3.20	3.90	5.09	6.54
United States	2.51	0.71	0.62	2.03	2.40	2.96	4.46

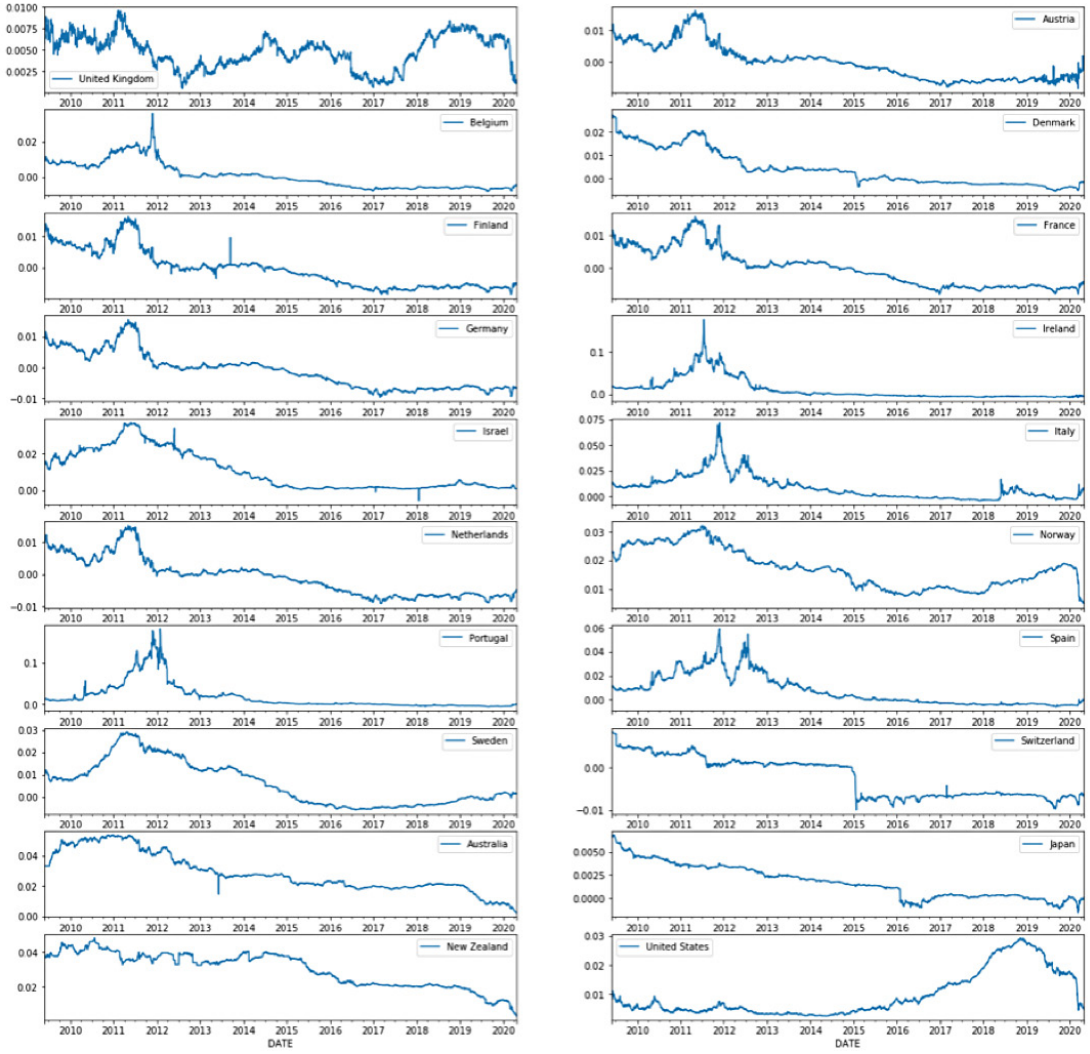
Appendices

A.5.2: Descriptive statistics of 1-year, 5-year and 10-year sovereign yields in (bp) for 15 emerging countries over the sample study period from 2010 to 2020

Emerging Countries							
Yield - 1Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	9.88	2.82	2.76	7.41	10.16	12.13	16.07
Chile	1.05	1.12	-2.34	0.38	0.92	1.79	5.26
Colombia	4.94	0.84	3.25	4.33	4.75	5.35	7.51
Peru	3.29	1.11	0.50	2.40	3.27	4.18	6.82
China	2.72	0.68	0.73	2.29	2.74	3.22	4.22
Korea	2.36	0.82	0.86	1.58	2.08	3.05	3.96
Indonesia	6.10	1.05	3.27	5.33	6.31	6.84	9.22
Malaysia	2.97	0.34	1.86	2.83	2.99	3.18	3.73
Thailand	2.02	0.68	0.66	1.49	1.74	2.64	3.75
Czech Republic	0.99	0.71	0.11	0.32	0.98	1.52	2.75
Poland	2.88	1.25	0.59	1.85	2.07	4.33	5.30
Hungary	3.04	2.67	0.04	0.45	2.10	5.88	8.81
Russia	7.37	2.11	4.03	5.96	6.92	8.77	16.92
South Africa	6.58	0.83	4.19	5.84	6.71	7.31	7.92
Romania	4.06	2.70	0.66	1.65	3.35	6.24	11.76
Yield - 5Y							
Country Name	Mean	Std	Min	0.25	0.5	0.75	Max
Brazil	11.06	2.15	5.86	9.53	11.44	12.53	16.73
Chile	1.67	0.87	-0.67	1.11	1.44	2.48	5.45
Colombia	6.48	0.91	4.41	5.91	6.29	7.02	9.70
Peru	4.66	0.84	2.33	4.32	4.66	5.00	6.86
China	3.28	0.45	1.96	2.99	3.23	3.56	4.58
Korea	2.63	1.02	0.93	1.76	2.34	3.46	4.80
Indonesia	7.37	1.23	4.54	6.66	7.51	8.19	10.87
Malaysia	3.68	0.26	2.70	3.50	3.74	3.87	4.41
Thailand	2.67	0.74	0.69	2.10	2.66	3.33	3.97
Czech Republic	1.51	0.86	0.24	0.77	1.45	2.03	3.65
Poland	3.24	1.38	0.56	2.04	2.56	4.73	5.73
Hungary	3.60	2.38	0.47	1.36	2.57	6.21	8.61
Russia	8.49	1.75	5.64	7.29	8.15	9.28	17.43
South Africa	7.67	0.75	5.61	7.25	7.72	8.15	9.70
Romania	4.96	2.10	2.13	2.98	4.42	6.83	11.00
Yield - 10Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	11.46	1.90	6.69	10.25	11.71	12.52	17.36

Chile	2.01	0.82	-0.22	1.49	1.85	2.63	5.49
Colombia	7.42	0.98	4.64	6.82	7.26	7.97	10.21
Peru	5.91	0.82	3.35	5.55	5.97	6.33	8.03
China	3.64	0.41	2.65	3.40	3.64	3.86	4.76
Korea	2.82	1.08	0.94	1.93	2.58	3.65	5.00
Indonesia	7.98	1.27	5.46	7.15	7.97	8.59	12.60
Malaysia	4.10	0.32	2.94	3.85	4.15	4.38	4.78
Thailand	3.17	0.78	0.88	2.67	3.11	3.83	4.71
Czech Republic	1.87	0.89	0.42	1.20	1.77	2.30	4.19
Poland	3.55	1.28	0.78	2.45	3.06	4.83	5.75
Hungary	4.26	2.06	0.95	2.36	3.51	6.47	8.01
Russia	8.63	1.42	6.01	7.72	8.33	9.22	16.06
South Africa	8.45	0.60	6.76	8.10	8.48	8.84	11.18
Romania	5.49	1.59	2.69	4.19	5.04	6.84	9.89

A.5.3: 20 Developed countries' 1-year maturity yield in (%) over the period 2010–2020



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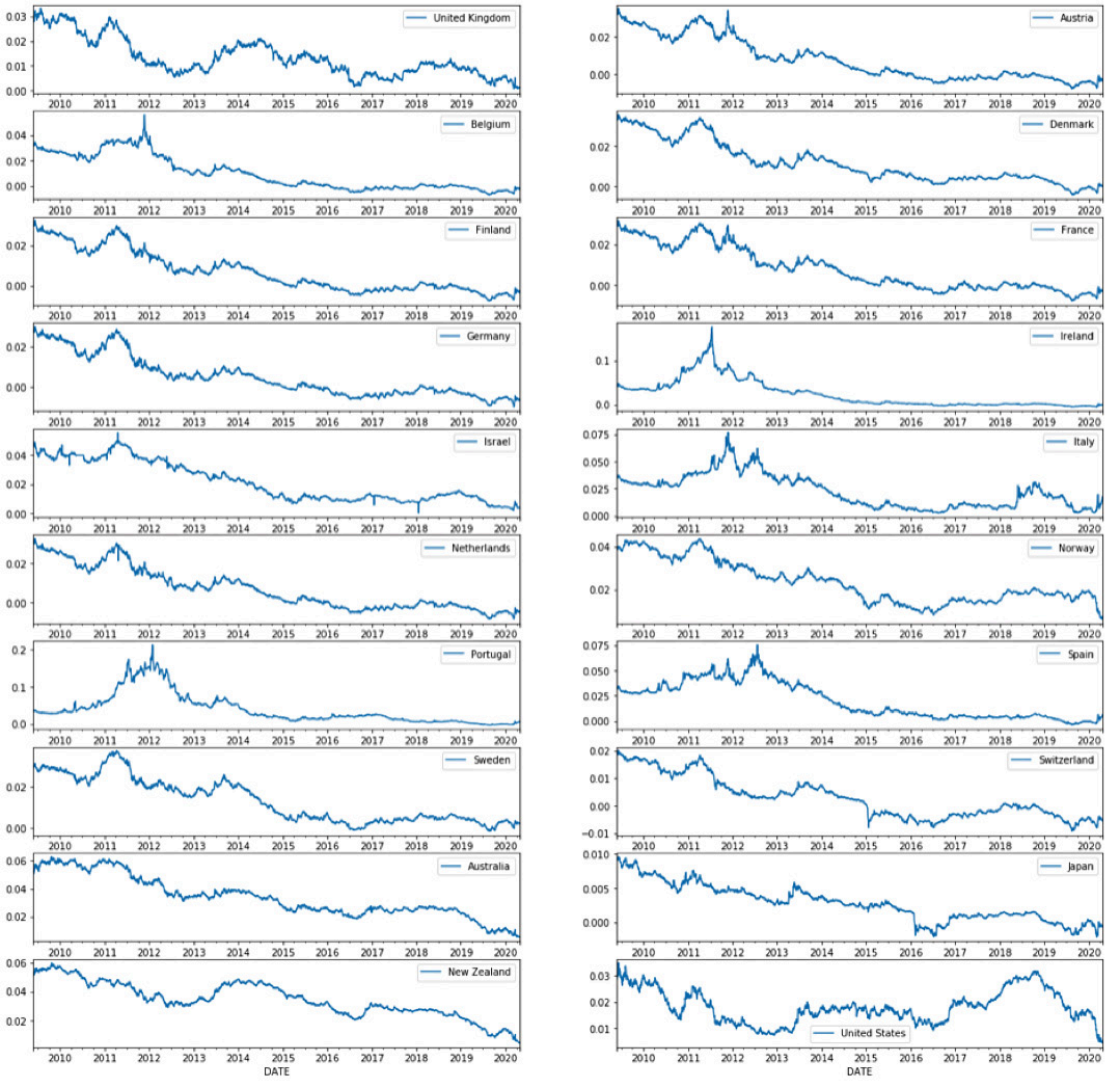
A.5.4: 20 Developed countries' 5-year maturity yield in (%) over the period 2010–2020



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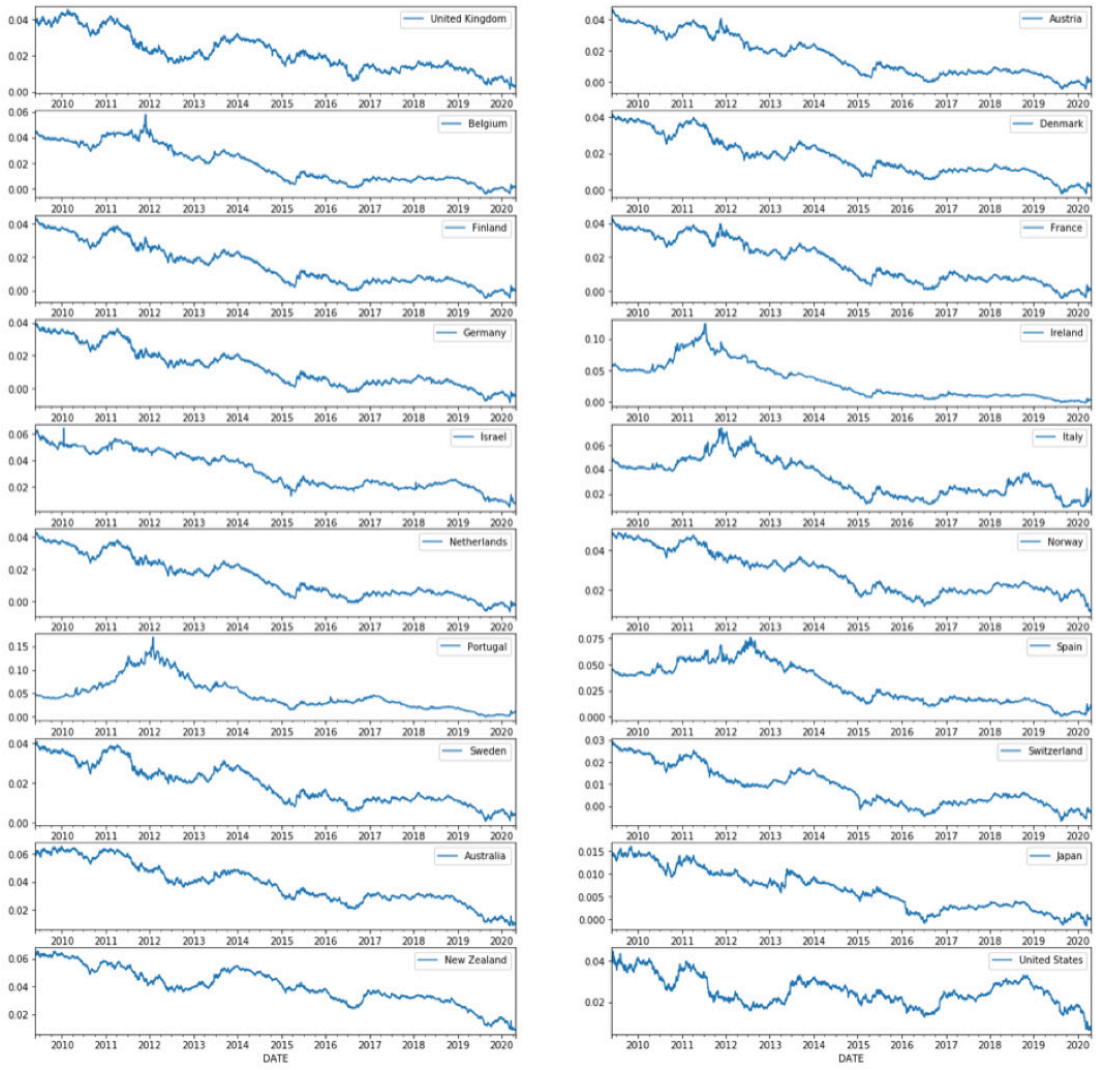
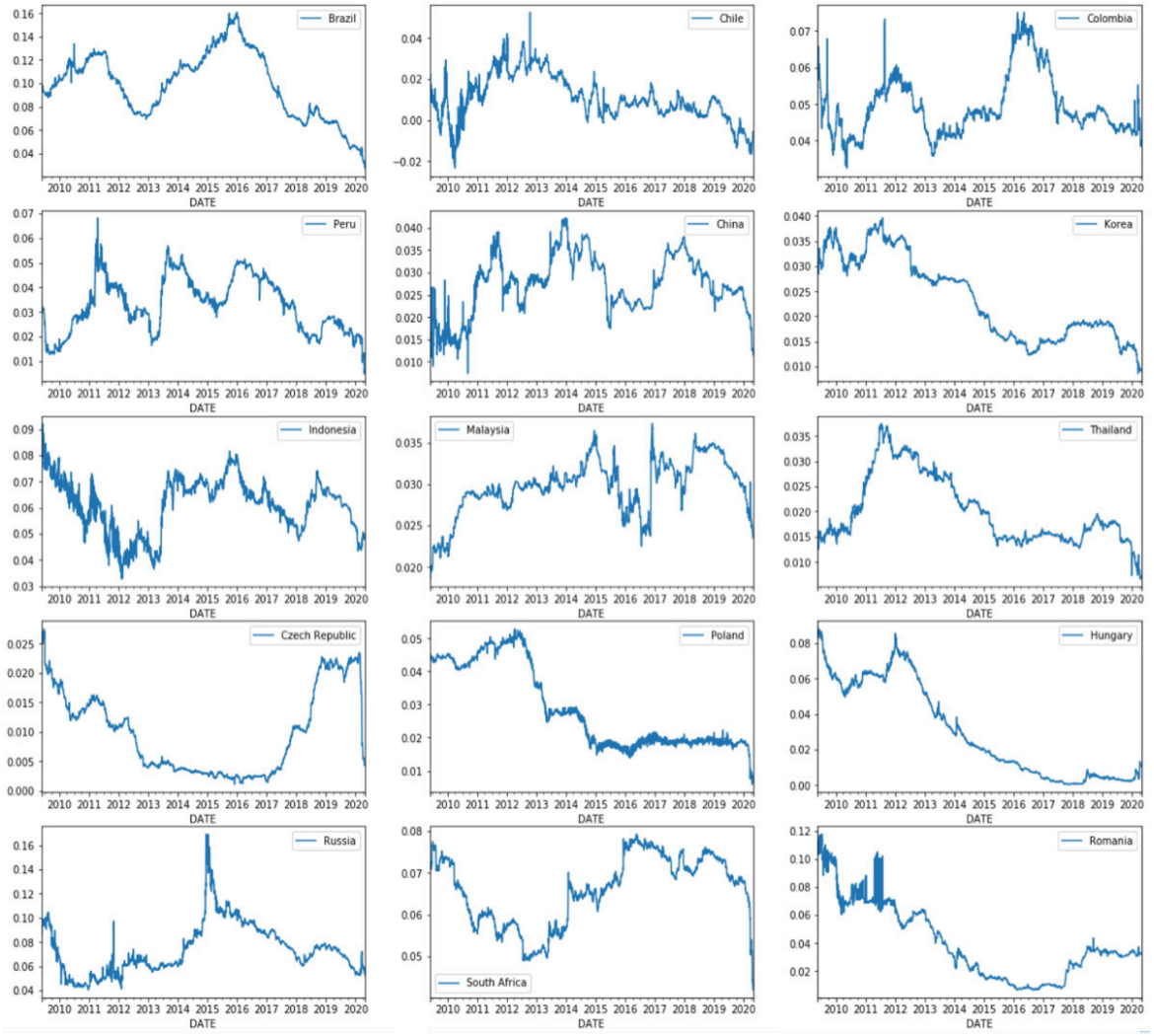
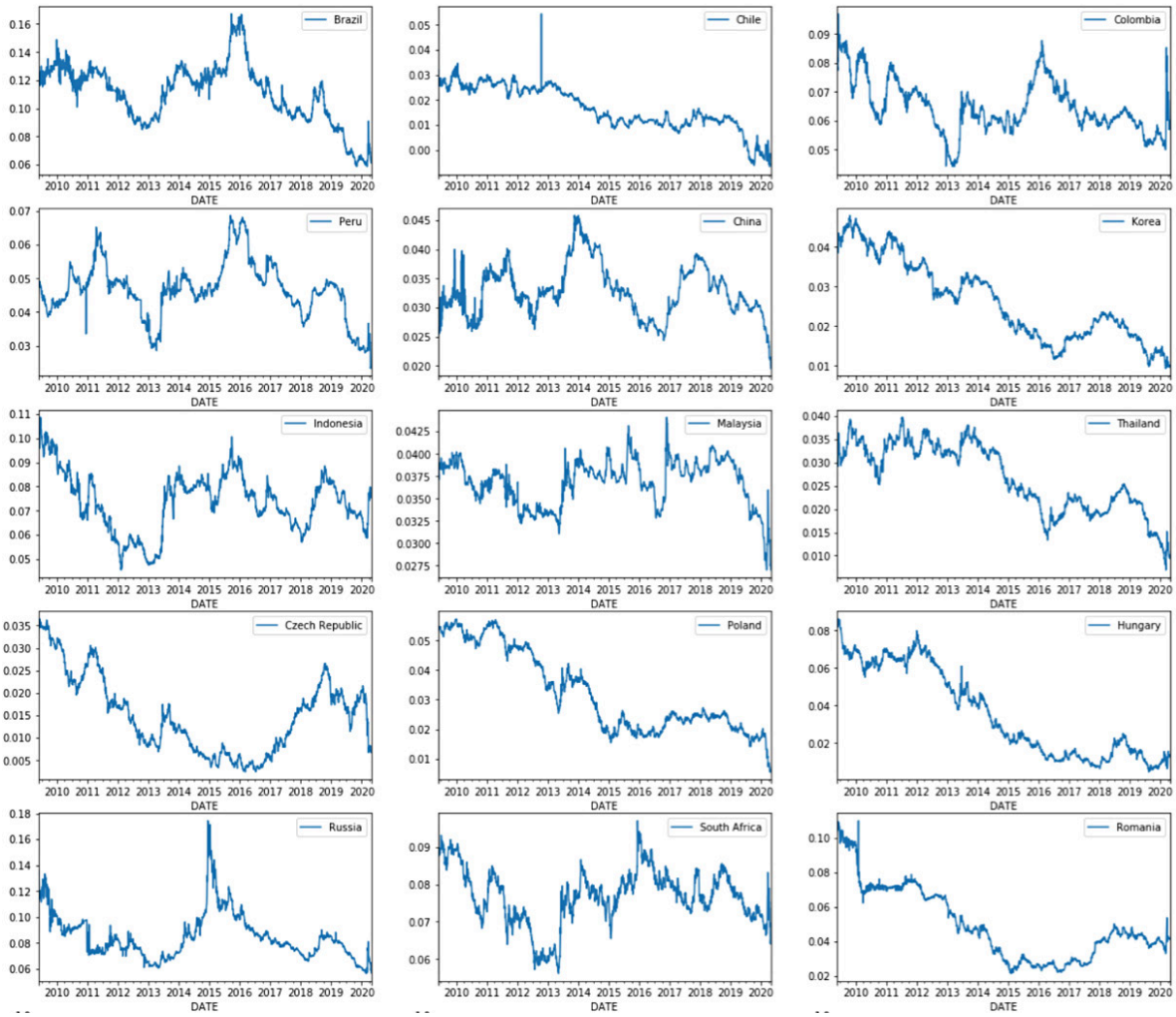
A.5.5: 20 Developed countries' 10-year maturity yield in (%) over the period 2010–2020



A.5.6: 15 Emerging countries' 1-year maturity yield in (%) over the period 2010–2020



A.5.7: 15 Emerging countries' 5-year maturity yield in (%) over the period 2010–2020



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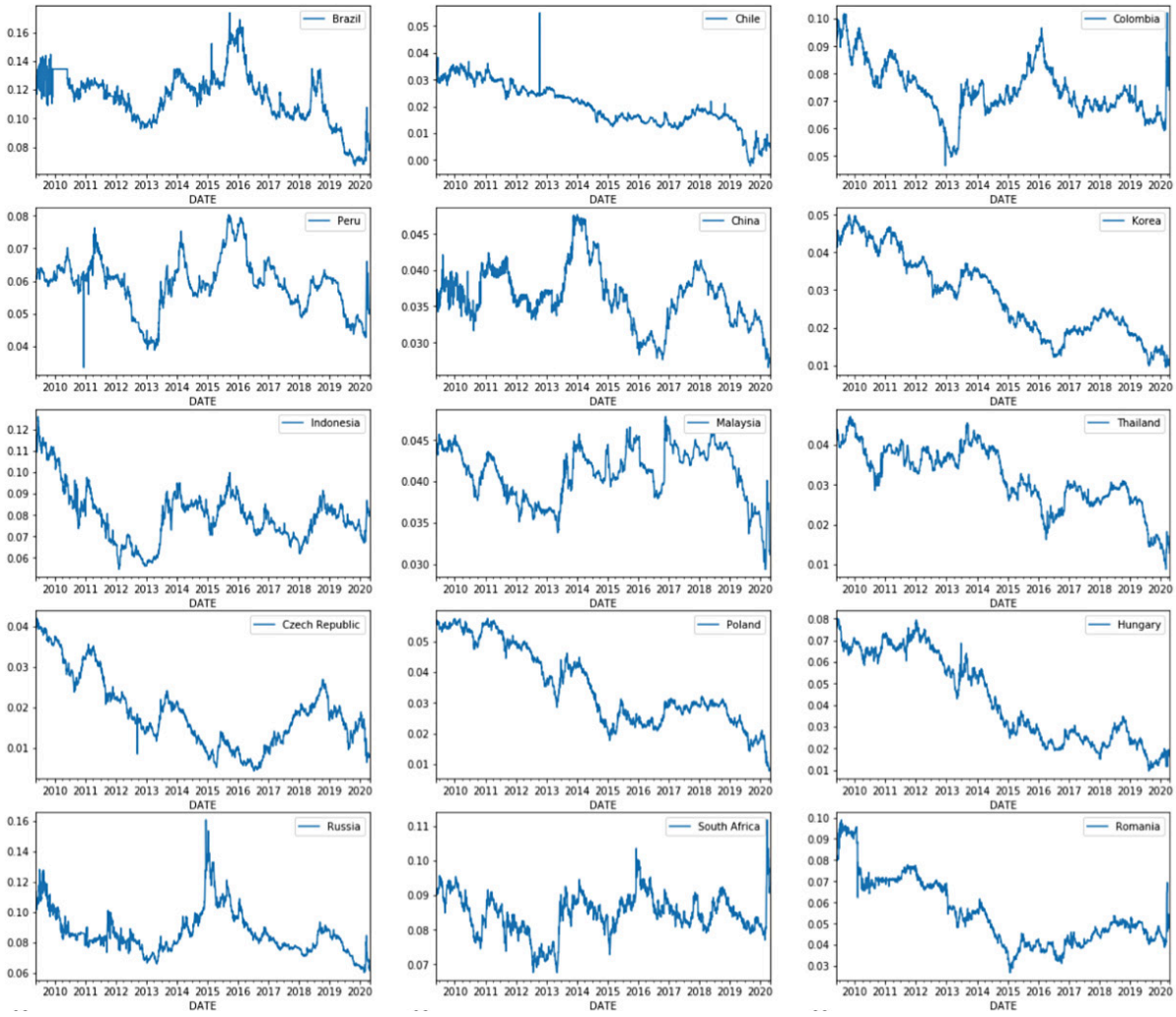
A.5.8: 15 Emerging countries' 10-year maturity yield in (%) over the period 2010–2020



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A.5.9: Descriptive statistics of 1-year, 5-year and 10-year sovereign yield spreads in (bp) for 20 developed countries over the sample study period from 2010 to 2020

Developed Countries							
Yield Spread - 1Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Australia	1.92	1.82	-1.18	0.42	2.25	3.33	5.00
Austria	-0.98	1.20	-3.58	-2.04	-0.46	-0.15	1.28
Belgium	-0.88	1.33	-3.56	-2.03	-0.41	0.01	2.85
Denmark	-0.54	1.34	-3.19	-1.58	-0.11	0.38	1.93
Finland	-1.02	1.21	-3.55	-2.12	-0.52	-0.19	1.26
France	-0.97	1.21	-3.53	-1.99	-0.44	-0.12	1.21
Germany	-1.06	1.22	-3.63	-2.16	-0.55	-0.19	1.19
Ireland	0.18	2.95	-3.49	-1.89	-0.36	0.95	17.04
Israel	0.09	1.57	-2.62	-1.24	-0.13	1.49	3.29
Italy	-0.14	1.64	-2.92	-1.64	-0.02	0.86	6.43
Japan	-0.78	0.88	-2.91	-1.36	-0.30	-0.10	0.08
Netherlands	-1.05	1.22	-3.63	-2.13	-0.52	-0.19	1.13
New Zealand	2.03	1.64	-0.92	0.60	2.96	3.41	4.27
Norway	0.76	1.21	-1.68	-0.08	1.16	1.79	2.82
Portugal	0.79	3.59	-3.27	-1.54	-0.11	1.91	17.73
Spain	-0.20	1.83	-3.33	-1.74	-0.15	1.11	5.17
Sweden	-0.35	1.54	-3.12	-1.69	-0.07	0.93	2.52
Switzerland	-1.18	1.11	-3.56	-2.05	-0.56	-0.22	0.11
United Kingdom	-0.47	0.73	-2.18	-1.12	-0.12	0.06	0.51
Yield Spread - 5Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Australia	1.57	1.43	-0.80	0.53	1.44	2.89	4.48
Austria	-1.04	1.18	-3.20	-2.03	-1.34	0.00	2.05
Belgium	-0.83	1.43	-3.10	-2.01	-1.30	0.14	4.27
Denmark	-0.66	1.03	-2.67	-1.51	-0.81	0.28	1.20
Finland	-1.13	1.05	-3.18	-2.03	-1.32	-0.15	0.79
France	-1.03	1.14	-3.14	-1.98	-1.29	-0.05	1.59
Germany	-1.33	1.01	-3.35	-2.18	-1.49	-0.39	0.61
Ireland	0.59	3.27	-2.94	-1.84	-0.96	1.99	15.91
Israel	0.33	1.42	-2.44	-0.85	-0.22	1.75	3.18
Italy	0.42	1.69	-2.23	-0.84	-0.27	1.55	6.29
Japan	-1.53	0.61	-3.06	-1.89	-1.49	-1.18	-0.41
Netherlands	-1.15	1.09	-3.25	-2.09	-1.36	-0.10	0.79
New Zealand	1.64	1.20	-0.77	0.89	2.14	2.62	3.44
Norway	0.53	0.99	-1.17	-0.34	0.29	1.50	2.29

Portugal	2.10	4.41	-2.43	-0.60	0.49	3.95	20.29
Spain	0.19	2.04	-2.66	-1.51	-0.48	1.82	6.78
Sweden	-0.51	1.15	-2.55	-1.45	-0.80	0.67	1.55
Switzerland	-1.54	0.79	-3.19	-2.14	-1.55	-0.79	-0.16
United Kingdom	-0.49	0.71	-2.13	-1.15	-0.24	0.08	0.51
Yield Spread - 10Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Australia	1.32	1.05	-0.58	0.65	1.26	2.32	3.19
Austria	-0.88	0.99	-2.55	-1.72	-1.17	0.06	1.88
Belgium	-0.61	1.19	-2.37	-1.57	-1.06	0.31	3.55
Denmark	-0.72	0.71	-2.12	-1.27	-0.78	-0.02	0.74
Finland	-0.98	0.87	-2.55	-1.72	-1.18	-0.10	1.02
France	-0.79	0.96	-2.45	-1.49	-1.08	0.02	1.76
Germany	-1.25	0.81	-2.83	-1.91	-1.46	-0.39	0.22
Ireland	0.79	2.67	-2.16	-1.26	-0.53	2.29	9.27
Israel	0.73	1.13	-0.97	-0.25	0.38	1.74	3.00
Italy	0.81	1.40	-1.12	-0.13	0.24	1.33	5.21
Japan	-1.87	0.50	-3.01	-2.21	-1.94	-1.51	-0.62
Netherlands	-1.05	0.89	-2.68	-1.79	-1.28	-0.13	0.68
New Zealand	1.51	0.89	-0.40	1.07	1.83	2.20	2.82
Norway	0.30	0.71	-0.93	-0.28	0.16	0.95	1.66
Portugal	2.23	3.30	-1.60	0.16	1.19	3.59	14.88
Spain	0.58	1.77	-1.69	-0.65	0.02	1.70	6.02
Sweden	-0.60	0.67	-1.97	-1.13	-0.58	0.03	0.67
Switzerland	-1.64	0.53	-2.71	-2.04	-1.71	-1.16	-0.59
United Kingdom	-0.35	0.62	-1.77	-0.96	-0.15	0.11	0.70

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A.5.10: Descriptive statistics of 1-year, 5-year and 10-year sovereign yield spreads in (bp) for 15 emerging countries over the sample study period from 2010 to 2020

Emerging Countries							
Yield Spread - 1Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	8.92	3.31	2.24	6.44	9.56	11.45	15.51
Chile	0.10	1.59	-3.03	-1.13	0.12	1.43	4.95
China	1.76	1.00	-0.63	0.97	1.76	2.53	3.93
Colombia	3.98	1.15	1.77	3.28	4.07	4.81	6.87
Czech Republic	0.04	0.73	-1.54	-0.57	0.08	0.54	1.95
Hungary	2.09	3.20	-2.48	-1.15	1.76	5.42	7.92
Indonesia	5.15	1.28	2.65	3.99	5.21	6.36	8.17
Malaysia	2.01	0.69	0.53	1.51	2.10	2.60	3.26
Peru	2.34	1.57	-1.10	1.05	2.62	3.49	6.43
Poland	1.93	1.76	-1.07	0.43	1.54	3.78	4.77
Romania	3.11	3.01	-0.69	0.65	1.84	5.87	10.98
Russia	6.42	2.24	3.51	4.72	5.80	7.81	16.53
South Africa	5.63	0.75	3.68	4.94	5.55	6.23	7.13
South Korea	1.40	1.38	-1.09	0.11	1.73	2.54	3.53
Thailand	1.06	1.24	-1.16	0.13	0.99	2.28	3.32
Yield Spread - 5Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	9.25	2.15	4.31	7.93	9.75	10.58	15.38
Chile	-0.14	1.04	-2.10	-0.88	-0.19	0.64	4.64
China	1.47	0.71	-0.94	1.03	1.53	1.98	3.16
Colombia	4.67	0.93	2.84	3.94	4.56	5.41	7.80
Czech Republic	-0.30	0.65	-1.55	-0.92	-0.29	0.35	0.96
Hungary	1.79	2.45	-1.90	-0.62	0.88	4.20	6.71
Indonesia	5.56	1.00	3.26	4.90	5.58	6.27	8.66
Malaysia	1.87	0.49	0.22	1.49	1.97	2.25	3.10
Peru	2.85	1.02	0.88	2.00	2.91	3.53	5.72
Poland	1.43	1.40	-0.72	0.29	0.76	2.81	3.84
Romania	3.15	2.04	0.50	1.32	2.42	5.14	8.39
Russia	6.68	1.74	3.82	5.46	6.30	7.59	15.75
South Africa	5.86	0.62	4.45	5.45	5.81	6.13	8.13
South Korea	0.82	1.05	-1.17	-0.11	0.58	1.84	2.55
Thailand	0.86	0.95	-0.96	0.12	0.76	1.61	2.70
Yield Spread - 10Y							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	8.94	1.74	4.95	7.94	9.00	9.73	15.17
Chile	-0.50	0.63	-1.75	-0.92	-0.59	-0.14	3.70
China	1.13	0.59	-0.88	0.78	1.30	1.57	2.22
Colombia	4.90	0.87	2.75	4.33	4.79	5.30	9.53

Czech Republic	-0.64	0.48	-1.54	-1.04	-0.67	-0.22	0.42
Hungary	1.75	1.78	-1.04	0.24	1.08	3.21	5.77
Indonesia	5.46	0.95	3.34	4.85	5.49	5.99	8.42
Malaysia	1.58	0.58	-0.12	1.25	1.61	2.00	3.30
Peru	3.39	0.90	-0.31	2.84	3.23	3.85	6.41
Poland	1.03	0.93	-0.42	0.22	0.75	1.82	3.09
Romania	2.98	1.31	0.71	1.92	2.54	3.88	6.17
Russia	6.12	1.40	3.76	5.16	5.80	6.78	13.84
South Africa	5.94	0.75	4.38	5.41	5.87	6.24	10.40
South Korea	0.31	0.73	-1.15	-0.25	0.24	0.92	1.76
Thailand	0.66	0.58	-0.39	0.18	0.63	1.07	2.09
Ireland	0.79	2.67	-2.16	-1.26	-0.53	2.29	9.27
Israel	0.73	1.13	-0.97	-0.25	0.38	1.74	3.00
Italy	0.81	1.40	-1.12	-0.13	0.24	1.33	5.21
Japan	-1.87	0.50	-3.01	-2.21	-1.94	-1.51	-0.62
Netherlands	-1.05	0.89	-2.68	-1.79	-1.28	-0.13	0.68
New Zealand	1.51	0.89	-0.40	1.07	1.83	2.20	2.82
Norway	0.30	0.71	-0.93	-0.28	0.16	0.95	1.66
Portugal	2.23	3.30	-1.60	0.16	1.19	3.59	14.88
Spain	0.58	1.77	-1.69	-0.65	0.02	1.70	6.02
Sweden	-0.60	0.67	-1.97	-1.13	-0.58	0.03	0.67
Switzerland	-1.64	0.53	-2.71	-2.04	-1.71	-1.16	-0.59
United Kingdom	-0.35	0.62	-1.77	-0.96	-0.15	0.11	0.70

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A.5.11: Descriptive statistics of Economic, Environmental, Social and Governance scores for 20 developed countries over the sample study period from 2010 to 2020

Developed Countries							
Economics							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Australia	5.72	0.19	5.40	5.59	5.68	5.83	6.23
Austria	6.30	0.08	6.14	6.26	6.30	6.35	6.48
Belgium	6.17	0.12	5.93	6.09	6.16	6.27	6.41
Denmark	7.08	0.33	6.39	6.82	7.17	7.36	7.58
Finland	6.31	0.16	6.05	6.19	6.29	6.39	6.65
France	6.00	0.12	5.64	5.98	6.04	6.08	6.12
Germany	6.36	0.15	5.86	6.26	6.36	6.47	6.62
Ireland	6.29	0.76	4.92	5.75	6.57	6.87	7.57
Israel	6.60	0.32	5.95	6.45	6.64	6.88	7.11
Italy	5.37	0.17	4.91	5.27	5.38	5.48	5.63
Japan	5.11	0.24	4.66	4.89	5.13	5.33	5.48
Netherlands	6.61	0.23	6.22	6.46	6.64	6.79	6.98
New Zealand	5.90	0.15	5.58	5.79	5.93	5.99	6.21
Norway	6.45	0.32	5.82	6.22	6.52	6.60	7.11
Portugal	5.11	0.42	4.17	4.84	5.28	5.40	5.69
Spain	5.49	0.34	4.88	5.15	5.58	5.79	5.93
Sweden	7.17	0.15	6.82	7.09	7.16	7.27	7.49
Switzerland	8.17	0.12	7.93	8.10	8.17	8.25	8.41
United Kingdom	5.33	0.09	5.11	5.27	5.32	5.39	5.50
United States	5.11	0.25	4.71	4.93	5.17	5.31	5.54
Mean	6.13	0.23	5.65	5.97	6.17	6.30	6.54
Std	0.79	0.16	0.86	0.82	0.78	0.79	0.82
Environment							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Australia	6.01	0.21	5.60	5.85	6.10	6.16	6.33
Austria	7.74	0.13	7.54	7.62	7.79	7.87	7.92
Belgium	6.47	0.15	6.25	6.36	6.47	6.63	6.67
Denmark	7.77	0.32	7.29	7.52	7.74	8.08	8.29
Finland	7.15	0.16	6.85	7.04	7.19	7.29	7.37
France	7.46	0.19	7.11	7.27	7.46	7.62	7.80
Germany	6.93	0.10	6.75	6.88	6.93	6.99	7.15
Ireland	7.22	0.20	6.79	7.09	7.25	7.40	7.43
Israel	5.29	0.24	4.83	5.14	5.25	5.50	5.67
Italy	6.60	0.08	6.44	6.52	6.65	6.67	6.70
Japan	6.22	0.32	5.68	5.95	6.26	6.39	6.71

Netherlands	6.38	0.15	6.12	6.25	6.41	6.47	6.68
New Zealand	7.62	0.15	7.37	7.48	7.66	7.72	7.92
Norway	8.05	0.10	7.88	7.95	8.07	8.14	8.19
Portugal	6.35	0.14	6.06	6.23	6.34	6.47	6.52
Spain	6.53	0.13	6.24	6.44	6.59	6.63	6.65
Sweden	8.11	0.14	7.89	8.00	8.09	8.25	8.31
Switzerland	8.26	0.12	8.05	8.20	8.26	8.36	8.46
United Kingdom	7.10	0.19	6.77	6.90	7.10	7.24	7.40
United States	6.29	0.14	5.96	6.20	6.29	6.38	6.50
Mean	6.98	0.17	6.67	6.84	7.00	7.11	7.23
Std	0.80	0.06	0.85	0.81	0.80	0.80	0.79

Social

Country Name	Mean	Std	Min	25%	50%	75%	Max
Australia	7.99	0.16	7.59	7.95	8.00	8.09	8.23
Austria	7.91	0.34	7.41	7.66	7.83	8.22	8.53
Belgium	8.00	0.15	7.78	7.89	7.96	8.09	8.32
Denmark	8.61	0.32	7.95	8.52	8.57	8.87	8.99
Finland	8.52	0.22	8.27	8.31	8.47	8.69	8.87
France	7.49	0.36	6.92	7.24	7.32	7.83	8.04
Germany	8.09	0.23	7.60	7.92	8.12	8.30	8.37
Ireland	8.08	0.26	7.71	7.87	8.05	8.21	8.58
Israel	4.87	0.48	4.18	4.35	4.91	5.33	5.44
Italy	6.57	0.21	6.24	6.37	6.57	6.70	7.07
Japan	7.12	0.18	6.86	6.98	7.09	7.30	7.38
Netherlands	8.24	0.30	7.79	8.07	8.14	8.47	8.75
New Zealand	8.34	0.10	8.18	8.26	8.34	8.41	8.51
Norway	8.69	0.13	8.41	8.62	8.71	8.74	8.93
Portugal	7.25	0.29	6.78	6.90	7.30	7.45	7.70
Spain	7.19	0.44	6.70	6.82	7.01	7.62	7.89
Sweden	8.23	0.19	7.98	8.09	8.21	8.36	8.60
Switzerland	7.80	0.13	7.50	7.74	7.82	7.93	7.97
United Kingdom	7.61	0.47	7.10	7.25	7.35	7.98	8.43
United States	6.30	0.22	5.95	6.08	6.33	6.47	6.68
Mean	7.64	0.26	7.25	7.44	7.61	7.85	8.06
Std	0.92	0.11	0.98	1.01	0.91	0.86	0.87

Governance

Country Name	Mean	Std	min	25%	50%	75%	max
Australia	8.41	0.15	8.10	8.28	8.44	8.55	8.61
Austria	8.00	0.08	7.85	7.95	7.99	8.03	8.15

Belgium	7.65	0.12	7.43	7.53	7.66	7.75	7.84
Denmark	8.77	0.08	8.63	8.71	8.77	8.85	8.87
Finland	8.50	0.15	8.12	8.46	8.54	8.56	8.73
France	7.73	0.12	7.51	7.64	7.72	7.83	8.01
Germany	7.96	0.10	7.71	7.92	7.96	8.01	8.18
Ireland	7.86	0.15	7.58	7.74	7.88	7.95	8.17
Israel	6.47	0.28	5.99	6.32	6.43	6.74	7.00
Italy	5.67	0.29	5.27	5.47	5.62	5.90	6.44
Japan	7.58	0.14	7.29	7.50	7.54	7.71	7.78
Netherlands	8.14	0.06	7.97	8.11	8.16	8.18	8.19
New Zealand	8.79	0.25	8.04	8.67	8.85	8.97	9.05
Norway	8.92	0.13	8.57	8.81	8.99	9.01	9.07
Portugal	6.87	0.08	6.80	6.82	6.84	6.91	7.17
Spain	6.64	0.24	6.24	6.55	6.63	6.77	7.33
Sweden	8.56	0.09	8.37	8.53	8.58	8.61	8.76
Switzerland	8.19	0.12	7.92	8.11	8.17	8.31	8.37
United Kingdom	8.13	0.12	7.90	8.00	8.18	8.22	8.27
United States	7.73	0.20	7.22	7.64	7.71	7.89	8.05
Mean	7.83	0.15	7.53	7.74	7.83	7.94	8.10
Std	0.85	0.07	0.87	0.87	0.87	0.82	0.70

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A.5.12: Descriptive statistics of Economic, Environmental, Social and Governance scores for 15 emerging countries over the sample study period from 2010 to 2020

Emerging Countries							
Economics							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	5.23	0.37	4.42	5.07	5.33	5.45	5.78
Chile	6.62	0.12	6.32	6.54	6.60	6.69	6.86
China	7.03	0.18	6.71	6.89	7.00	7.12	7.50
Colombia	5.13	0.25	4.82	4.95	5.05	5.27	5.72
Czech Republic	6.82	0.33	6.33	6.54	6.73	7.15	7.40
Hungary	6.26	0.36	5.60	5.93	6.25	6.58	6.92
Indonesia	5.40	0.16	5.06	5.32	5.42	5.53	5.67
Malaysia	6.13	0.12	5.91	6.07	6.12	6.15	6.59
Peru	6.13	0.17	5.74	6.01	6.14	6.25	6.43
Poland	5.98	0.20	5.67	5.82	5.99	6.12	6.32
Romania	5.56	0.54	4.78	5.03	5.67	6.12	6.32
Russia	6.21	0.37	5.48	5.95	6.21	6.52	6.84
South Africa	6.76	0.17	6.26	6.64	6.80	6.88	7.03
South Korea	4.96	0.16	4.68	4.86	4.93	5.04	5.57
Thailand	6.41	0.26	5.85	6.18	6.48	6.65	6.76
Mean	6.04	0.25	5.58	5.85	6.05	6.24	6.51
Std	0.65	0.12	0.69	0.67	0.64	0.66	0.62
Environment							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	5.39	0.13	5.21	5.30	5.43	5.45	5.71
Chile	6.43	0.18	6.16	6.32	6.37	6.60	6.76
China	3.93	0.18	3.76	3.80	3.85	4.04	4.46
Colombia	5.69	0.17	5.43	5.59	5.70	5.78	6.08
Czech Republic	6.48	0.11	6.29	6.44	6.49	6.55	6.70
Hungary	6.25	0.30	5.73	5.98	6.21	6.49	6.79
Indonesia	3.79	0.13	3.57	3.69	3.82	3.84	4.14
Malaysia	5.55	0.17	5.30	5.41	5.57	5.66	5.98
Peru	5.15	0.13	4.99	5.04	5.12	5.20	5.49
Poland	6.34	0.14	6.13	6.21	6.37	6.41	6.60
Romania	6.09	0.39	5.52	5.87	6.01	6.38	6.95
Russia	5.57	0.22	5.25	5.34	5.55	5.67	6.10
South Africa	4.05	0.18	3.84	3.90	4.05	4.10	4.59
South Korea	5.98	0.17	5.65	5.84	6.07	6.08	6.23
Thailand	5.00	0.23	4.60	4.79	5.02	5.22	5.26
Mean	5.45	0.19	5.16	5.30	5.44	5.56	5.86
Std	0.91	0.07	0.87	0.90	0.91	0.94	0.90

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Social							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	3.50	0.39	2.89	3.19	3.66	3.79	4.11
Chile	5.93	0.52	5.30	5.41	5.88	6.38	6.86
China	2.40	0.61	1.74	1.85	2.32	3.08	3.28
Colombia	3.13	0.88	2.27	2.35	2.62	4.06	4.41
Czech Republic	6.89	0.20	6.55	6.72	6.91	6.99	7.39
Hungary	6.16	0.17	5.93	6.00	6.10	6.33	6.53
Indonesia	3.20	0.57	2.31	2.61	3.20	3.79	3.93
Malaysia	3.81	0.21	3.45	3.63	3.86	3.95	4.19
Peru	3.79	0.51	3.02	3.38	3.70	4.33	4.50
Poland	6.37	0.45	5.63	5.92	6.46	6.80	7.01
Romania	5.16	0.12	4.98	5.08	5.14	5.22	5.48
Russia	3.13	0.67	2.33	2.47	2.90	3.96	4.08
South Africa	3.97	0.72	2.87	3.13	3.93	4.69	4.90
South Korea	7.10	0.32	6.67	6.80	7.00	7.42	7.60
Thailand	3.48	0.24	2.90	3.35	3.54	3.64	3.83
Mean	4.53	0.44	3.92	4.13	4.48	4.96	5.21
Std	1.57	0.23	1.72	1.69	1.61	1.43	1.47
Governance							
Country Name	Mean	Std	Min	25%	50%	75%	Max
Brazil	5.33	0.21	4.96	5.19	5.31	5.47	5.89
Chile	7.13	0.12	6.89	7.03	7.14	7.18	7.37
China	4.34	0.33	3.85	4.15	4.29	4.47	5.23
Colombia	5.37	0.17	5.17	5.25	5.34	5.44	5.75
Czech Republic	6.54	0.37	6.11	6.23	6.39	6.96	7.09
Hungary	6.09	0.31	5.61	5.80	6.06	6.42	6.49
Indonesia	4.95	0.18	4.64	4.82	4.95	5.08	5.43
Malaysia	6.89	0.15	6.67	6.77	6.89	7.05	7.09
Peru	5.71	0.29	5.21	5.55	5.75	5.97	6.05
Poland	6.30	0.24	5.92	6.19	6.30	6.44	6.71
Romania	5.61	0.26	5.16	5.37	5.66	5.78	6.34
Russia	4.52	0.71	3.68	3.88	4.27	5.23	5.81
South Africa	6.60	0.36	6.02	6.17	6.73	6.92	6.99
South Korea	6.65	0.21	6.44	6.52	6.56	6.70	7.36
Thailand	5.35	0.27	4.88	5.14	5.44	5.63	5.71
Mean	5.83	0.28	5.41	5.60	5.81	6.05	6.35
Std	0.86	0.14	0.95	0.91	0.89	0.83	0.71

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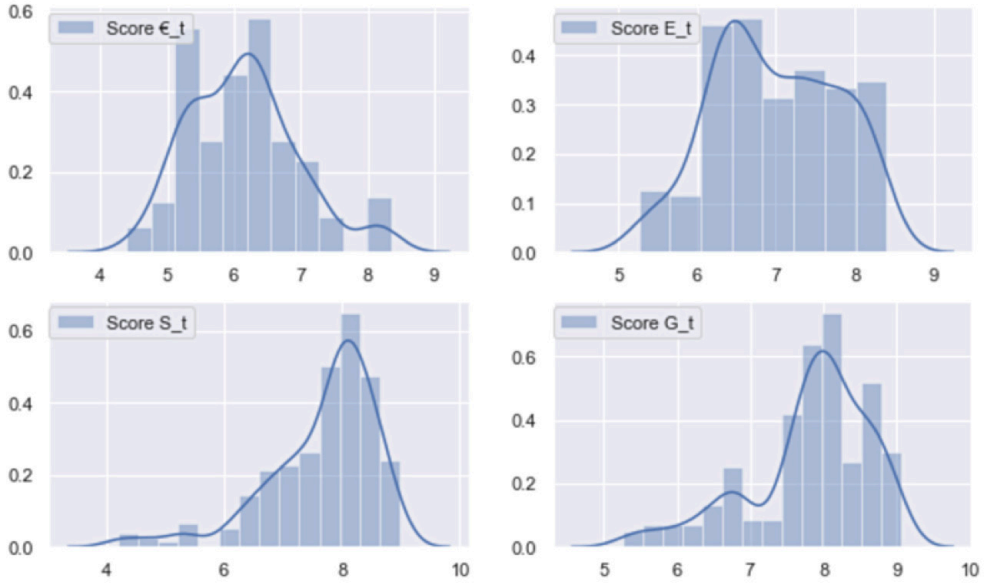
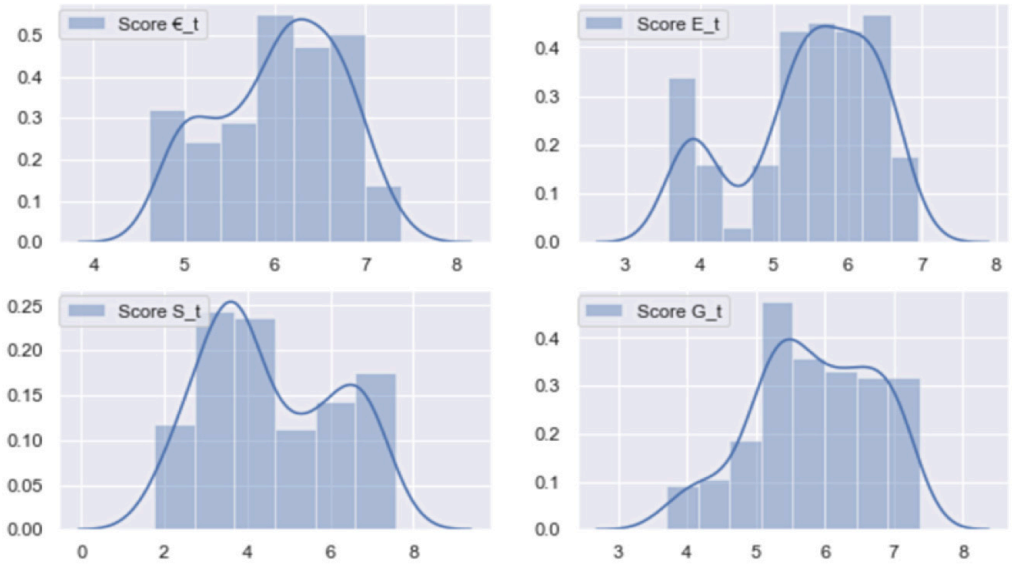
A.5.13: Average of Economic, Environmental, Social and Governance distributions for 20 developed countries over the sample period from 2010 to 2020



A.5.14: Average of Economic, Environmental, Social and Governance distributions for 15 emerging countries over the sample period from 2010 to 2020



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A.5.15: Average Economic, Environmental, Social and Governance scores and rankings for 20 developed countries and 15 emerging countries over the sample study period from 2010 to 2020

Developed Countries								
Country Name	Economics	Ranking (Economics)	Environment	Ranking (Environment)	Social	Ranking (Social)	Governance	Ranking (Governance)
Australia	5.72	14	6.03	19	8.00	10	8.40	6
Austria	6.30	10	7.75	5	7.94	11	8.00	10
Belgium	6.17	11	6.47	14	8.01	9	7.64	15
Denmark	7.11	3	7.79	4	8.62	2	8.76	2
Finland	6.31	9	7.15	9	8.53	3	8.49	5
France	5.99	12	7.47	7	7.51	14	7.74	13
Germany	6.36	7	6.94	11	8.10	8	7.95	11
Ireland	6.33	8	7.21	8	8.10	7	7.86	12
Israel	6.62	5	5.31	20	4.88	20	6.48	19
Italy	5.37	16	6.60	12	6.59	18	5.70	20
Japan	5.11	19	6.22	18	7.13	17	7.57	16
Netherlands	6.62	4	6.39	15	8.26	5	8.13	8
New Zealand	5.90	13	7.62	6	8.34	4	8.75	3
Norway	6.45	6	8.04	3	8.70	1	8.92	1
Portugal	5.12	18	6.34	16	7.27	15	6.88	17
Spain	5.51	15	6.53	13	7.22	16	6.67	18
Sweden	7.16	2	8.11	2	8.25	6	8.55	4
Switzerland	8.17	1	8.26	1	7.81	12	8.18	7
United Kingdom	5.32	17	7.11	10	7.64	13	8.12	9
United States	5.10	20	6.29	17	6.29	19	7.71	14

Emerging Countries								
Country Name	Economics	Ranking (Economics)	Environment	Ranking (Environment)	Social	Ranking (Social)	Governance	Ranking (Governance)
Brazil	5.26	13	5.40	10	3.51	10	5.35	12
Chile	6.62	4	6.44	2	5.96	5	7.12	1
China	7.02	1	3.96	14	2.44	15	4.38	15
Colombia	5.15	14	5.71	7	3.18	13	5.38	10
Czech Republic	6.81	2	6.52	1	6.89	2	6.56	5
Hungary	6.25	6	6.27	4	6.16	4	6.10	7
Indonesia	5.41	12	3.81	15	3.23	12	4.97	13
Malaysia	6.12	9	5.57	9	3.81	9	6.90	2
Peru	6.14	8	5.16	11	3.82	8	5.70	8
Poland	5.97	10	6.35	3	6.38	3	6.31	6
Romania	5.53	11	6.13	5	5.15	6	5.64	9
Russia	6.21	7	5.59	8	3.17	14	4.58	14
South Africa	6.76	3	4.08	13	4.00	7	6.59	4
South Korea	4.96	15	5.98	6	7.11	1	6.68	3
Thailand	6.42	5	5.01	12	3.49	11	5.36	11

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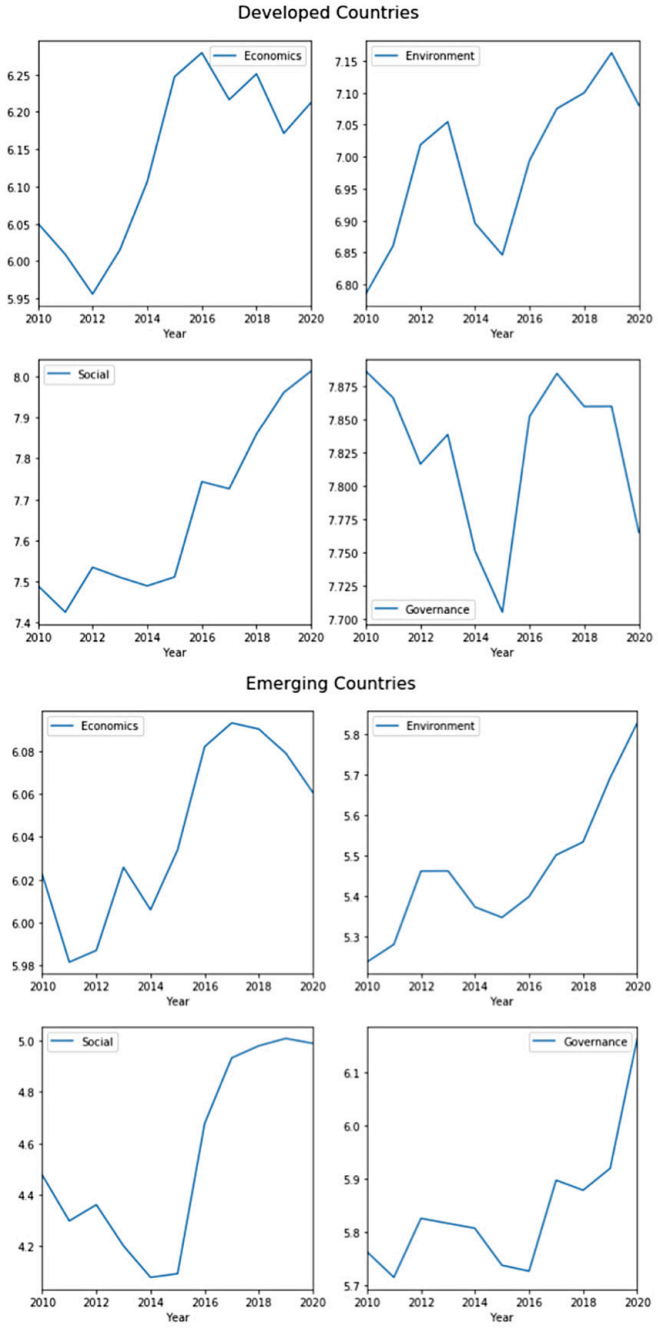
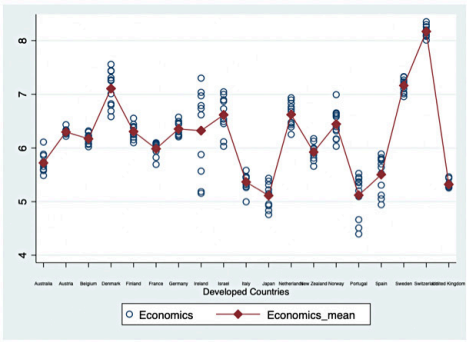
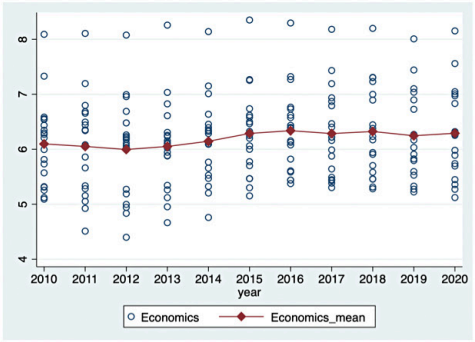
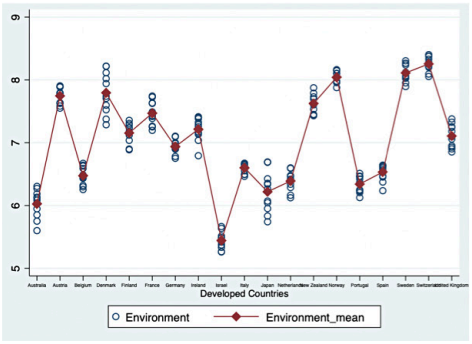
A.5.16: Average of Economic, Environmental, Social and Governance dimensions for all countries, by region (developed and emerging countries) over the sample period 2010–2020

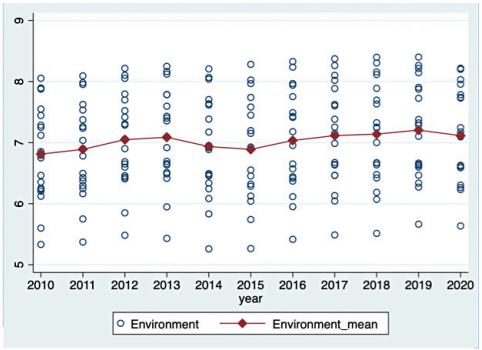


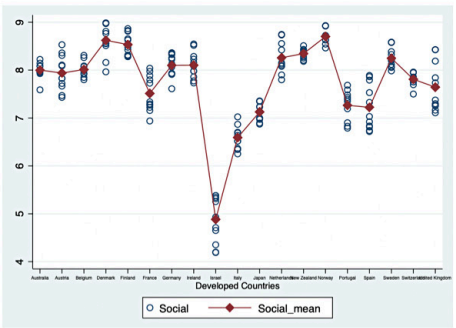
A.5.17: Heterogeneity across 20 developed countries and over time (2010–2020): Economic, Environmental, Social and Governance dimensions

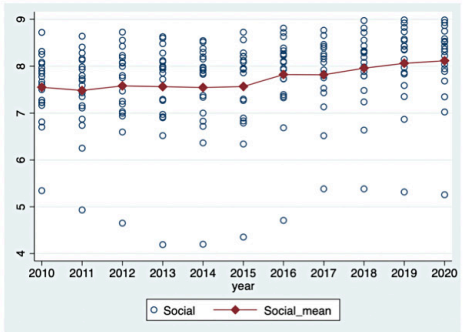


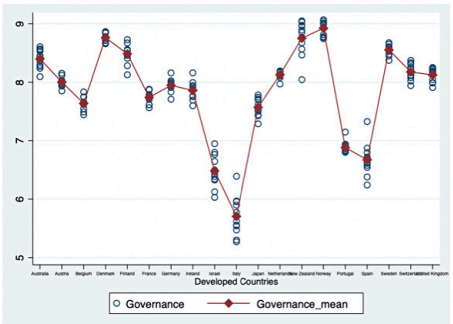


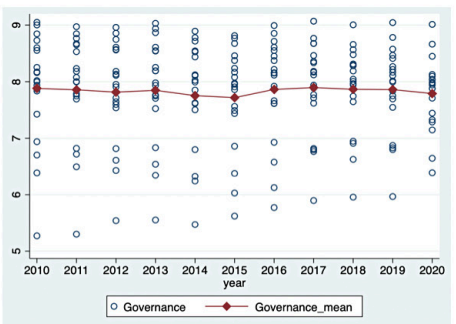




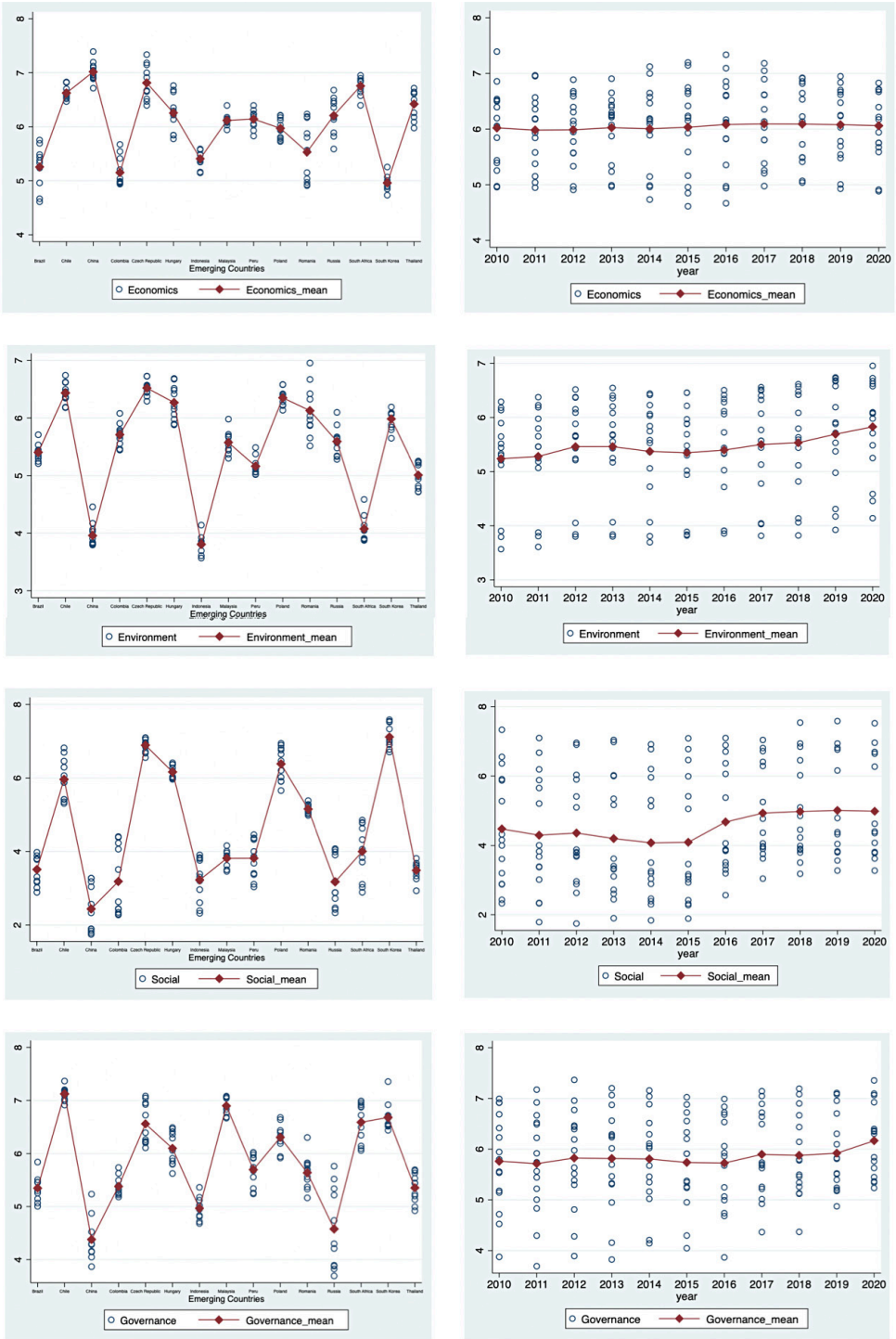




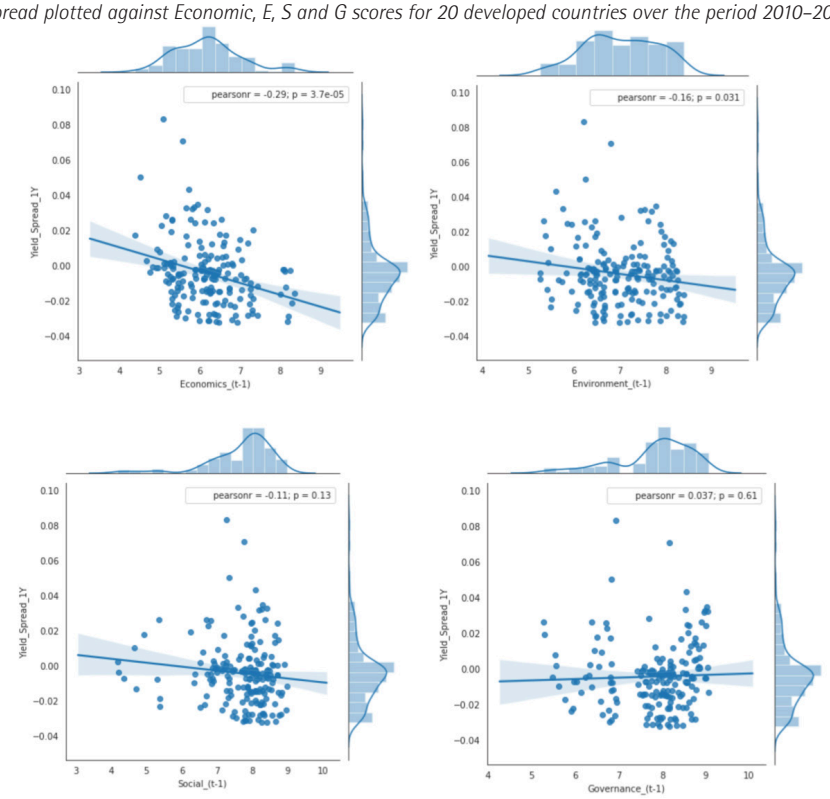




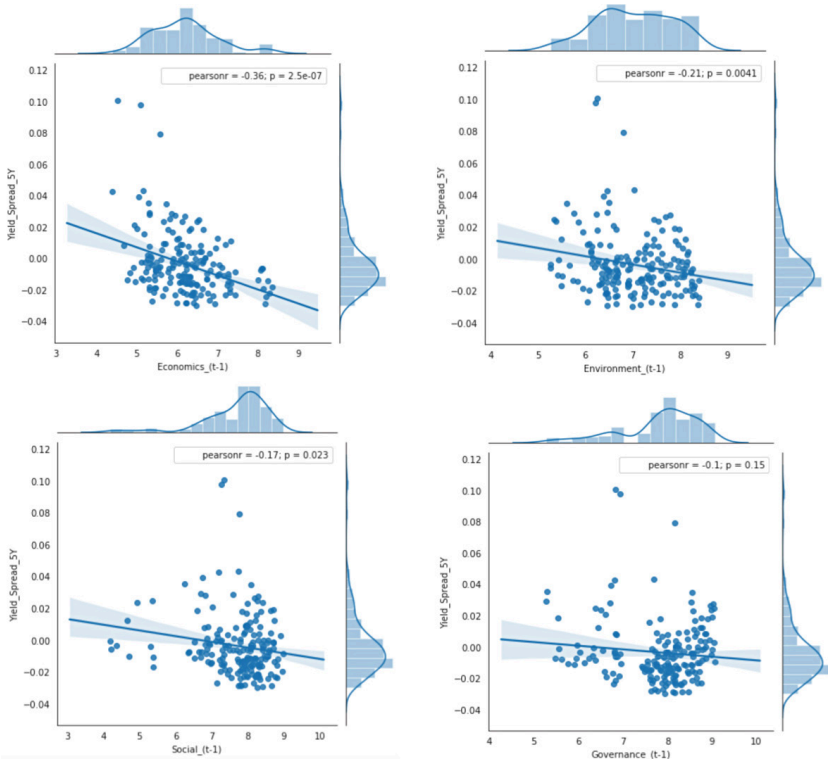
A.5.18: Heterogeneity across 15 emerging countries and over time (2010–2020): Economic, Environmental, Social and Governance dimensions



A.5.19: 1-year yield spread plotted against Economic, E, S and G scores for 20 developed countries over the period 2010–2020



A.5.20: 5-year yield spread plotted against Economic, E, S and G scores for 20 developed countries over the period 2010–2020



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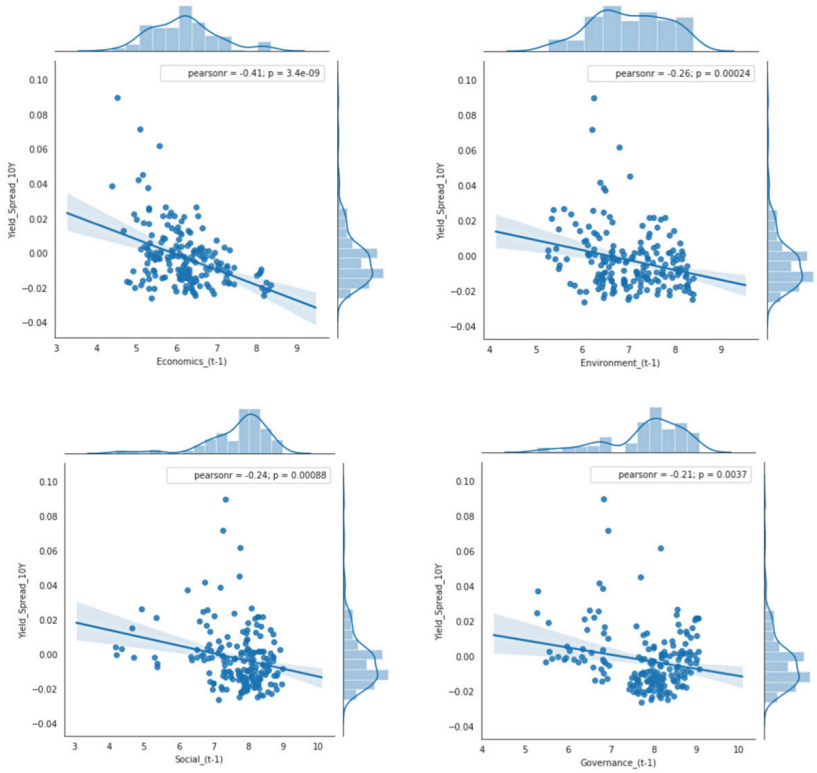
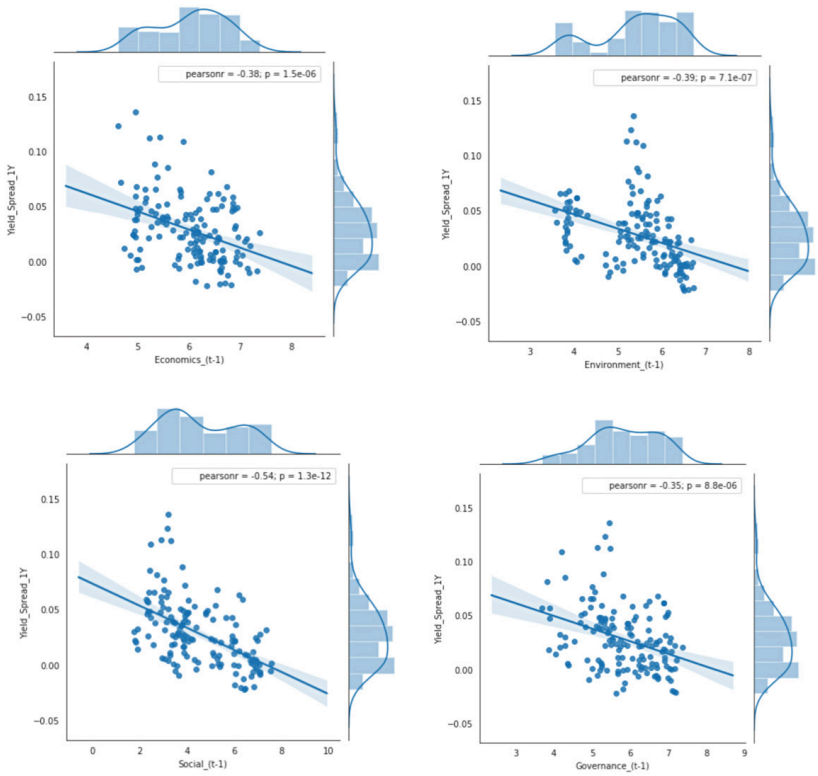
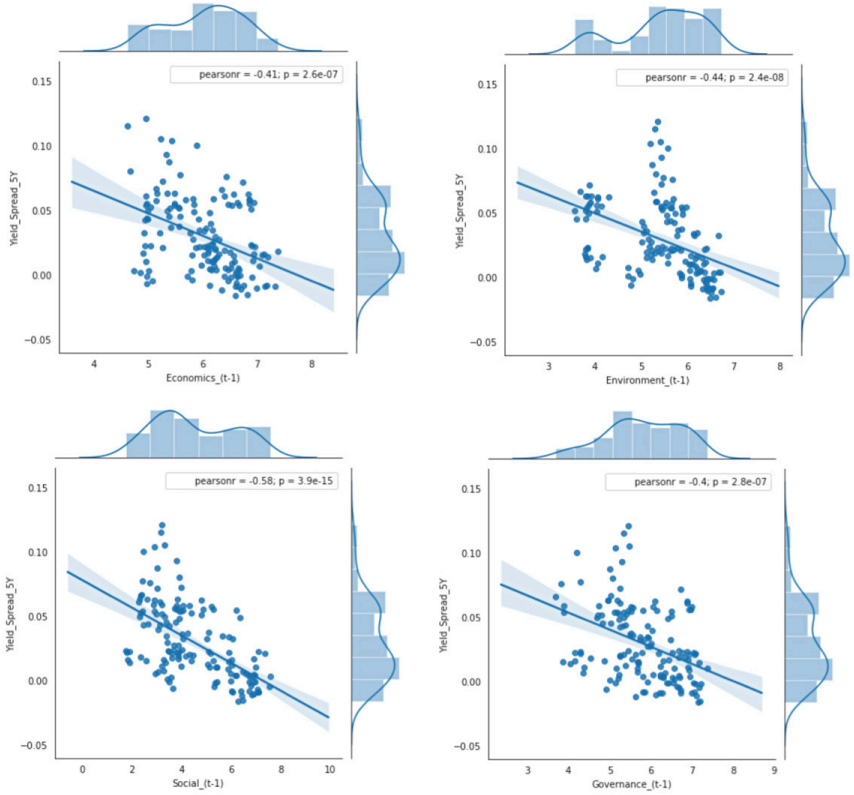
A.5.21: 10-year yield spread plotted against Economic, E, S and G scores for 20 developed countries over the period 2010–2020



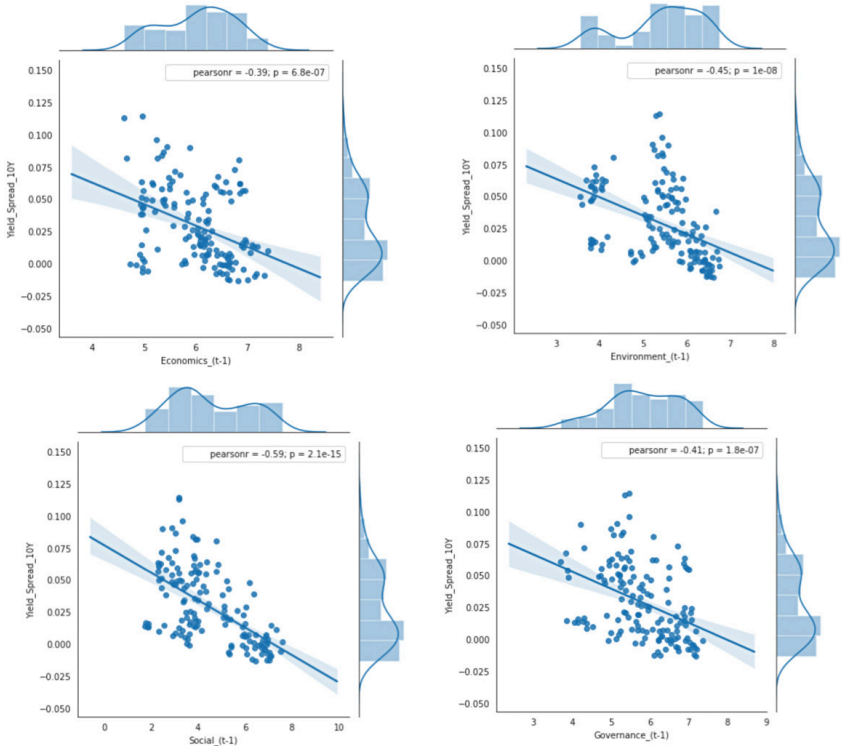
A.5.22: 1-year yield spread plotted against Economic, E, S and G scores for 15 emerging countries over the period 2010–2020



A.5.23: 5-year yield spread plotted against Economic, E, S and G scores for 15 emerging countries over the period 2010–2020



A.5.24: 10-year yield spread plotted against Economic, E, S and G scores for 15 emerging countries over the period 2010–2020



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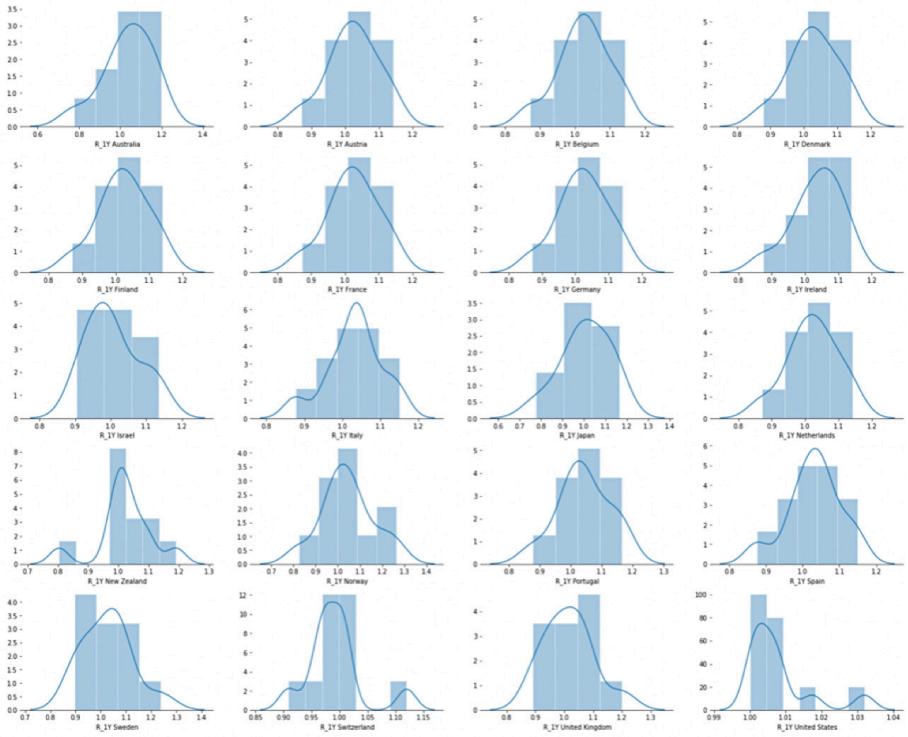
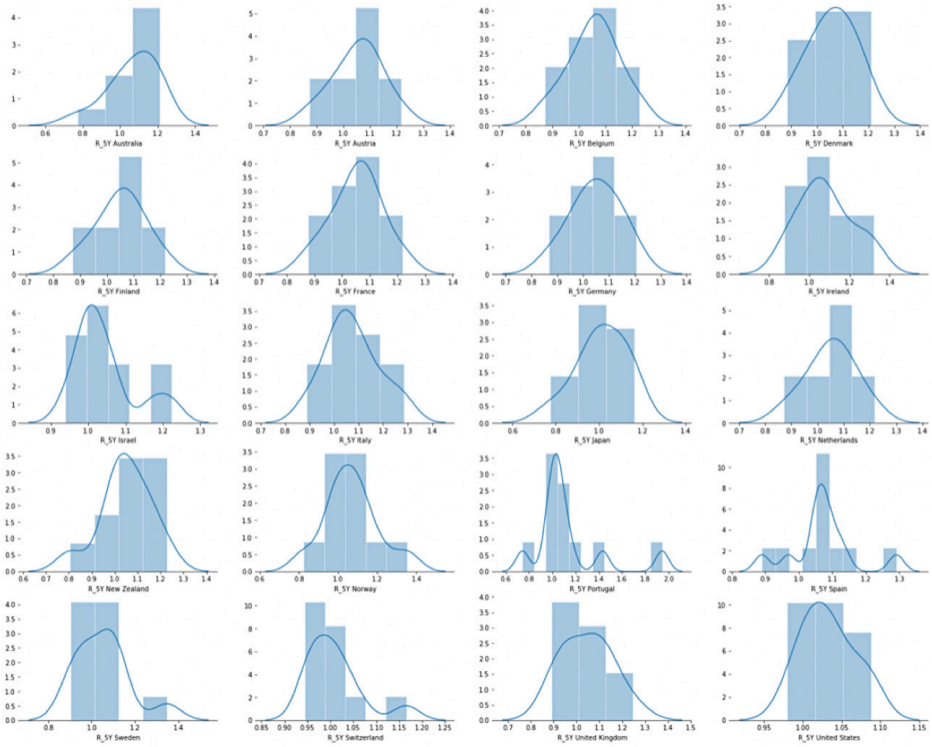
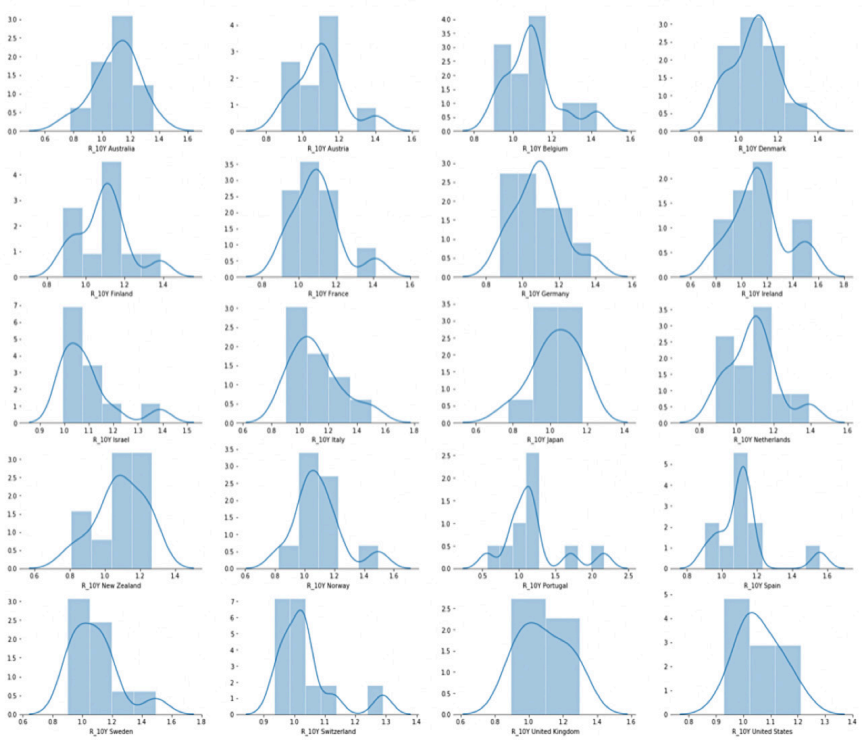
A.5.25: Developed countries' 1-year maturity bond returns distribution over the period 2010–2020



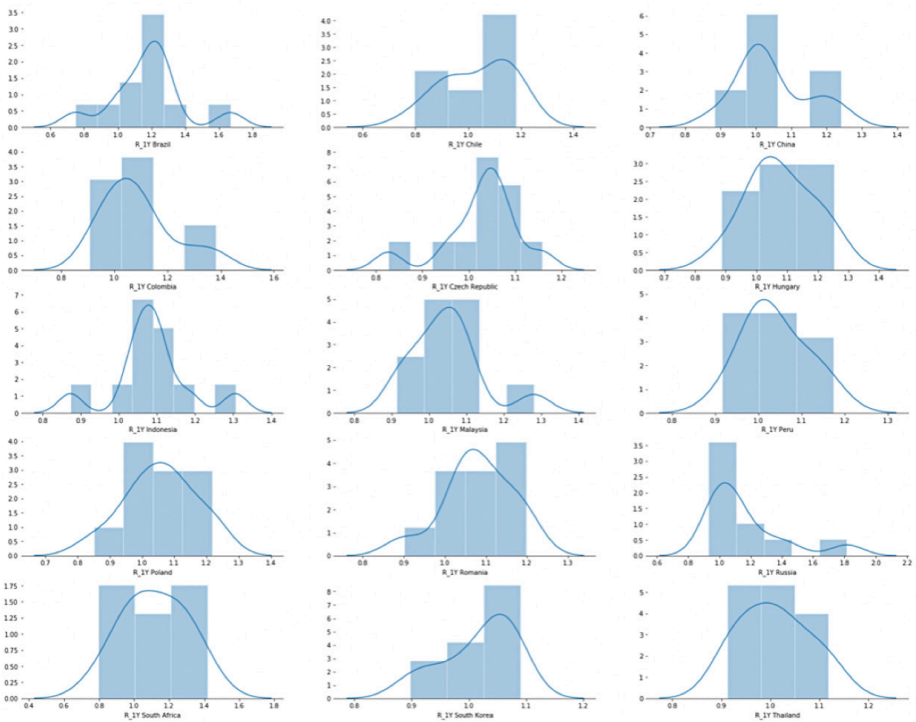
A.5.26: Developed countries' 5-year maturity bond returns distribution over the period 2010–2020



A.5.27: Developed countries' 10-year maturity bond returns distribution over the period 2010–2020



A.5.28: Emerging countries' 1-year maturity bond returns distribution over the period 2010–2020



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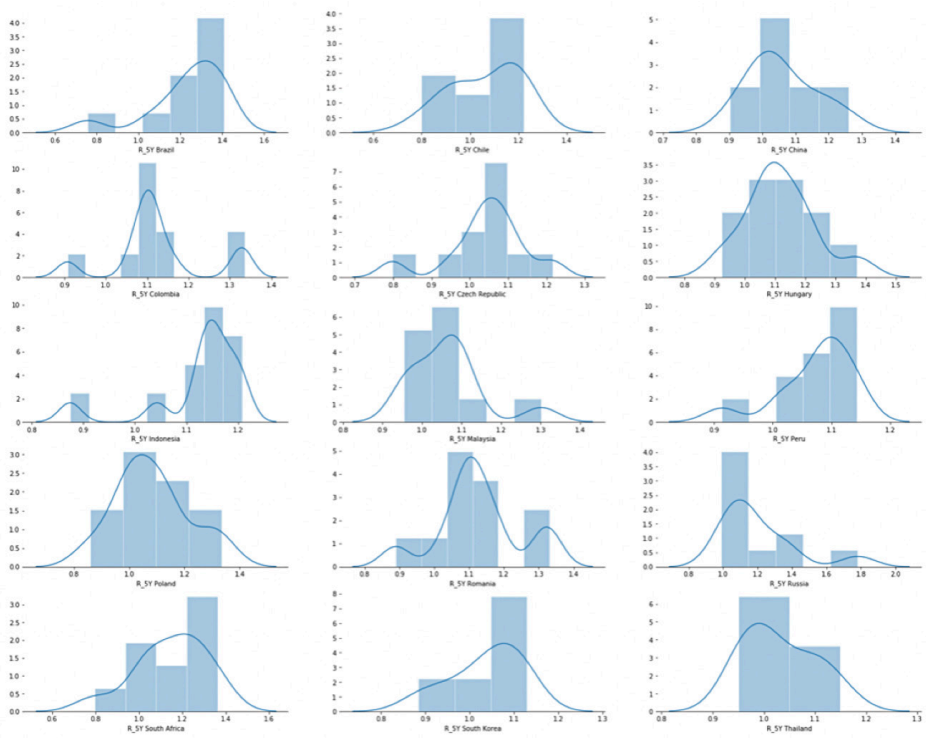
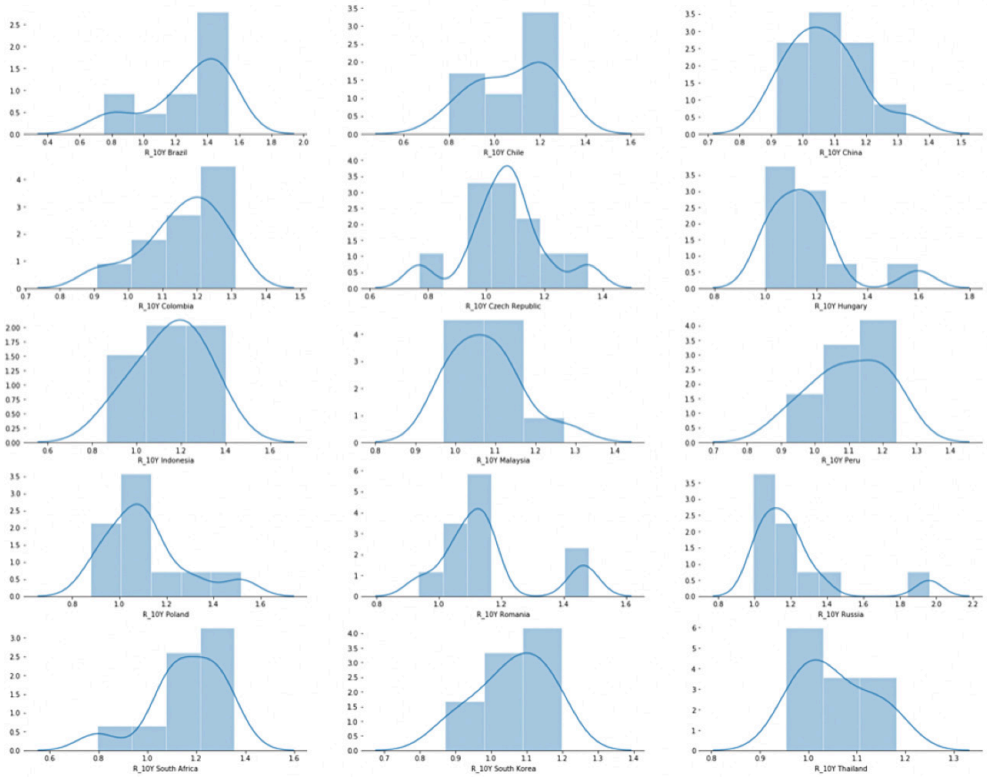
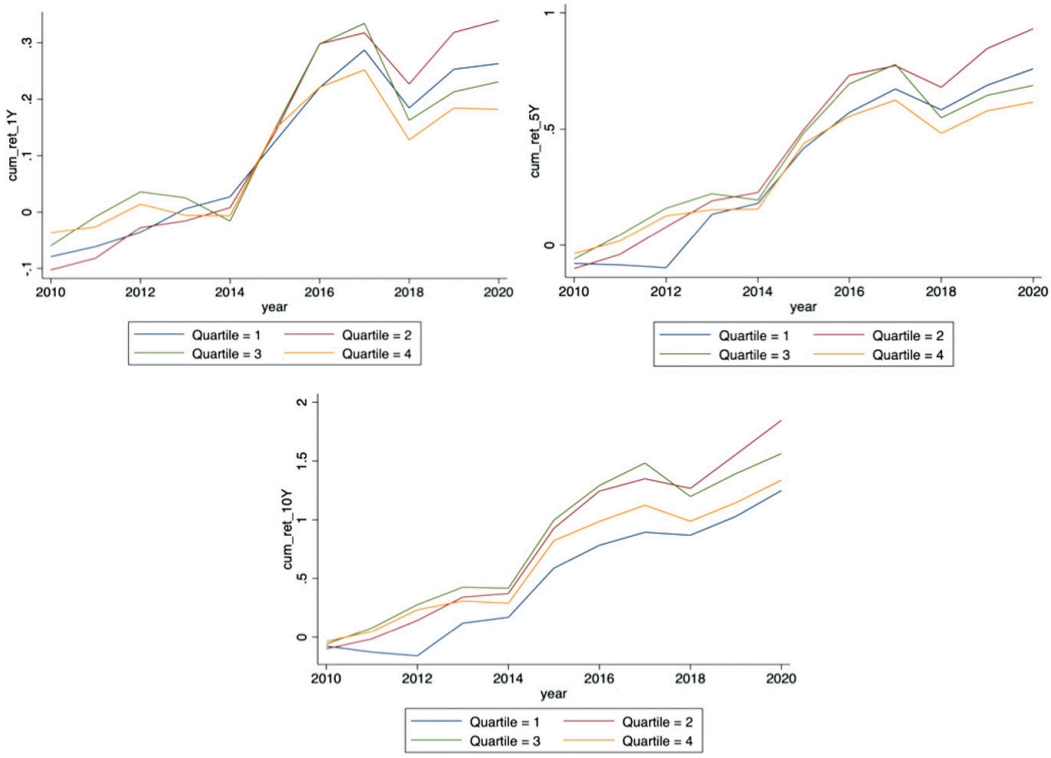
A.5.29: Emerging countries' 5-year maturity bond returns distribution over the period 2010–2020



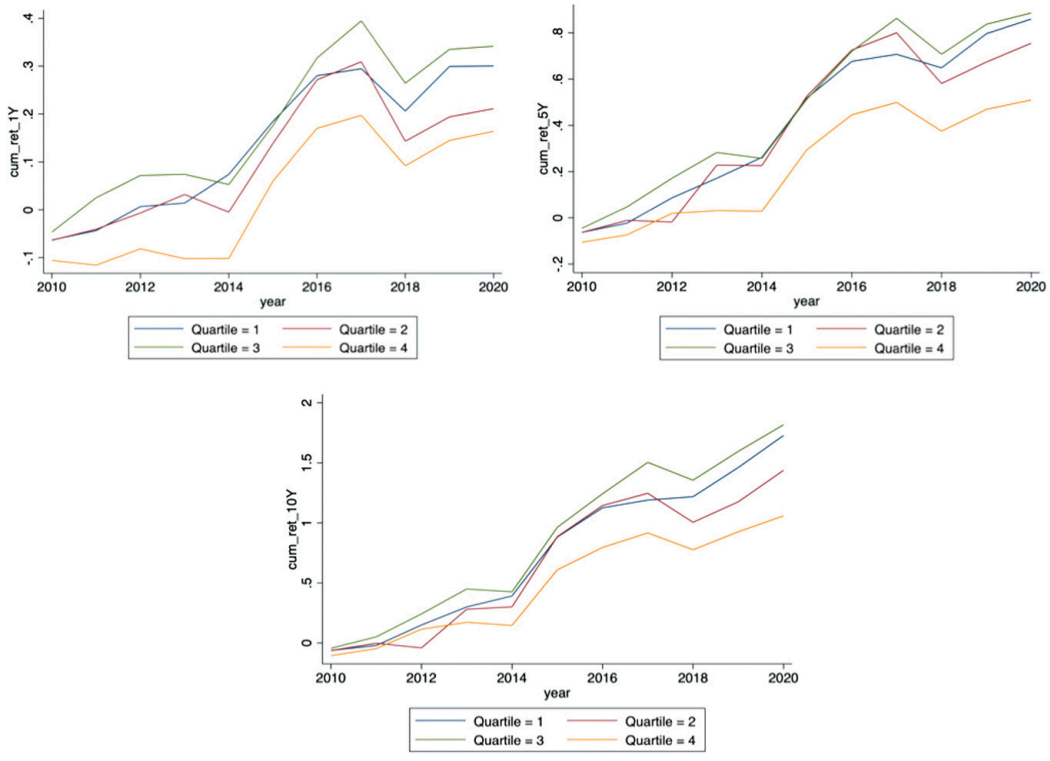
A.5.30: Emerging countries' 10-year maturity bond returns distribution over the period 2010–2020



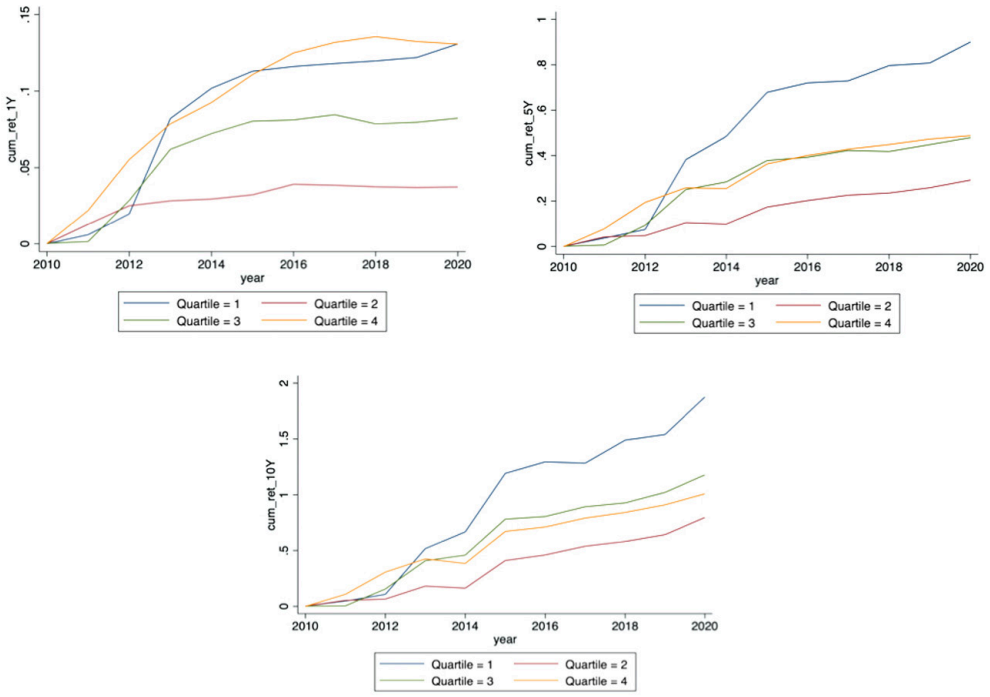
A.5.31: Cumulative returns of Economics-based quartiles for developed countries over the period 2010–2020



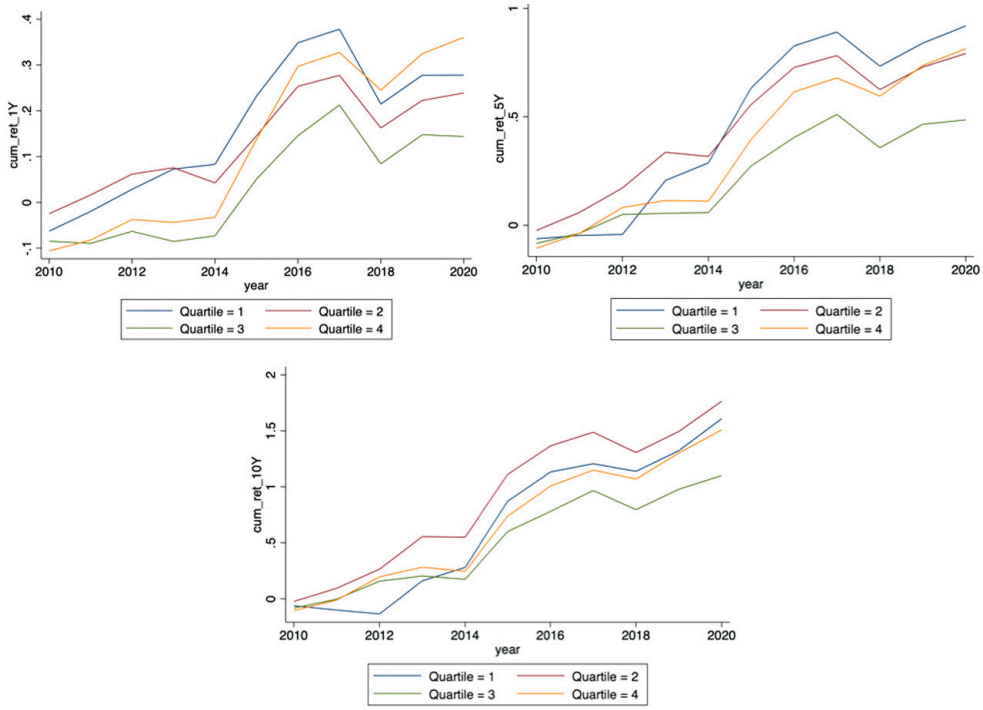
A.5.32: Cumulative returns of Environment-based quartiles for developed countries over the period 2010–2020



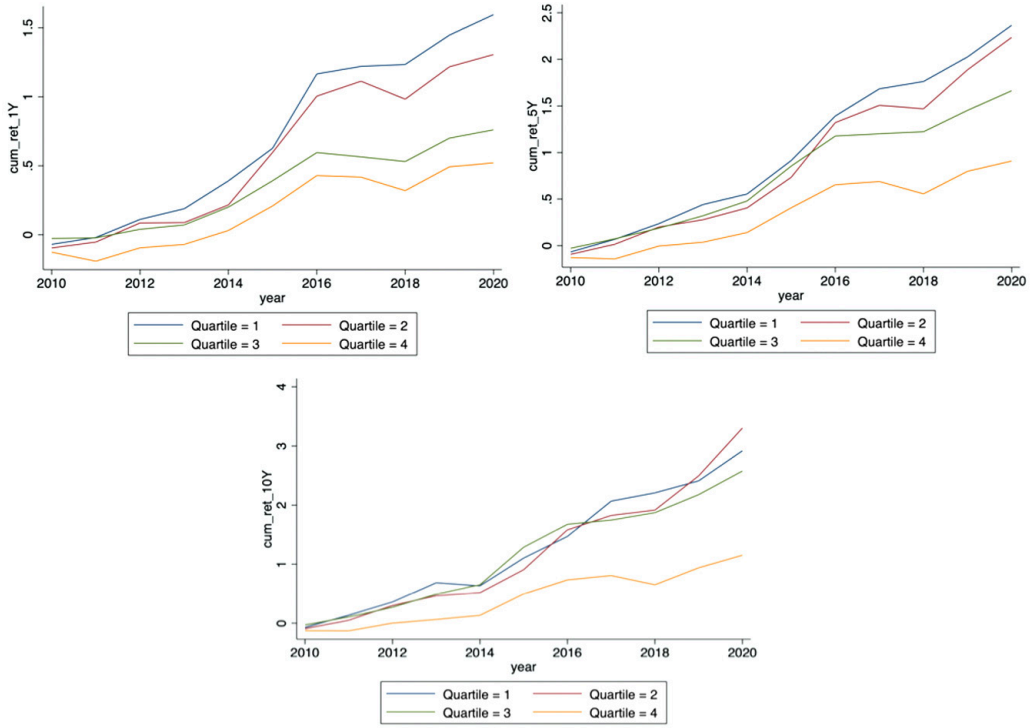
A.5.33: Cumulative returns of Social-based quartiles for developed countries over the period 2010–2020



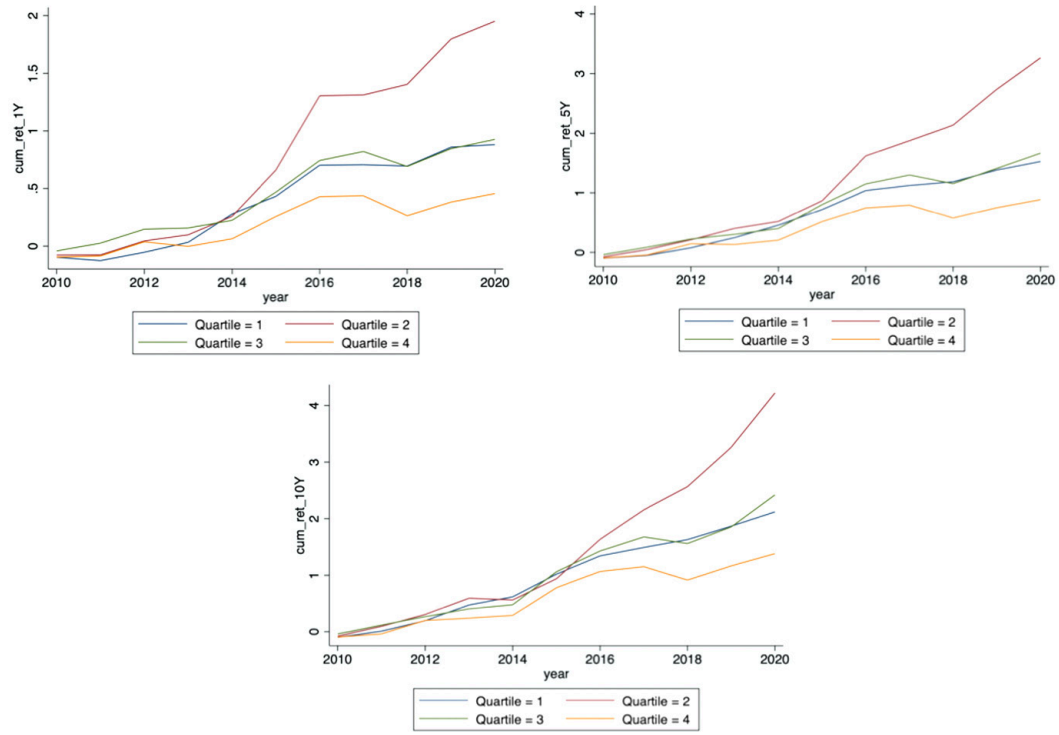
A.5.34: Cumulative returns of Governance-based quartiles for developed countries over the period 2010–2020



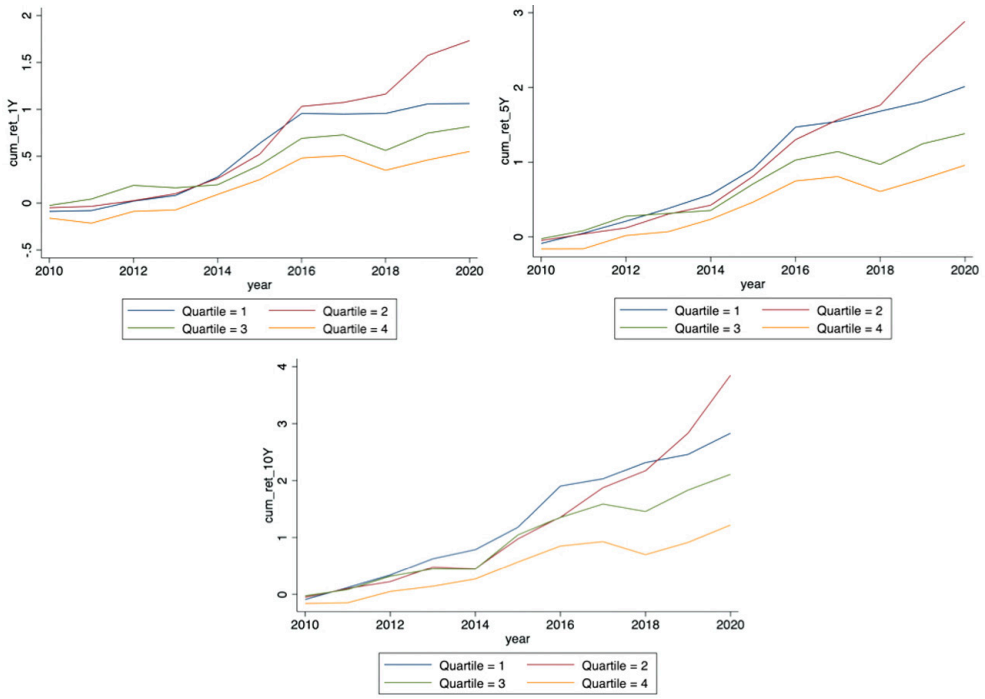
A.5.35: Cumulative returns of Economics-based quartiles for emerging countries over the period 2010–2020



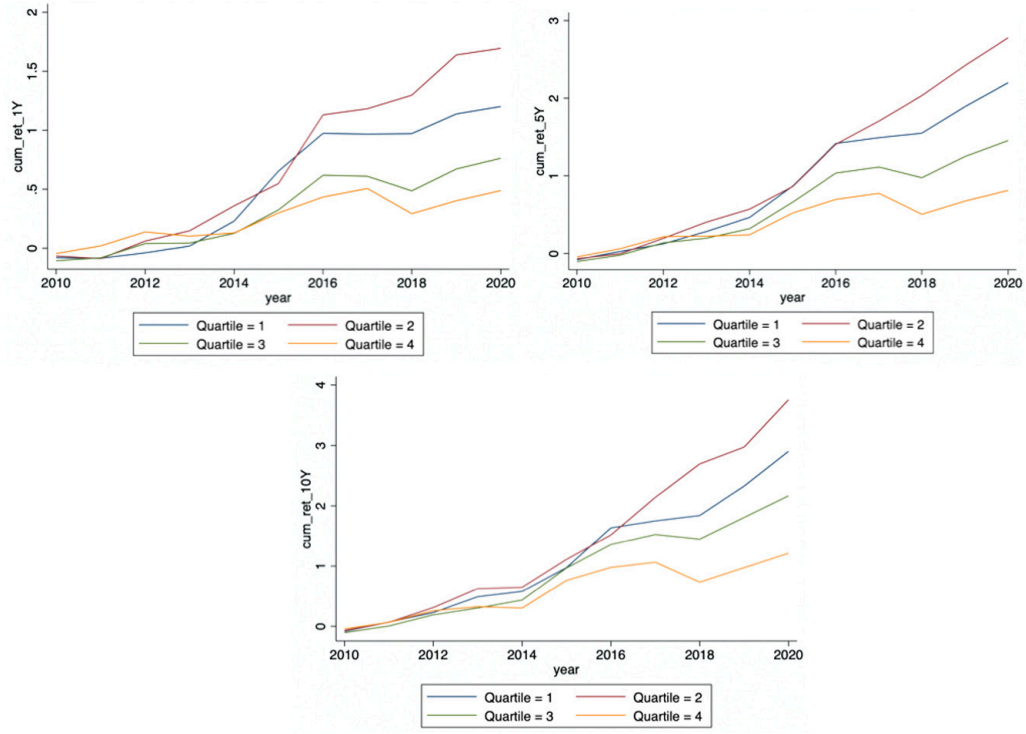
A.5.36: Cumulative returns of Environment-based quartiles for emerging countries over the period 2010–2020



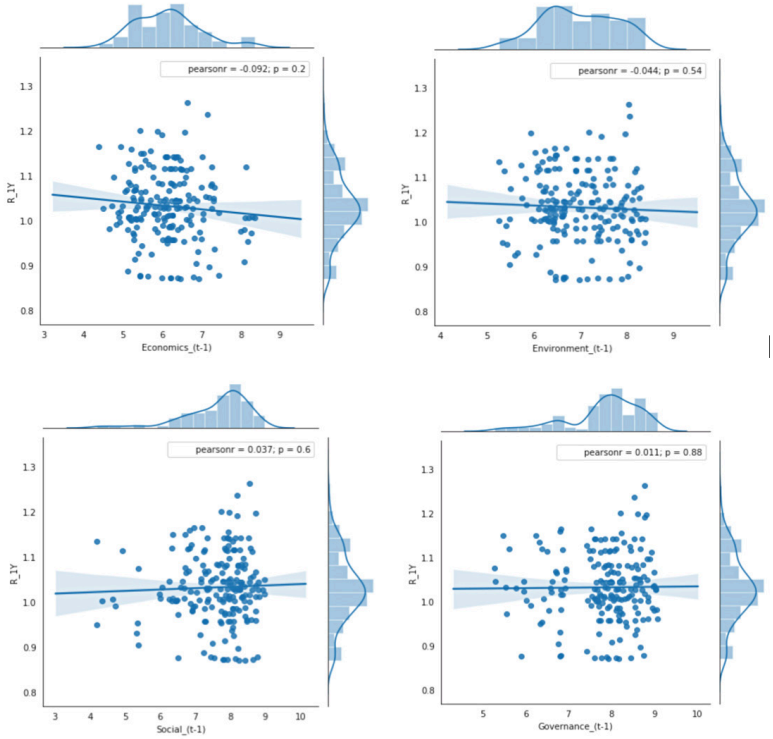
A.5.37: Cumulative returns of Social-based quartiles for emerging countries over the period 2010–2020



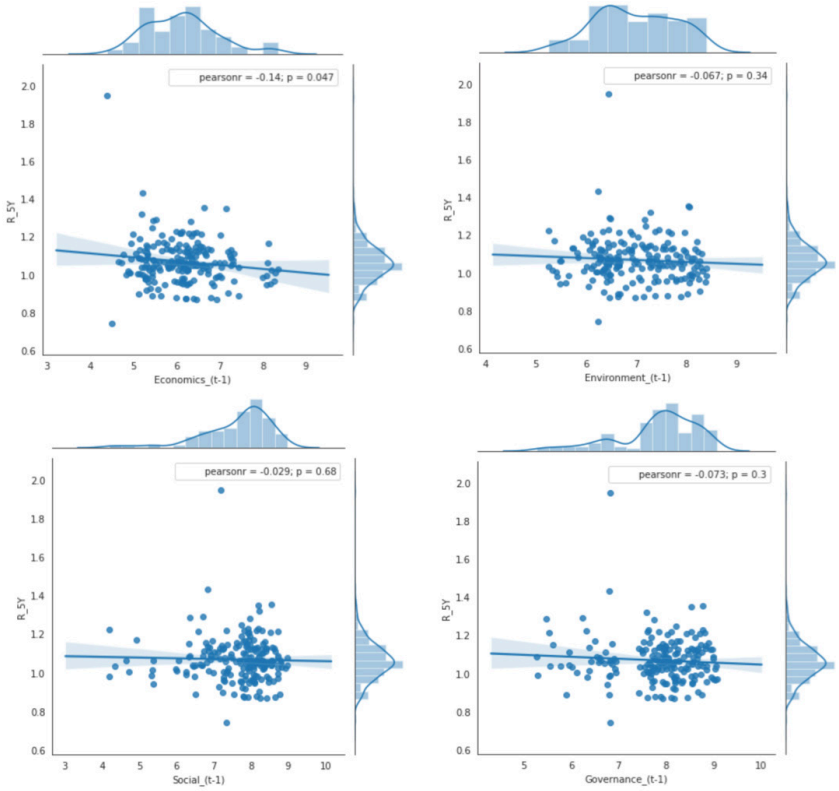
A.5.38: Cumulative returns of Governance-based quartiles for emerging countries over the period 2010–2020



A.5.39: 1-year maturity bond returns plotted against Economic, E, S and G scores for 20 developed countries over the period 2010–2020



A.5.40: 5-year maturity bond returns plotted against Economic, E, S and G scores for 20 developed countries over the period 2010–2020



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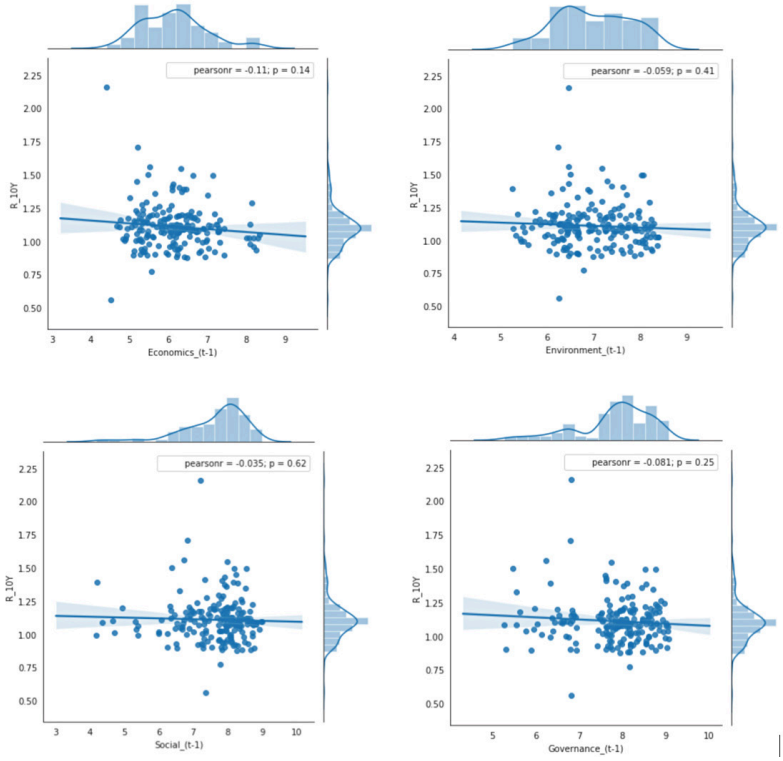
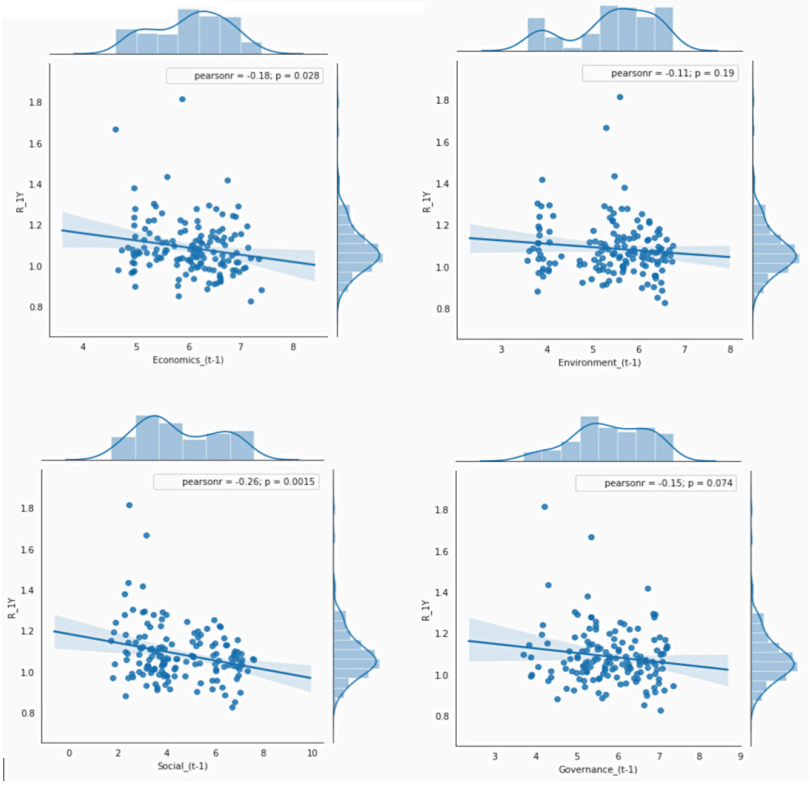
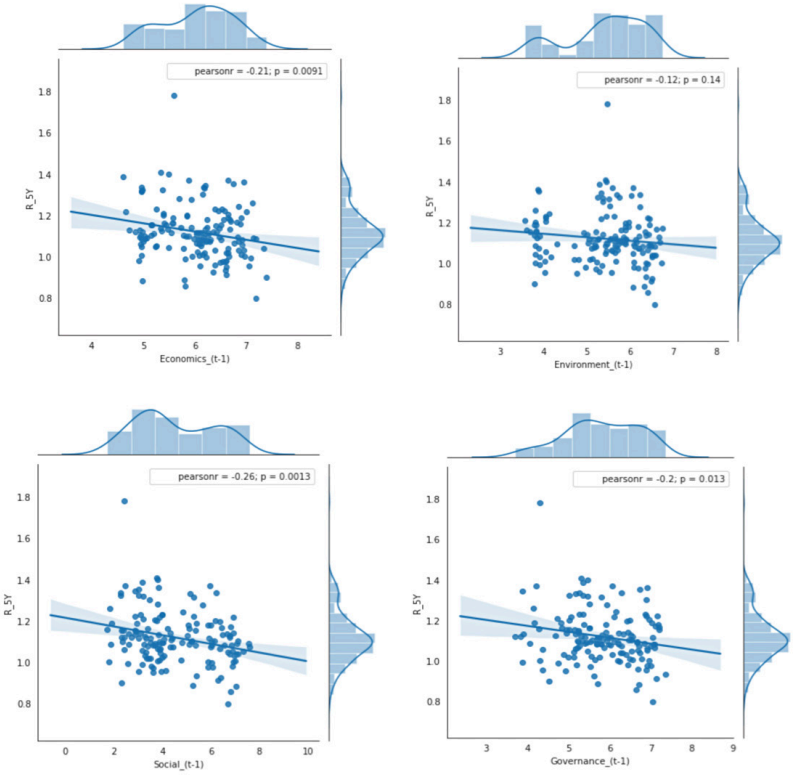
A.5.41: 10-year maturity bond returns plotted against Economic, E, S and G scores for 20 developed countries over the period 2010–2020



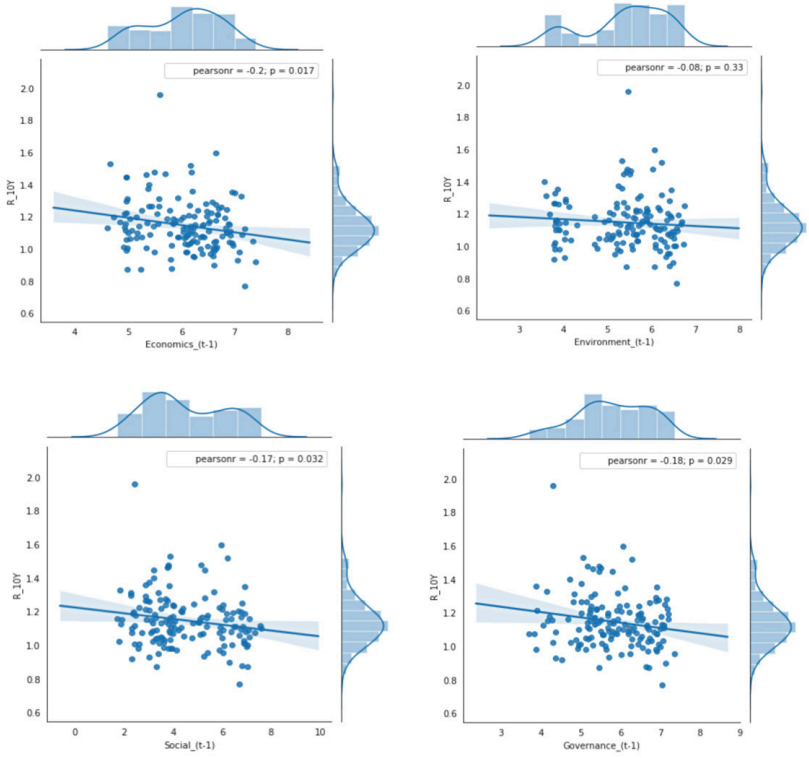
A.5.42: 1-year maturity bond returns plotted against Economic, E, S and G scores for 15 emerging countries over the period 2010–2020



A.5.43: 5-year maturity bond returns plotted against Economic, E, S and G scores for 15 emerging countries over the period 2010–2020



A.5.44: 10-year maturity bond returns plotted against Economic, E, S and G scores for 15 emerging countries over the period 2010–2020



Appendices

A.6.1: Tracking errors of unconstrained and ESG-constrained optimized portfolios for developed countries

Developed Countries	
Increase in Environment Score	Tracking Error (bps)
0%	0.00
5%	2.73
10%	10.88
15%	26.76
Increase in Social Score	Tracking Error (bps)
0%	0.00
5%	5.11
10%	18.13
15%	58.82
Increase in Governance Score	Tracking Error (bps)
0%	0.00
5%	3.64
10%	13.24

A.6.2: Tracking errors of unconstrained and ESG-constrained optimized portfolios for emerging countries

Emerging Countries	
Increase in Environment Score	Tracking Error (bps)
0%	0.00
5%	7.48
10%	18.93
15%	37.60
20%	75.59
Increase in Social Score	Tracking Error (bps)
0%	0.00
5%	3.03
10%	6.06
15%	9.09
20%	12.19
25%	15.58
30%	19.21
35%	23.07
40%	27.20
45%	31.90
50%	37.02
55%	42.58
60%	49.70
Increase in Governance Score	Tracking Error (bps)
0%	0.00
5%	7.18
10%	15.15
15%	25.49
20%	47.42

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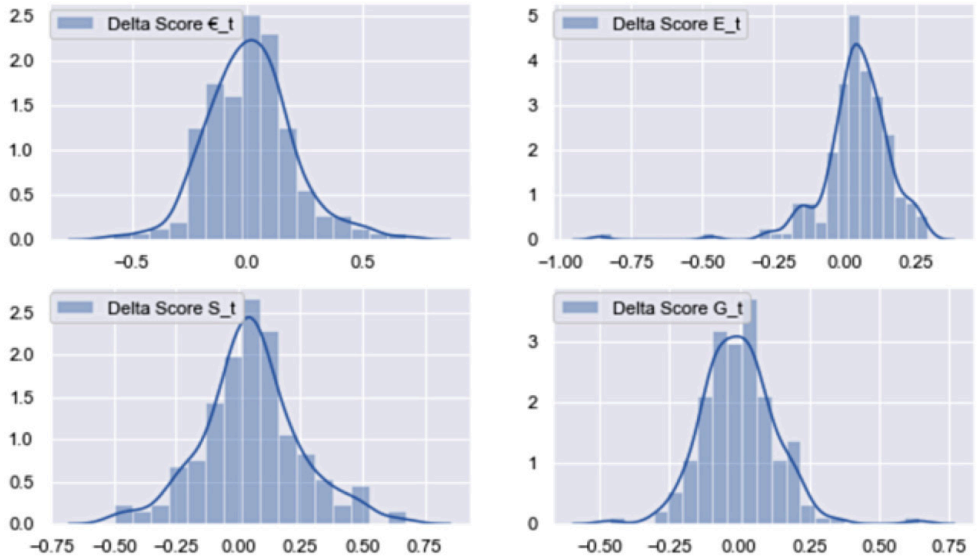
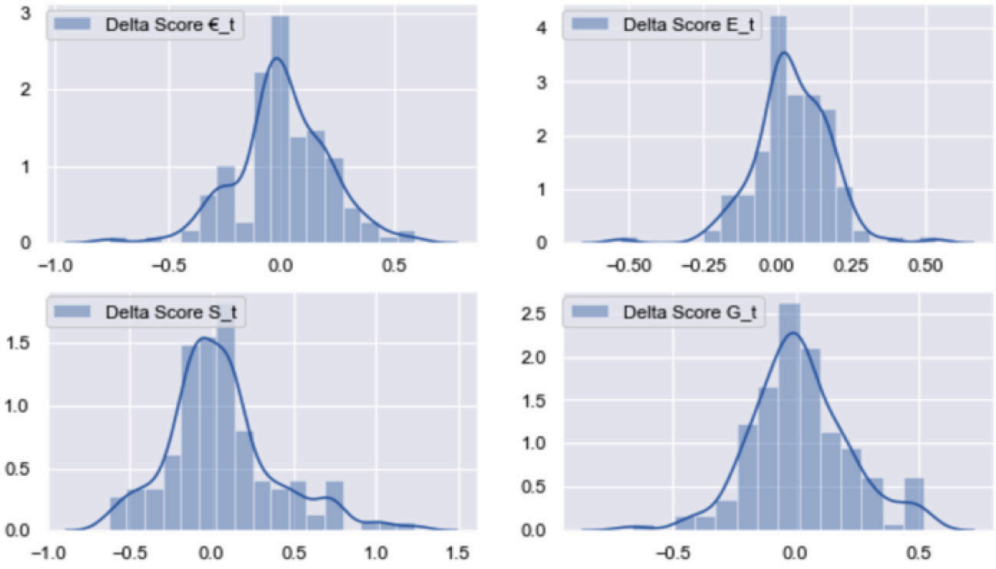
A.6.3: Delta score distributions for developed countries from 2010 to 2020



A.6.4: Delta score distributions for emerging countries from 2010 to 2020



A.6.5: Delta score statistics for developed countries from 2010 to 2020

	Economics	Environment	Social	Governance
Mean	0.01	0.04	0.05	0.00
Standard deviation	0.19	0.13	0.20	0.13
Maximum	0.69	0.29	0.67	0.64
Minimum	-0.58	-0.86	-0.50	-0.47

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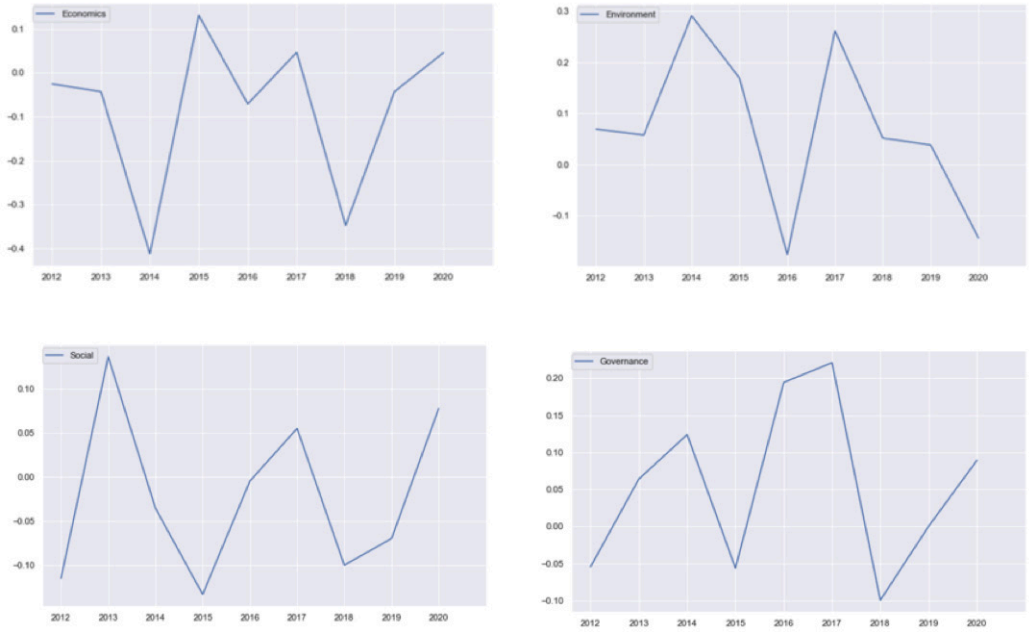
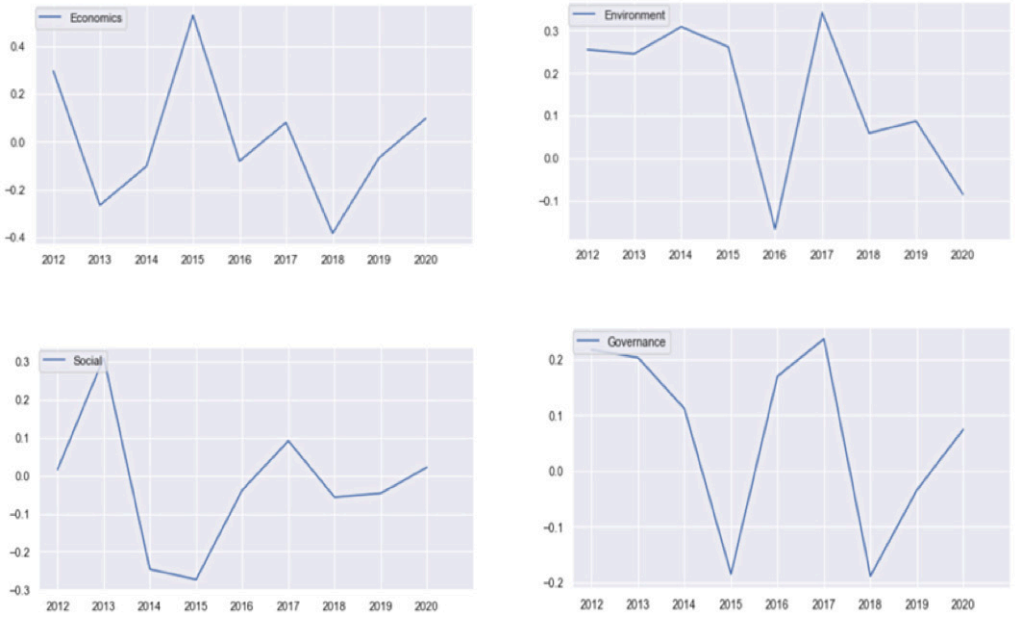
A.6.6: Delta score statistics for emerging countries from 2010 to 2020

	Economics	Environment	Social	Governance
Mean	0.01	0.05	0.06	0.02
Standard deviation	0.21	0.13	0.33	0.20
Maximum	0.59	0.54	1.23	0.52
Minimum	-0.77	-0.53	-0.63	-0.67

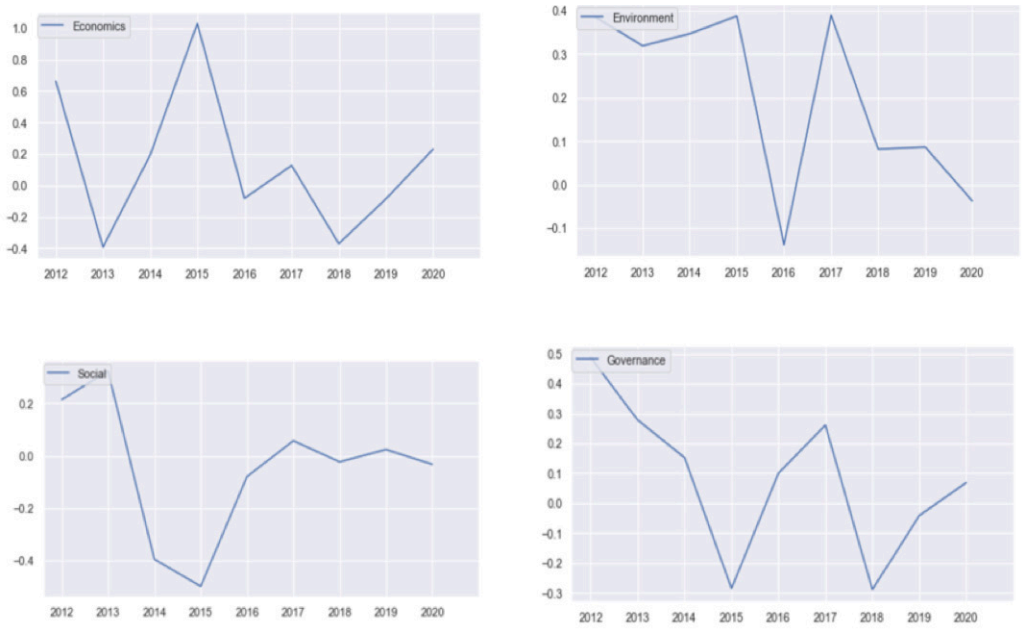
A.6.7: Long-short strategy based on Economic, Environmental, Social or Governance dimensions for developed countries: 1-year maturity bonds



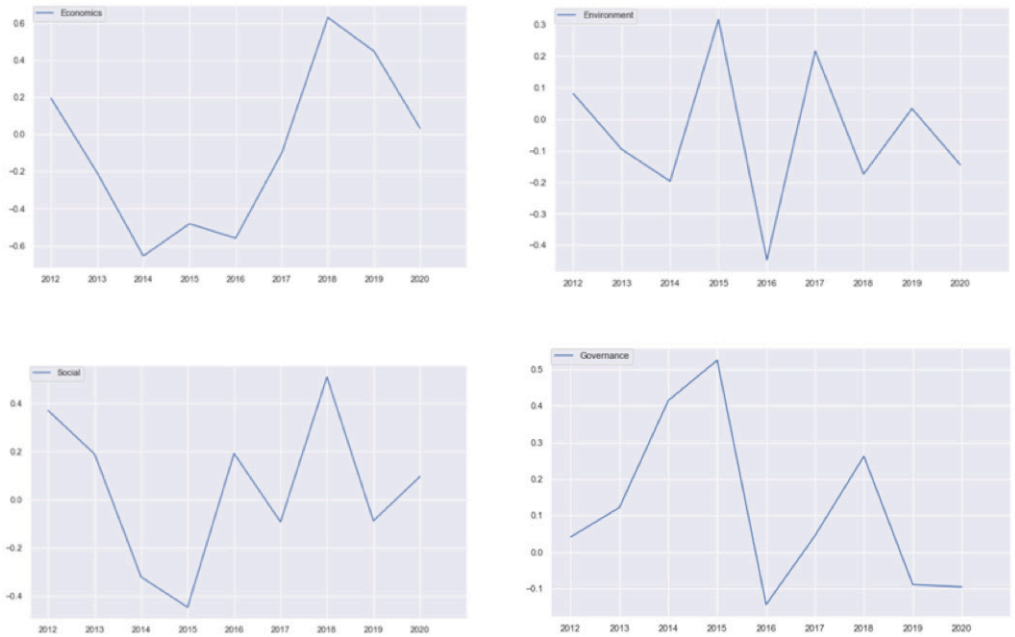
A.6.8: Long-short strategy based on Economic, Environmental, Social or Governance dimensions for developed countries: 5-year maturity bonds



A.6.9: Long-short strategy based on Economic, Environmental, Social or Governance dimensions for developed countries: 10-year maturity bonds



A.6.10: Long-short strategy based on Economic, Environmental, Social or Governance dimensions for emerging countries: 1-year maturity bond



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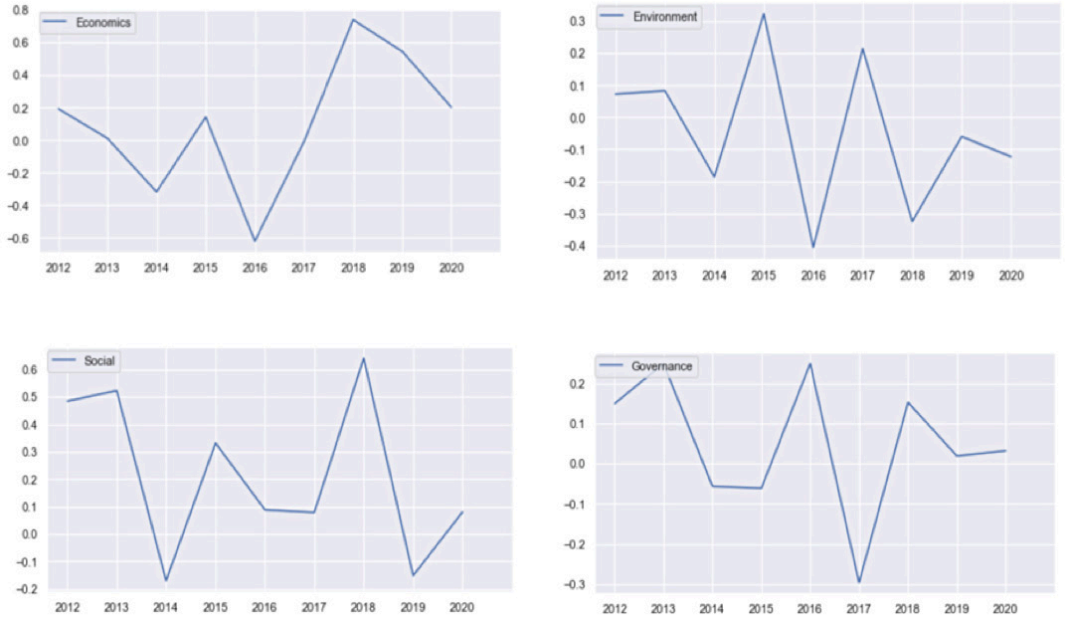
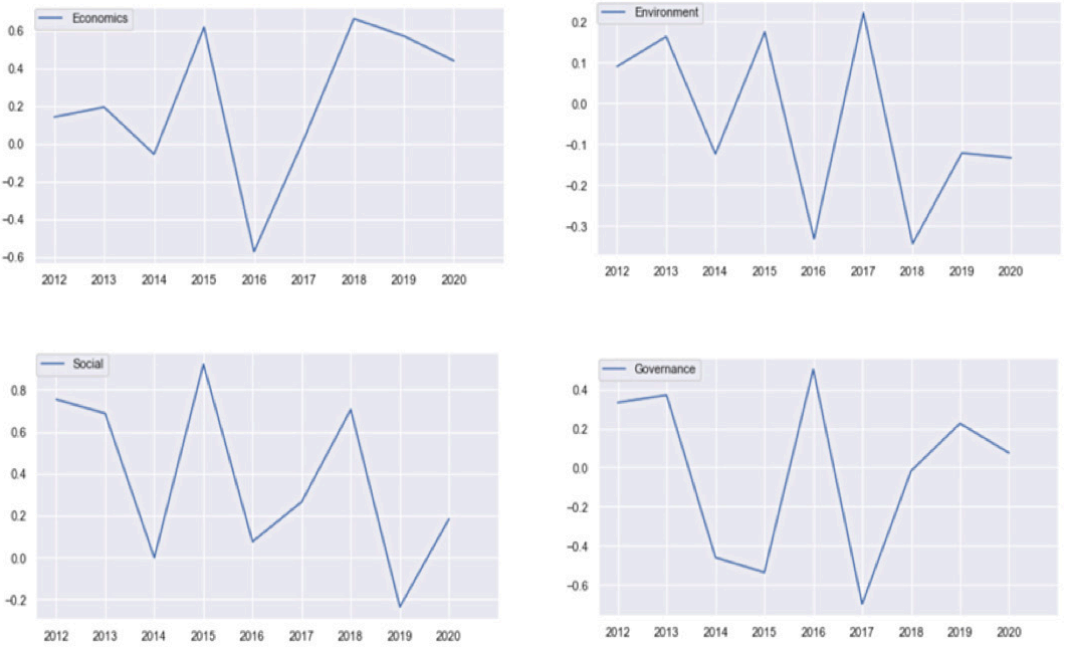
A.6.11: Long-short strategy based on Economic, Environmental, Social or Governance dimensions for emerging countries: 5-year maturity bond



A.6.12: Long-short strategy based on Economic, Environmental, Social or Governance dimensions for emerging countries: 10-year maturity bond



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With more than €158 billion[1] in assets under management, Amundi ETF, Indexing and Smart Beta is one of Amundi's strategic business areas and is a key growth driver for the Group.

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With over 30 years of benchmark construction and replication expertise, Amundi is a trusted name in ETF & Index management among the world's largest institutions. The team is also recognized for its ability to develop Smart Beta & Factor Investing solutions, with more than 10-year track-record.

1 - All figures and data are provided by Amundi ETF, Indexing & Smart Beta at 31/12/2020

About EDHEC-Risk Institute

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Academic Roots & Practitioner Reach

EDHEC Business School is actively pursuing an ambitious policy to produce academic research that is both practical and relevant. This policy, known as "Research for Business" and now labelled "Make an Impact", aims to make EDHEC an academic institution of reference in a small number of areas in which the school has reached critical mass in terms of expertise and research results. EDHEC is putting its academic expertise to work in addressing some of the major issues affecting society, most notably the climate emergency. EDHEC initiatives in the fields of sustainable finance and sustainable business are expected to be major contributions to the response to the sustainability challenges facing our economy.

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The institute, in partnership with industry leaders, boasts a team of permanent professors, engineers and support staff, as well as affiliate professors and research associates. Their collective work has a particularly significant footprint in the areas of **factor investing, retirement investing** and **sustainable investing**. Its philosophy is to validate its work by publishing in international academic journals, as well as to make it available to the sector through position papers, published studies, online courses, on-campus workshops and global conferences.

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As part of its policy of transferring know-how to the investment industry, EDHEC-Risk Institute set up Scientific Beta, an original initiative to boost the take-up of the latest advances in smart beta design and implementation by the whole investment industry. On 31 January 2020, Singapore Exchange (SGX) acquired a majority stake in Scientific Beta, a transaction that vindicates

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the school's "Make an Impact" model and its focus on producing research that is useful for both students and businesses. EDHEC-Risk Institute also contributed to the launch of EDHEC Infrastructure Institute (EDHEC*infra*), a spin-off dedicated to benchmarking private infrastructure investments. EDHEC*infra* is now a provider of research and indices on unlisted infrastructure investments.

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- Le Sourd, V. and L. Martellini. The EDHEC European ETF and Smart Beta and Factor Investing Survey 2020 (September).
- Fays, B., Lambert, M., and N. Papageorgiou Risk Optimizations on Basis Portfolios: The Role of Sorting (June).

2019 Publications

- Martellini, L. and V. Milhau. Factor Investing in Liability-Driven and Goal-Based Investment Solutions (December).
- Le Sourd, V. and L. Martellini. The EDHEC European ETF and Smart Beta and Factor Investing Survey 2019 (August).
- Maeso, J.M., Martellini, L. and R. Rebonato. Cross-Sectional and Time-Series Momentum in Sovereign Bond Markets (May).
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- Maeso, J.M., Martellini, L. and R. Rebonato. Factor Investing in Sovereign Bond Markets - Time-Series Perspective (May).

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- Martellini, L. and V. Milhau. Smart Beta and Beyond: Maximising the Benefits of Factor Investing (February).

Notes

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