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Greenium in Sovereign Green Bonds: A Tool to Achieve the Sustainable Development Goals in the East and South Asian Nations

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Abstract

The market for sovereign green bonds has grown exponentially from the pioneer issue by Poland in the year 2016 which have led to majority of the European Union member states to maintain a green curve alongside their conventional debt securities. The literature available report that the existence of sovereign greenium remains contested, and hence this paper has tried to estimate this premium using bond-level Z-spreads. Using the dataset from the LSEG Refinitiv universe of 2905 government debt securities, the study constructed a sample of 313 fixed-coupon bonds denominated in euros, issued by nine EU member states, viz. Austria, Belgium, France, Germany, Ireland, Italy, Lithuania, Netherlands and Spain. After controlling for remaining maturity, Bid-Ask spread and country-specific yield-curve shapes, green bonds traded at Z-spread of about 3.8 basis points lower compared to the conventional bonds of the same countries. The result was found to be significant in 12 of 14 alternative specifications and corroborated by three bond-level methods- higher for AAA/AA bonds (~ 5 basis points) and near to 1 basis point for Germany's matched twin bonds. The greenium is economically small of about € 140 million a year but is positive and statistically significant. We contrast these results with India's Sovereign Green Bond programme and derive policy implications for country's regulatory bodies.

Keywords: Sovereign green bonds; Greenium; Z-spread; European Union; Climate finance

1. Introduction

The satisfaction of the target as envisioned in the Paris Agreement 2015 and fulfilment of the Sustainable Development Goals (SDGs) requires mobilization of huge amount of capital; the majority of which must be supported by the government of the respective countries. Each sovereign issuer of green bonds publishes a green bond framework reflecting its own priorities and macro-economic fundamentals. The proceeds obtained from issuance of

sovereign green bonds indicate a positive signal to the financial markets that the government is serious on financing this transition (Flammer, 2021).

The first such sovereign bond was issued by Poland in December 2016, followed by French OATs (*Obligations assimilables du Trésor*) amounting to € 7 billion in January 2017. By the year 2022, 14 EU member states had issued 28 sovereign green bonds of approximately € 147 billion (Grzegorczyk & Wolff, 2022). In the year 2020, Germany went further by issuing green "twin" bonds with the same coupon and maturity as existing conventional Bunds, creating a natural comparison for measuring the price of the green bonds (Ando et al., 2023).

The question at hand is the existence of lower cost of capital pertaining to the green labels associated with such sovereign bonds. The probability of accepting lower returns and earning a greenium resides on the fact that the investing community derives non-pecuniary value by holding ecologically friendly assets (Fama & French, 2007; Baker et al., 2022). However, the sovereign green bonds markets are smaller and less liquid in comparison to the conventional lines. As the revenues earned by the government are fungible and are backed by the full state support, a marginal investor may take advantage of arbitrage opportunities in both these financial instruments (Lewandowski & Smoleńska, 2023).

The evidence on the empirical existence of sovereign greenium is mixed. (Doronzo, et al., 2021) find that sovereign green bonds were on average issued 3.8 basis points (bps) above the issuer's curve in the primary market; however only a 0.5 bp greenium was observed in the secondary market for France, Belgium, Netherlands and Ireland. Matching green bonds exactly with conventional bonds, (Grzegorczyk & Wolff, 2022) report greeniums in the range of 3 – 16 bps for 10 EU pairs, but no significant effect is observed when green bonds are compared with interpolated curves. Comparing the existence in advanced and emerging economies, (Ando et al., 2023) found greenium of about 4 bps across 15 countries- advanced economies (2.7 bps) and emerging markets (11.6 bps). Estimating separate term structures for green and conventional Bunds, (D'Amico et al., 2025) estimate a benchmark German greenium of roughly 4 bps. (Larcker and Watts, 2020) mentions that if the payoffs and risk features are held constant, the green and non-green bonds of the same issuer are treated as similar and hence, negates the existence of greenium. In an analysis of about 2000 green and 180,000 non-green issues, (Löffler et al., 2021) found that on an average, yield for green securities is 15-20 bps lower than that of traditional bonds using propensity score matching and coarsened exact matching techniques.

This study thus contributes to the research strand in three possible ways. Firstly, the paper considers the full cross-section of EU member state- green and conventional bonds and applied the International Monetary Fund (IMF) Z-spread framework. Secondly, it experiments on the decision of how to model the yield curve- when one common curve is imposed on all countries as outlined in the baseline IMF assumption, it detects the existence of no greenium; however, a sovereign premium of about 4 bps is observed when each country is allowed its own curve shape. Finally, regression estimates with three bond-level measures, viz. Twin bond structures, Interpolation method and IMF synthetic-bond technique are triangulated, and robustness checks are tested to suggest policy measures on the India's Sovereign Green Bond (SGrB) programme. Accordingly, the following research questions have been framed for undertaking this study:

- Do sovereign green bonds issued by EU member states trade at lower Z-spreads than comparable conventional bonds of the same issuer?
- How large is the greenium, and is it robust with respect to the bond-level measurement methods? If Yes, does it differ across countries, credit quality and maturity?

- What does the EU evidence imply for the design of India's sovereign green bond market?
- The corresponding Null Hypothesis framed is given below: $H_0: \beta = 0$, i.e., the green label has no effect on the Z-spread, such that maturity, liquidity and country effects are controlled for.

2. Literature Review

2.1 Arguments for and Against Sovereign Greenium

Two strands of theory predict the presence of greenium in green labelled debt securities. The preference or clientele channel propounds that when the investors treat assets as consumption goods and derive utility from holding these securities, the expected Return on Assets (RoA) decline in equilibrium (Fama and French, 2007). (Baker et al., 2022) formalized this proposition for pro-environmental investors who are inclined to concentrate their holdings in green bonds and accept lower yields. However, (Zerbib, 2019) argues on the risk channel that the projects financed by green issuers are less exposed to climate related risks and hence, reflect lower risk profile rather than utility factor. As both the above-mentioned channels are strengthened by certification and external reviews, (Bachelet et al., 2019; Pietsch & Salakhova, 2022) concludes the reduction of information asymmetry regarding the usage of proceeds.

On the contrary, three arguments predict little or no greenium for sovereign securities. Firstly, a nation issuing green and conventional bonds share an identical claim on the same tax base and accordingly, the risk profile is comparatively muted. Secondly, sovereign green frameworks impose no penal action for non-compliance which weakens its credibility structure (Grzegorczyk & Wolff, 2022; Lewandowski & Smoleńska, 2023). Thirdly, trading volumes of green bonds are lower and held till maturity which carries an illiquidity premium offsetting the preference effect (Febi et al., 2018).

2.2 Evidence from Corporate, Supranational and Municipal Green Bonds

Early studies on matching green and traditional bonds found a greenium at issuance of these securities. Greenium of ~18 bps was found for a sample of 21 green bonds in the primary market by (Ehlers and Packer, 2017); but a negligible differential in the secondary market. Using propensity-score matching on 121 euro-denominated bonds, (Gianfrate and Peri, 2019) found a greenium of around 18–21 bps at issuance that is smaller in the secondary market. (Zerbib, 2019) constructed synthetic conventional counterparts for 110 green bonds and concluded a small negative yield premium of about 2 bps. With roughly 2,000 green and 180,000 conventional bonds, (Löffler et al., 2021) estimated yields of 15–20 bps lower for green bonds.

(Hachenberg and Schiereck, 2018) showed only marginal differences, with government-related green bonds trading slightly wider; (Larcker and Watts, 2020) found essentially no greenium among 640 exactly matched US municipal pairs. No significant greenium in asset-swap spreads was found by (Ma et al., 2020) and (Flammer, 2021) found no pricing advantage for corporate issuers, attributing the benefits of green issuance to signalling and investor-base effects. The hypothesis that the value of the green label in US municipal bonds changed over time was showed by (Karpf and Mandel, 2018).

In the case of institutional issuers, (Bachelet et al., 2019) found greenium for certified bonds. Analysing a sample size of about 270,000 bonds issued between 2007 and 2018, (Fatica et

al., 2021) proved greenium for supranational institutions and non-financial corporation. However, no greenium was observed related to financial organisations. (Pietsch and Salakhova, 2022) estimated a greenium of ~4.3 bps for euro area matched pairs, which rose to the extent of 5.3 bps for externally reviewed bonds. Consistent with the growth of sustainable asset management, (Caramichael and Rapp, 2024) observed an issuance premium in the range of 3 to 8 bps from 2019 onwards. (MacAskill et al., 2021) reported a greenium of about 1 to 9 bps in the secondary market while concluding such evidence in 56% and 70% of primary and secondary market studies respectively.

2.3 Coverage on Sovereign Green Bonds

The literature available on sovereign green bonds is sparse. An early study by (Kapraun et al., 2019) found that green bonds issued by sovereigns in euros and US dollars trade at lower yields than its conventional counterparts. Comparing the issue yields of 38 sovereign green bond tranches from 10 countries, (Doronzo et al., 2021) at the Bank of Italy, propounded that green bonds were 3.8 bps more expensive at issuance. In the secondary market, a statistically significant but economically negligible greenium of 0.5 bp existed for France, Belgium, Netherlands and Ireland. At Bruegel, (Grzegorczyk and Wolff, 2022) matched 10 EU sovereign green bonds with conventional bonds and found greeniums ranging from ~ 3 bps (Denmark) to 16 bps (Spain), although for a larger sample they could not establish a significant effect.

At the IMF, (Ando et al., 2023) assembled 23 sovereign green bonds and 189 conventional comparators from 15 countries and conducted regression on daily Z-spreads of a green dummy, remaining tenor and bid–ask spreads with country, week and currency fixed effects. (Lewandowski and Smoleńska, 2023) reviewed the governance of member-state green frameworks and concluded that there is little evidence on investors rewarding sovereign issuers with materially lower borrowing costs. Rather, the motivations are geared towards signalling effects, investor diversification and the development of domestic green markets.

Based on the literature reviewed, three research gaps have been identified for the present work. Firstly, studies on sovereign green securities are based on a handful of exact matches (yield precise, but narrow evidence), or on interpolated curves (noisy) and few apply regression methodology on groups of countries. Secondly, the panel estimates have been conducted by pooling countries having different curve shapes and spread levels, thus biasing the green parameters towards bonds concentrated at higher maturities. Finally, the policy relevance of the EU experience for emerging sovereign issuers such as India has not been examined by any strand of available literature.

3 Methodology

3.1 Measuring the Cost of Sovereign Debt: the Z-Spread

As per the procedure followed by (Doronzo et al., 2021; Ando et al., 2023), the outcome variable is the bond's zero-volatility spread (Z-spread), which is the constant spread (in bps), that must be added to every point of the benchmark zero-coupon curve so that the discounted value of the bond's cash flows equals its market price. For bond *i* with cash flows CF_t at times *t*, the Z-spread Z_i solves

(1)

where P_i is the dirty price and r_t the benchmark zero rate for maturity *t*.

Sovereign green bonds are concentrated at higher maturities and carry comparatively lower coupons. As Z-spread is less affected than Yield-To-Maturity (YTM) for differences in coupon and duration between the green and conventional bonds, it is the most appropriate measure for analysing the greenium present in sovereign bonds.

3.2 Cross-Sectional Baseline Model

The baseline specification follows equation (1) of (Ando et al., 2023):

(2)

where Z_{ij} is the Z-spread of bond *i* issued by country *j*; $Green_{ij}$ equals 1 for a labelled green bond and 0 otherwise; $Maturity_{ij}$ is remaining maturity in months, controlling for the term premium; $BidAsk_{ij}$ is the quoted bid–ask spread (in bps), controlling for liquidity; and μ_j are country-fixed effects capturing sovereign credit risk. As all bonds are priced on the same date, the time fixed effects of the considered bonds are absorbed into the constant term. The coefficient of interest is β_1; a negative β_1 implies that green bonds trade at lower spreads, i.e., a positive greenium equal to $-\beta_1$.

3.3 Country-Specific Yield Curves

Equation (2) above assumes that the spread curve has the same slope in every country. It is observed that green bonds are, on average, about three years longer than conventional bonds, hence a mis-specified curve loads onto the green dummy. The preferred specification therefore allows each country its own quadratic curve as given below:

(3)

so that each green bond is compared with conventional bonds of the same issuer at the same point on that issuer's own curve.

Robustness checks use a cubic curve, bid–ask spreads in price points, log issue size, sub-samples by country and credit quality, the exclusion of influential observations, country-clustered standard errors and quantile regressions at the 25th, 50th and 75th percentiles.

3.4 Bond-Level Greenium Measures

To ensure that the regression results are not an artefact of functional form, the greenium related to sovereign bonds is also computed bond by bond using three methods:

Twin bonds: for Germany, each green bond is compared with its conventional twin with identical coupon and maturity, $G_i = Z_{twin} - Z_{green}$

Interpolation method: Z-spread of a synthetic conventional bond is obtained by linear interpolation between the nearest shorter (L) and longer (U) conventional bonds of the same issuer:

$$\hat{Z}_i = Z_L + [(T_i - T_L)/(T_U - T_L)] * (Z_U - Z_L),\ G_i = \hat{Z}_i - Z_i$$

(4)

Synthetic bonds: For each country in the EU, a regression of conventional Z-spreads on Maturity, (Maturity)^2 and Bid–Ask spread is estimated and used to predict the spread of a counterfactual conventional bond with the green bond's characteristics. The final greenium is

the prediction minus the green bond's actual Z-spread. Subsequently, mean greeniums are tested against zero with *t*-tests and Wilcoxon signed-rank tests.

3.5 Estimation and Diagnostics

All models in this study have been assessed using ordinary least squares regression with Heteroskedasticity-consistent (HC) standard errors. The preliminary diagnostic tests include the Breusch–Pagan (BP) test for heteroskedasticity, the Jarque–Bera (JB) test for normality of residuals, Ramsey's Regression Equation Specification Error Test (RESET) test for functional form, Variance Inflation Factors (VIF) for multicollinearity and Cook's distance for influential observations.

4 Data and Its Sources

4.1 Data Source

Bond-level data were taken from the LSEG (Refinitiv) fixed-income workspace, wherein the dataset contains 6,928 euro-area public-sector instruments, including 2,905 central-government bonds, bills and Separate Trading of Registered Interest and Principal of Securities (STRIPS). For each debt instrument, Refinitiv reported the issuer, instrument type, coupon type, coupon, issue and maturity dates, amount issued, green bond flag, the Z-spread (reported in the field "ZC Volatility") and the quoted Bid–Ask spread.

The analysis is restricted to countries that have at least one green bond with valid pricing, so that every green bond can be compared with conventional bonds of the same issuer. Nine member states qualify, with 2,421 instruments in total. Following the methodology in (Ando et al., 2023), comparable plain fixed-coupon euro bonds have been considered for the study (Table 1). Bills, STRIPS and commercial papers are excluded; so are inflation-linked bonds, floating-rate and step-up bonds, zero-coupon bonds, Belgian retail state notes, bonds with less than one year to maturity and bonds with missing spreads. Finally, conventional bonds must mature within seven years of the shortest and longest green maturity of the same country- outside the baseline model maturity window and accordingly, the final sample comprised of 313 bonds: 30 green and 283 conventional respectively.

4.2 Sample Construction

Table 1. Bonds considered for the study

Steps followed	Number of Bonds
Exported data from LSEG (Refinitiv)	6928
of which, central government instruments	2905
of which, issued by the nine countries with priced green bonds	2421
less: Bills/ STRIPS/ Commercial papers	(1874)
less: Outside baseline maturity window (green ±7 years)	(83)
less: Inflation linked bonds	(49)
less: remaining maturity less than 1 year	(39)
less: Belgian retail state notes	(35)
less: Not plain fixed coupon (Floating Rate Notes/ Step-up/ Zero) bonds	(27)

Steps followed	Number of Bonds
less: Z-spread or Bid-Ask missing	(1)
Final Sample	313
of which, green bonds	30
of which, conventional bonds	283

Source: LSEG (Refinitiv), Authors' calculations

4.3 Description of the Variables

Table 2. Variable definitions for the study

Variable	Definitions	Unit
Z	Z-Spread over the Benchmark Zero curve	bps
Green	'1' if the bond carries green bond flag; '0' otherwise	1/0
Maturity	Remaining term to maturity	Years
BidAsk	Quoted bid–ask spread converted to yield	Bps
Amount	Amount issued	€ billions

5 Exploratory Data Analysis

Table 3 compares the green and conventional bonds of the EU member states considered for the present study. The dataset shows green bonds have slightly lower Z-spreads than conventional bonds (Mean of 49.56 vis-a-vis 52.51 bps). Green bonds are about 2.81 years longer on average (12.17 v/s 9.36 years) and smaller in amount issued (€ 12.40 v/s 21.75 billions). Mean Bid-Ask spreads are somewhat higher for green bonds (0.68 v/s 0.47) but the median values are lower (0.08 v/s 0.12 bps). As the distribution of Bid-Ask spreads is highly skewed, green bonds are not clearly less liquid in quoted terms.

Table 3. Descriptive statistics by green status

Variable	Group	N	Mean	SD(σ)	Min	Max	Skew.	Kurt.
Z-spread (bp)	Green	30	49.56	53.46	-12.92	137.78	0.32	-1.62
	Conventional	283	52.51	44.30	-12.04	150.02	0.32	-1.08
Maturity (years)	Green	30	12.17	7.41	1.01	26.84	0.20	-1.05
	Conventional	283	9.36	7.19	1.01	29.84	1.07	0.34
BidAsk (bps)	Green	30	0.68	1.45	0.01	7.02	3.32	12.55
	Conventional	283	0.47	1.03	0.01	10.19	5.35	37.92
Amount (€ billions)	Green	30	12.40	6.98	0.07	36.30	1.73	4.83
	Conventional	283	21.75	13.07	0.03	71.54	1.28	2.77

Source: Authors' Calculations

Country-wise data analysis is presented in Table 4. Spread levels among the member states differ enormously. From close to zero or negative in Germany to more than 120 bps in France and around 80–100 bp in Italy, which confirms the need for country fixed effects in the analysis. Raw gaps calculated are of mixed sign implying that green bonds sit further out on

curves that slope in different directions. For example- In Germany, the curve slopes downward, so long green Bunds mechanically show lower spreads, whereas in Italy and France the curve slopes upward, so long green bonds show higher spreads (Figure 1).

Table 4. Features by country and green status

Country	Group	N	Z (bps)	Maturity (years)	BidAsk (bps)	Raw Gap
Austria (AT)	Conventional	25	22.21	10.28	1.12	(10.64)
	Green	2	11.57	12.61	0.80	
Belgium (BE)	Conventional	25	63.82	7.77	0.52	8.18
	Green	2	72.00	9.53	0.22	
France (FR)	Conventional	33	122.20	13.67	0.16	8.61
	Green	4	130.81	15.95	0.07	
Germany (DE)	Conventional	60	0.63	8.15	0.40	(3.29)
	Green	9	(2.66)	10.24	1.10	
Ireland (IE)	Conventional	22	15.58	10.33	0.80	(12.40)
	Green	2	3.18	10.72	0.40	
Italy (IT)	Conventional	86	79.16	7.48	0.14	20.68
	Green	6	99.84	12.47	0.04	
Lithuania (LT)	Conventional	5	80.81	2.92	5.49	9.71
	Green	1	90.52	1.56	7.02	
Netherlands (NL)	Conventional	10	9.25	11.76	0.41	(6.95)
	Green	2	2.30	15.26	0.07	
Spain (ES)	Conventional	17	58.31	15.02	0.06	1.72
	Green	2	60.03	18.30	0.06	

Source: Authors' Calculations; Raw Gap = Green − Conventional mean Z-spread (not adjusted for maturity)

Within each country, green bonds lie close to the conventional curve, and in most of the cases slightly below it. The shapes of the curves, however, differ sharply among the member states: concave and steep for Italy, France and Belgium; flat or gently downward-sloping for Germany, Netherlands and Ireland; and noisy for Austria, Spain and Lithuania. A model that forces a single slope on all these countries will therefore misplace the long-dated green bonds relative to their own curves.

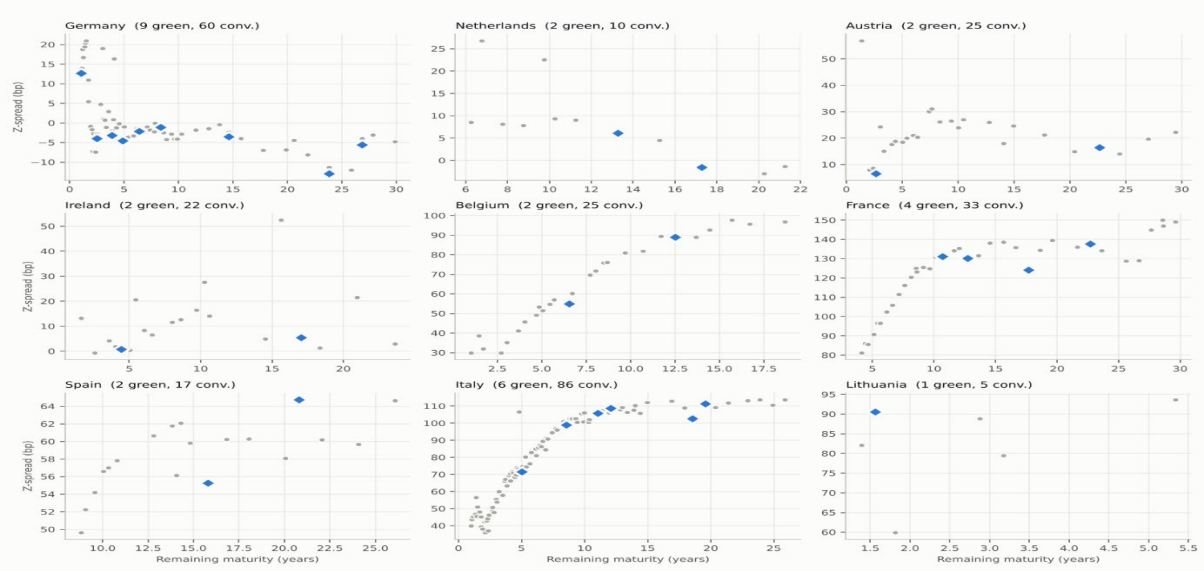


Figure 1. Z-spread against remaining maturity (country-wise)

Source: LSEG (Refinitiv), Authors' Calculations, Grey dots = Conventional bonds; Blue diamonds = Green bonds.

Table 5. Variance Inflation Factors and Pearson Correlation Matrix

Variable	Z-spread	Green	Maturity	BidAsk spread	Amount issued
VIF	---	1.06	1.11	1.18	1.12

Variable	Z-spread	Green	Maturity	BidAsk spread	Amount issued
Z-spread	1.000	-0.019	0.234	-0.136	0.212
Green	-0.019	1.000	0.114	0.059	-0.214
Maturity	0.234	0.114	1.000	-0.289	0.009
BidAsk spread	-0.136	0.059	-0.289	1.000	-0.256
Amount issued	0.212	-0.214	0.009	-0.256	1.000

Source: Authors' Calculations

As evident from Table 5 above, the unconditional correlation between the green dummy and the Z-spread is close to zero (-0.019), while the Z-spread is positively correlated with Maturity (0.234) and issue size (0.212) and negatively with the Bid–Ask spread (-0.136), reflecting the country mix. Also, all the variance inflation factors values are below 1.2 and hence, ruling out the possibility of multicollinearity.

Table 6. Diagnostic Tests for country specific curves

Test	Statistic	p-value	Hypothesis / rule	Conclusion
Breusch–Pagan	64.374	<0.001	H_0: Homoskedastic errors	Rejected → robust (HC) SEs
Jarque–Bera	273.002	<0.001	H_0: Normal residuals	Rejected (fat tails) → robust & quantile checks
Ramsey RESET	20.342	<0.001	H_0: No omitted non-linearity	Rejected
Durbin–Watson	1.222		≈2 = no serial correlation along	Positive autocorrelation

Test	Statistic	p-value	Hypothesis / rule	Conclusion
			the curve	
Influential obs. (Cook's D)	27.000		Count	Re-estimated without them

Source: Authors' Calculations

The Breusch–Pagan test rejects homoskedasticity, which is why heteroskedasticity-robust standard errors are used throughout the analysis. The Jarque–Bera test rejects normality of residuals – a few bonds, such as Austria's 0.75% 2028 and Ireland's long bonds, lie well off their individual curves. The use of quantile regressions and the Cook's distance check confirms the results. The RESET test indicates remaining non-linearity in the curve fit; the cubic specification described in the methodology addresses the concern and leaves the greenium essentially unchanged. A Durbin–Watson statistic of 1.22, computed with bonds ordered along each curve, indicates some residual correlation between neighbouring maturities, as expected for yield curves, but it does not affect the consistency of the cross-sectional estimates.

6 Findings and Analysis

The main regression analysis is presented in Table 7 which shows that in the IMF baseline model (Equation 2 above), which imposes a common linear term structure on all countries, the green coefficient is 0.189 bp and statistically insignificant from zero (p-value = 0.945). Adding a quadratic tenor term, modifies the coefficient negative (-2.155 bps) but it remains insignificant (p-value = 0.386). In the next iteration, each EU member state is allowed its own curve and, the coefficient turns to -3.838 bps with a robust standard error of 1.372 (p-value = 0.005), and the explanatory power of the model rises from $R^2 = 0.880$ to 0.975. Green bonds of EU member states therefore trade at Z-spreads about 3.84 bps lower than conventional bonds of the same issuer at the same point on its curve, which in turn rejects the Null Hypothesis H_0 at the 1% significance level.

Table 7. Regression Results

Specification	Green coeff.	Green SE	Green (p value)	Maturity coeff. (per year)	BidAsk coeff.	R^2
Baseline model (linear tenor)	0.189	2.741	0.945	1.213	0.453	0.880
Including Maturity²	-2.155	2.484	0.386	4.745	2.593	0.901
Country-specific curves [preferred]	-3.838	1.372	0.005***	0.461	0.625	0.975

*Note: The country-specific model is based on the interaction of maturity terms with country dummies; the coefficient is the slope of the reference country (Austria); Authors' Calculations; ***p<0.01*

The major methodological finding of this paper is the contrast between the three results. Pooling countries whose curves have opposite slopes forces a misplaced curve through the long-dated green bonds. In Germany, the common upward slope over-predicts green spreads, while in Italy and France it under-predicts them, and the errors cancel out each other. This helps to explain why studies that rely on pooled curves or on noisy interpolation (Doronzo et al., 2021; Grzegorczyk & Wolff, 2022) fail to find a greenium, whereas exact matches and curve-consistent comparisons make positive contributions.

Table 8. Robustness Checks

Specification (Country specific curves)	Green coeff.	Green SE	Green (p value)
Standard Errors clustered by country	-3.838	1.094	0.000***
Excl. influential observations (Cook's D)	-2.440	1.028	0.018**
Quantile regression (q = 0.25)	-2.835	1.110	0.011**
Quantile regression (q = 0.50)	-2.955	1.117	0.009***
Quantile regression, (q = 0.75)	-1.804	1.372	0.190
Bid–Ask spread in price points	-3.249	1.290	0.012**
Cubic country curves	-3.229	1.357	0.017**
Excluding Italy	-3.866	1.601	0.016**
Excluding Germany	-4.292	1.807	0.018**
AAA/AA issuers only (AT, DE, IE, NL)	-4.990	1.896	0.008***
Higher-spread issuers only (BE, ES, FR, IT, LT)	-2.452	2.013	0.223
Including log issue size	-4.956	1.321	0.000***
Remaining maturity ≥ 2 years	-4.032	1.269	0.001***
Excluding Lithuania	-4.216	1.361	0.002***

*Source: Authors' Calculations; ***p<0.01; **p<0.05*

Table 8 reports further robustness checks on country specific curves summarizing all estimated at the 95% confidence intervals. Clustering standard errors by country leaves the estimate significant. Dropping the influential observations identified by Cook's distance lowers the greenium to 2.440 bps, but it remains significant (p-value = 0.018). Median regression – which is insensitive to outliers – gives 2.955 bps (p-value = 0.009); the effect is also found to be significant at the 25th percentile (2.835 bps); but smaller and insignificant at the 75th percentile (1.804 bps).

The greenium is also robust to measure liquidity in price points (3.249 bps), to cubic country curves (3.229 bps) and to excluding Italy (3.866 bps), Germany (4.292 bps) or Lithuania (4.216 bps), and it rises to 4.956 bps when log issue size is controlled for, because larger bonds trade at lower spreads and green bonds are smaller. It is larger among the AAA/AA issuers, viz. Austria, Germany, Ireland and Netherlands at 4.99 bps (p-value = 0.008), and smaller and insignificant among the higher-spread issuers, i.e., Belgium, Spain, France, Italy and Lithuania at 2.452 bps (p-value = 0.223). Overall, the green coefficient is significant in 12 of the 14 alternative specifications. Economically, a greenium of 3.8 bps on the approximately € 372 billion of green bonds in the sample implies an overall interest savings of roughly € 140 million per year.

Table 9. Sovereign Greenium (country-wise)

Country	Green bonds	Conventional bonds	Green coef.	p-value	Greenium (bps)
Austria	2	25	-10.48**	0.040	10.48
Belgium	2	25	-3.60	0.247	3.60
France	4	33	-3.15	0.463	3.15
Germany	9	60	-1.57	0.427	1.57

Ireland	2	22	-10.37**	0.028	10.37
Italy	6	86	-3.77	0.156	3.77
Netherlands	2	10	-3.84	0.361	3.84
Spain	2	17	-0.55	0.849	0.55

*Source: Authors' Calculations (OLS of Z-spread on Green, Maturity, Maturity^2 and BidAsk); **p<0.05*

Estimating the model separately for each member state of the EU (Table 9), yields a positive greenium in all eight countries (Lithuania omitted with 5 conventional bonds) for which it can be estimated. The estimates are largest for Austria (10.48 bps) and Ireland (10.37 bps) – the only two results that are individually significant. Greenium ranges between 1.5 and 4 bps for Belgium, France, Germany, Italy and the Netherlands, whereas for Spain- it is close to zero. With only one or two green bonds in most countries these country estimates are imprecise, but their consistent sign reinforces the pooled result. They also echo (Grzegorczyk and Wolff, 2022), who report greeniums of about 3 to 4 bps for Germany and 8 to 16 bps for Austria, Belgium, France, the Netherlands and Spain over 2020–22 period, suggesting that country premiums have since compressed.

Figure 2 and Table 10 present the three bond-level measures defined in the study, viz. Twin bonds, Interpolation methods and Synthetic bonds. On an average, all three results yield positive values. The German twins provide the cleanest comparison because coupon, maturity and issuer are identical in nature. Greenium value averages around 0.81 bp (median 1.07 bp), is positive for eight out of nine pairs and is highly significant (t-test p-value = 0.005). The interpolation method gives a mean of 1.87 bps and a median of 1.01 bps (positive for 69% of the bonds and the Wilcoxon p-value = 0.035). The larger dispersion figure reflects the noise of using only two neighbouring bonds. The baseline IMF synthetic-bond method gives greenium of 3.67 bps (median 3.46 bps; positive for 76% of bonds; p-value = 0.005). All the results are in line with the regression estimates observed at Table 7 above.

Table 10. Bond- level greenium

Method	**Mean (bps)**	**Median (bps)**	**SD(σ)**	**Share(%)**	**t-stat**	**t (p-value)**	**Wilcoxon p-value**
German Twins	0.81	1.07	0.63	88.9	3.84	0.005	0.008
Interpolation	1.87	1.01	6.25	69.0	1.61	0.118	0.035
Synthetic bond	3.67	3.46	6.51	75.9	3.03	0.005	0.005

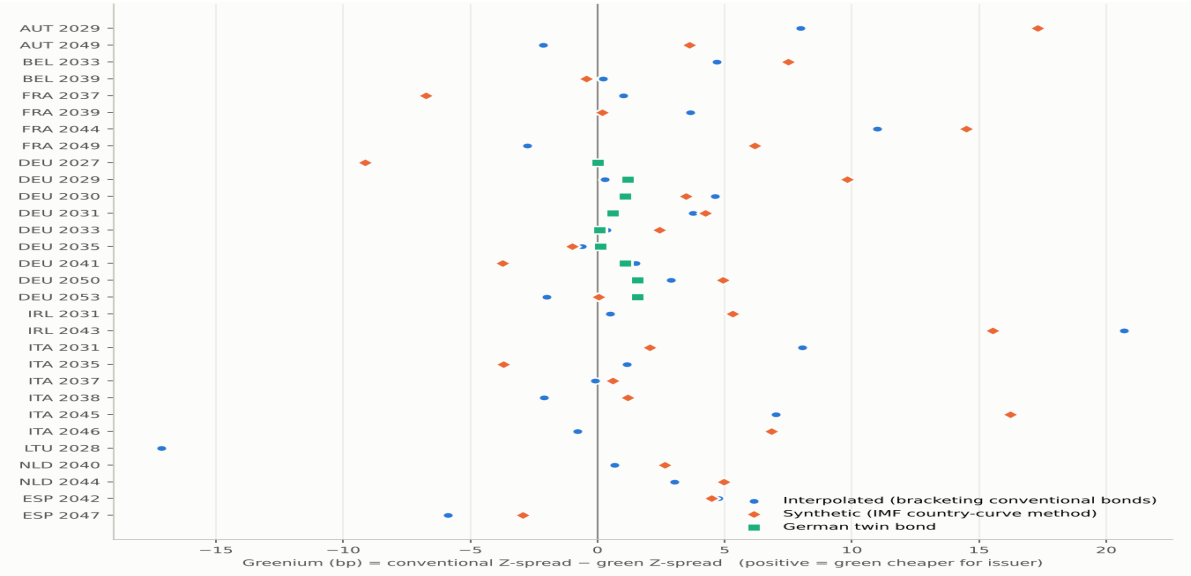


Figure 2. Bond-level greenium (30 EU sovereign green bonds)
Source: Authors' Calculations; Greenium = Conventional − green Z-spread. Lithuania has no synthetic estimate (too few conventional bonds)

Table 11. Greenium across the maturity spectrum

Bucket	Interpolated – mean	Interpolated – median	Synthetic – mean	Synthetic – median
≤ 5 y	0.00	2.12	5.16	4.76
5 – 10 y	2.72	1.16	1.47	2.07
10 – 20 y	3.89	1.50	4.32	2.65
> 20 y	-1.99	-2.13	2.36	3.61

Source: Authors' Calculations

Table 11 groups the green bonds by remaining maturity profile (synthetic-bond measure). The greenium averages 5.16 bps up to five years bucket, 1.47 bps at five to ten years bucket, 4.32 bps at ten to twenty years bucket and 2.36 bps beyond twenty years. There is no monotonic pattern observed in the above results, which indicate that the greenium is present along the whole curve, thereby assisting the governments to lengthen their debt maturity profile.

7 Sovereign Green Bonds (Sgrbs) in India

India announced sovereign green bonds (SGrBs) in the Union Budget 2022-23, and the Government approved its Sovereign Green Bonds Framework on November 09, 2022 (India Briefing, 2022). The framework followed the International Capital Market Association (ICMA) Green Bond Principles and listed nine eligible categories for implementation in India.

As the government's debt manager, RBI auctioned SGrBs alongside conventional government securities- the debut auction on January 25, 2023 raised ₹ 8,000 crore at 7.10% for the five-year bond and 7.29% for the ten-year bond – about 5 and 6 bps below comparable conventional benchmarks yielding 7.15% and 7.35% respectively (Business Standard, 2023). A second ₹ 8,000 crore tranche followed on February 09, 2023 and, by February 2025 eight issuances had raised nearly ₹ 53,000 crore (Policy Circle, 2025). Access was widened in

2024 through the RBI's scheme for trading and settlement of SGrBs in the International Financial Services Centre (IFSC) at GIFT City, which allowed eligible foreign investors in the IFSC to bid in primary auctions and trade in the secondary market (Business Standard, 2024). For the second half of 2026-27, the borrowing calendar provided for ₹ 15,000 crore of 30-year SGrBs in ₹3,000 crore tranches, with 5% reserved for retail investors (GoldenPi, 2026).

India's debut greenium of 5–6 bps was slightly larger than the EU estimates as brought out in this paper. Subsequent auctions cleared at greeniums of only 2–3 bps, against a global average of 7–8 bps cited by market commentators (Policy Circle, 2025). Moreover, the RBI cancelled a 10-year auction in May 2024 when bids came in 1–7 bps above the conventional benchmark, accepted only ₹ 1,697 crore of a ₹ 6,000 crore auction in August 2024. Also, there was devolvement of ₹7,443 crore out of ₹10,000 crore on primary dealers in November 2024 and January 2025. In June 2025, a 30-year auction was cancelled even though bids were more than twice the notified amount because the investors were not prepared to pay a greenium (Trivedi, 2025).

The EU evidence helps explain this pattern. Firstly, greeniums are small even in the deepest green markets (few basis points) – so a government that insists on a meaningful discount at every auction will find lower demand for its bonds. Secondly, the EU greenium is concentrated among the safest, most liquid issuers and is supported by a large base of dedicated ESG investors with Article 8/9 mandates. On the contrary, India's domestic investor base is dominated by banks, insurers and provident funds that hold government securities for regulatory and asset-liability reasons and have few green mandates. Thirdly, India's SGrBs are thinner, infrequent, single-tranche lines that are mostly held to maturity, so their secondary-market trading deserves an illiquidity premium. Fourthly, unlike Germany, India has not built a green curve twinned with liquid conventional benchmarks, so investors cannot easily switch between the two. Finally, India's recent shift of SGrB issuance to the 30-year segment, where insurance and pension demand is structurally strong, mirrors the long-end concentration of EU green issuance and appears to be the right move.

8 Conclusion and Policy Implications

This paper has estimated the sovereign greenium for EU member states using a single, consistently filtered cross-section of 313 Refinitiv-priced euro government bonds and the IMF Z-spread framework extended with country specific yield curves. Green bonds trade about 3.8 bps below conventional bonds of the same issuer after controlling for the country-specific yield curves, maturity and liquidity. The estimate is statistically significant, robust to alternative functional forms, sub-samples, influential observations and quantile estimation, and consistent with three bond-level measures. It is larger for AAA/AA issuers and smaller for higher-spread sovereigns, and about 1 bp for Germany's exactly matched twins. For EU debt managers, sovereign green bonds are therefore at least cost-neutral and modestly cheaper, while delivering signalling, investor-diversification and market-development benefits.

The RBI, as debt manager to the Government of India, and as the regulator of the banks that dominate the government securities market, can draw several lessons from the EU experience:

The EU greenium is a few basis points and fluctuates over time. Accepting bids at or near the conventional curve while the market develops as mentioned in (Doronzo et al., 2021) would

allow the proper formation of the green curve, after which a greenium can potentially emerge in the secondary market.
Liquidity is the binding constraint. Fewer, larger lines that are regularly re-opened through the year, as France, Italy and Netherlands have done, would reduce the illiquidity premium and support index inclusion.
Germany's twin model, which matches each green bond to a liquid conventional bond with the same coupon and maturity, gives investors a cheap exit and makes the greenium transparent. A similar structure, or a standing switch facility into the matching conventional benchmark, would address investors' liquidity concerns.
India's move to 30-year SGrBs aligns issuance with insurers and pension funds that need long-dated assets; regular engagement with these investors and with IFSC-based foreign ESG funds may be continued.
Timely, project-level allocation and impact reports – published on a fixed calendar and externally reviewed – are associated with larger greeniums in the corporate literature (Pietsch & Salakhova, 2022) and help counter the fungibility objection to sovereign green bonds.
Requiring banks and other regulated entities to disclose climate-related financial risks and the share of green assets in their portfolios would create balance-sheet demand for SGrBs, in the way that EU disclosure rules have created dedicated green investors.

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