

A Work Project, presented as part of the requirements for the Award of a Master's degree in  
International Finance from the Nova School of Business and Economics.

THE ROLE OF CURRENCY DENOMINATION IN THE AFRICAN GREEN BOND  
MARKET – EXAMINING YIELD DIFFERENTIALS AND IMPLICATIONS FOR  
FINANCIAL ADVISING WITH INSIGHTS FROM THE DZ BANK AND DBSA

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14/01/2025

Abstract (100 words maximum)

This thesis examines the role of currency denomination in African Green Bonds, focusing on yield differentials and the presence of Greenium. Empirical analysis reveals no significant evidence of Greenium but confirms a robust currency premium, with Hard Currency Bonds yielding lower rates than Local Currency Bonds. Insights from interviews with DZ Bank and DBSA highlight the importance of addressing default risk, illiquidity, and strategic trade-offs between currencies. While Green Bonds show limited potential to mitigate currency premiums, the findings underscore the need for tailored advisory strategies. DZ Bank is positioned to support sustainable finance growth through active engagement in Africa.

Keywords: Green Bonds, ESG, African Bond Market, Currency Denomination, Sustainable Finance, Financial Advising, Local Currency, Hard Currency, Greenium, Currency Risk, Emerging Markets, Africa, Quantile Regression, OLS Regression, DZ Bank, Sustainability Bonds, Sustainability-Linked Bonds

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209).

## **Chapter 1 Introduction and Motivation**

Africa contributes only 4% of global greenhouse gas (GHG) emissions yet faces severe climate change impacts. Many African countries spend up to 9% of their national budgets on disaster response, while economic losses in sub-Saharan Africa can reach 5% of GDP annually (Bank 2023b; Tyson 2021). Meeting these challenges requires external financing, with adaptation and mitigation costs exceeding \$200 billion per year (Hoskisson et al. 2017; World Meteorological Organization 2024). Green bonds have emerged as a key tool to raise funds for projects with measurable environmental benefits (Bhutta et al. 2021). Despite their potential, African Green Bonds face significant barriers such as high financing costs, illiquid markets, and limited international investor confidence (Ahmed et al. 2022; Kodongo et al. 2023). Currency denomination further complicates the African Green Bond market. Local Currency Bonds help match debt obligations with domestic revenues but often struggle with volatility and liquidity issues, making them less attractive to international investors (Jain 2023; Tyson 2021). On the other hand, Hard Currency Bonds mitigate exchange rate risks but can increase debt burdens when local currencies depreciate (Pilling et al. 2023). These trade-offs raise important questions about how currency choices influence bond pricing and accessibility.

Frameworks such as the Climate Bonds Initiative (CBI) and Green Bond Principles enhance credibility and reduce information asymmetry, yet gaps remain in understanding whether Local or Hard Currency Bonds offer better outcomes for African issuers (Mutarindwa et al. 2024). This thesis addresses these gaps by examining yield differentials and the existence of Greenium in African Green Bonds. The analysis combines empirical findings with qualitative insights from stakeholders, namely the Development Bank of Southern Africa (DBSA) and DZ Bank.

It is developed in collaboration with DZ Bank, a key financial institution in sustainable finance. As the central bank for over 700 cooperative banks in Germany, DZ Bank partners with institutions like the African Development Bank (AfDB) and DBSA to promote transparency

and attract global investors (“We are DZ BANK” n.d.; Appendix A.1). My internship as a Debt Origination Intern in Debt Capital Markets at DZ Bank’s Singapore branch provided valuable experience in bond issuance processes across emerging markets. This included exposure to both local and hard currency issuances, offering a comparative perspective relevant to Africa's Green Bond market.

The findings indicate that while Hard Currency Bonds offer lower yields due to reduced exchange rate risk, they place a heavier debt burden on issuers during currency depreciation (Pilling et al. 2023). Furthermore, no significant evidence of Greenium is observed, reflecting the challenges of achieving pricing advantages in markets with high credit risks and low liquidity. Interviews emphasized the need for institutions like DZ Bank to take on balance sheet risks to signal confidence and attract investors (Appendix A.2). By combining technical expertise with a deeper understanding of local economic conditions, DZ Bank can play a transformative role in supporting Africa’s sustainable finance goals.

This thesis investigates the role of currency denomination in African Green Bonds, analyzing the presence of Greenium, currency premiums, and their interaction using Ordinary Least Squares (OLS) and Quantile Regression. Empirical results are complemented by insights from DZ Bank and the DBSA, offering recommendations to address structural challenges and scale sustainable finance in Africa.

## **Chapter 2 Literature Review**

### **2.1 The Role of Green Bonds in Sustainable Finance**

The 2015 Paris Agreement marked a critical moment in the global response to Climate Change, aiming to limit global temperature rise to well below 2°C, ideally 1.5°C (Henderson et al. 2020; “The Paris Agreement — UNFCCC” n.d.). However, current policies fall short, with projections estimating global warming will reach 2.6°C by the end of the century (Environment

2024). Achieving the 1.5°C target requires global emissions to decrease by 42% by 2030 and 57% by 2035 compared to 2019 levels (Environment 2024). Meeting these goals demands substantial public and private investments, with annual funding needs in Emerging and Developing Economies (EMDE) estimated at USD 6.7 to 11.7 trillion by 2035 (Environment 2024; Otek Ntsama et al. 2021).

Green bonds, representing just 2% of the \$126.9 trillion fixed-income market, hold significant potential to channel investments into sustainable projects (Jain 2023). This is because several factors hinder the growth of this market. For emerging economies those factors include insufficient institutional frameworks for managing Green bonds, limited issuance volumes, and elevated transaction expenses (Banga 2019). As a key product of sustainable finance, Green Bonds mobilize private capital for projects with measurable environmental benefits (Ahmed et al. 2022; Chouhan et al. 2024). They account for two-thirds of the broader Green, Social, Sustainable, and Other Labeled (GSS+) bond market, aligning investments with global climate goals (Chouhan et al. 2024). Since the introduction of Green Bonds by the European Investment Bank (EIB) in 2007, they have gained traction as fixed-income instruments with their proceeds dedicated to environmentally beneficial projects (Bhutta et al. 2021; Taghizadeh-Hesary et al. 2022).

Issuers often benefit from a potential Greenium—lower yields accepted by environmentally conscious investors (Boulle 2021; Cortellini & Panetta 2021). However, evidence on the prevalence of Greenium is mixed. While some studies report Greenium in up to 70% of secondary market cases, others find it depends on issuer creditworthiness, governance standards, and market maturity (Cortellini & Panetta 2021; Fatica et al. 2021; MacAskill et al. 2020). Critics argue that Greenium may act more as a marketing tool than a structural financial benefit, especially in markets with weaker governance and reporting standards (MacAskill et al. 2020). Robust project reporting and third-party certification improve transparency but

increase issuance costs, posing challenges for first-time issuers (Tang & Zhang 2018). Frameworks like the International Capital Market Association (ICMA) Green Bond Principles and CBI standards are vital for ensuring credibility (“Explaining green bonds” 2014).

## **2.2 The African Green Bond Market**

Africa contributes only 4% of global GHG emissions but disproportionately suffers Climate Change impacts, with GDP losses between 5 to 15% per capita annually (Bank 2023a, 2023b). Emerging economies on the continent require substantial external financing to meet climate goals, with annual needs exceeding \$200 billion (Ngwenya & Simatele 2020; Taghizadeh-Hesary et al. 2022). Yet, the African Green Bond market remains underdeveloped due to limited issuance and illiquid secondary markets (Kodongo et al. 2023; Marbuah 2020).

Despite its current size, Africa has significant potential for Green Bond growth. By 2023, over 20 Green Bonds had been issued across countries like Tanzania, Rwanda, Gabon, Seychelles, Nigeria, South Africa, Kenya, Morocco, Mozambique, Namibia, Mauritius, and Zambia (Nkombo 2024). Multilateral development and Government banks, such as the AfDB, are leading issuer in this market (Mutarindwa et al. 2024). The AfDB issued Africa’s first CBI-aligned Green Bond in 2010 and accounted for \$521 million out of the \$1.96 billion total issuance by 2023 (Chouhan et al. 2024). Municipal issuances, such as South Africa’s and Kenya Power’s \$300 million green loan, demonstrate the potential of Green Bonds to address local sustainability needs (Chouhan et al. 2024; Taghizadeh-Hesary et al. 2022). Meanwhile, DBSA, a government-owned company development finance institution (DFI), focuses on infrastructure projects to promote sustainable development (“Green Bond Principles (ICMA)” 2021).

Nevertheless, international investor participation remains limited due to risks such as currency volatility and low liquidity (Tyson 2021). More than 80% of local currency Green Bonds are held domestically, reflecting the dominance of local stakeholders (Jain 2023). African financial markets are also weakly responsive to sovereign credit rating (SCR) announcements, as sub-

investment grade ratings and illiquidity already deter active investment (Mutize & Gossel 2018). While SCRs offer valuable long-term signals, their limited short-term impact underscores the dominance of passive investors and the importance of risk mitigation strategies. Certification by entities such as CBI enhances credibility but can be prohibitively expensive for smaller issuers (Jain 2023; Mutarindwa et al. 2024). By building on successful past issuances, Africa can leverage existing public, private, and environmental capacities to reduce its trillion-dollar climate finance gap (Nkombo 2024).

### **2.3 Currency Denomination in Green Bond Markets**

Currency denomination plays a central role in the cost and accessibility of Green Bonds. African bonds face higher financing costs than those in advanced or other emerging markets due to perceived risks and sovereign debt mispricing (Bank 2023a). In 2021, sovereign Eurobond yields averaged 1.1% in advanced economies, 4.9% in emerging markets, and 5% in Africa, with 40% of African bonds exceeding yields of 8% (Bank 2023a).

Local currency bonds align debt with domestic revenues but face challenges such as exchange rate volatility, illiquidity, and higher yields demanded by investors (Ivashkovskaya & Mikhaylova 2020; Jain 2023). These bonds currently account for only 20% of Green Bond issuances in EMDE markets, compared to 80% of conventional bonds (Jain 2023). Hard Currency Bonds, primarily denominated in USD or Euro, reduce exchange rate risk but can burden issuers when domestic currencies weaken (Pilling et al. 2023). This creates a mismatch between investor preferences and issuers' financial realities, particularly in infrastructure projects where revenues are typically local (Jain 2023).

African currencies operate within pegged, quasi-pegged, and free-floating systems, each presenting unique risks for investors (Ganti 2024; Pilling et al. 2023). Developing strong regulatory frameworks, offering incentives, and fostering collaboration between public and private sectors are key to unlocking Africa's Green Bond potential (Nkombo 2024).

Overall, the literature highlights Green Bonds' transformative potential to address Africa's climate finance needs but underscores barriers such as illiquidity, high yields, and currency mismatches. While Local Currency Bonds align with domestic revenues, their volatility and limited demand contrast with the lower risk but heavier debt burden of Hard Currency Bonds (Ivashkovskaya & Mikhaylova 2020; Pilling et al. 2023). Building on these insights, this thesis empirically examines how currency denomination influences yield differentials and market performance in African Green Bonds, offering recommendations for scaling sustainable finance on the continent.

## **Chapter 3 Empirical Analysis**

### **3.1 Analyzing Greenium and Currency Premium in the African Green Bond Market**

This empirical analysis examines the pricing dynamics of Green and conventional Bonds within the African Bond Market, with a specific focus on determining the optimal currency for issuing Green Bonds. The study centers around three interrelated themes: the Greenium, which is represented as the yield differential between Green and conventional bonds (Larcker and Watts 2020); the currency premium, which captures the currency risk as the yield differential between bonds issued in local and hard currencies (De Santis and Gérard 1998); and the interaction between these two factors, exploring whether the currency premium is mitigated for Green Bonds. By investigating these elements, the analysis seeks to provide insights into whether Green Bonds are best issued in local or hard currencies. To address these questions, the analysis utilizes a dataset comprising Green, Sustainable and Sustainability-Linked (in the following summarized as Green Bonds) and conventional bonds issued in both local and hard currencies by the same issuers. This allows to compare both bond types as the default risk and other characteristics are the same. The OLS Regression is used to analyze the relationship between the Yield to Maturity (YTM) and key explanatory variables, incorporating bond-specific characteristics and issuer factors. The empirical analysis is organized into four primary

comparisons as displayed in Table 1. The analysis further investigates whether the currency premium differs between Green and conventional bonds, providing a comprehensive perspective on how sustainability factors interact with currency risk. The findings aim to offer actionable insights for policymakers, issuers, and investors seeking to optimize the issuance of Green Bonds in the African Bond Market. The subsequent chapter outlines the hypotheses that guide this study, connecting the empirical framework to the broader context of sustainability and currency considerations in emerging markets.

*Table 1: Bond Comparison Bucket Overview for Empirical Analysis*

<i>Local Currency, Non-Green Bond vs. Local Currency, Green Bond</i>	LNG vs. LG	Testing for <b>Greenium</b> within Local Currency Bonds
<i>Hard Currency, Non-Green Bond vs. Hard Currency, Green Bond</i>	HNG vs. HG	Testing for <b>Greenium</b> within Hard Currency Bonds
<i>Local Currency, Non-Green Bond vs. Hard Currency, Non-Green Bond</i>	LNG vs. HNG	Testing for <b>currency premium</b> within conventional bonds
<i>Local Currency, Green Bond vs. Hard Currency, Green Bond</i>	LG vs. HG	Testing for <b>currency premium</b> within Green Bonds

### 3.2 Hypotheses

This study develops hypotheses to address the dual objectives of understanding the Greenium and currency premium, as well as their interaction, within the African Bond Market. Specifically, the hypotheses are structured to determine whether Green Bonds are better suited for issuance in local or hard currencies. The hypotheses can be found in Table 2. These hypotheses form the foundation of the empirical analysis, guiding the investigation into the optimal conditions for Green Bond issuance in the African Bond Market.

*Table 2: Hypotheses Overview*

Hypotheses 1 (H1)	Green Bonds (Environmental, Social, Governance (ESG) bonds) exhibit a lower YTM compared to conventional bonds issued by the same issuer, regardless of currency.
Hypotheses 2 (H2)	Bonds issued in hard currencies (e.g., USD, EUR) have a lower YTM compared to those issued in local currencies (e.g., ZAR, GNS).
Hypotheses 3 (H3)	The interaction between the Greenium and the currency premium suggests that Green Bonds exhibit a smaller YTM differential between local and hard currencies compared to conventional bonds, indicating that Green Bonds mitigate currency risk.

### **3.3 Methodology**

This analysis focuses on assessing the presence of a Greenium and a currency premium in the African Bond Market. By examining the yields of Green Bonds and conventional bonds issued by African entities in both local and hard currencies, the study seeks to determine whether investors are willing to pay a premium for sustainable finance instruments and how this interacts with the choice of currency. The findings aim to provide insights into the cost of capital for green projects in Africa and the broader implications for the development of the continent's Green Bond market.

#### ***3.3.1 Data Source***

The dataset consists of 85 Green, Sustainability-Linked, and Sustainability Bonds from 26 issuers, alongside 1,364 conventional bonds issued by the same entities. This inclusion ensures that issuer-specific factors, such as default risk, remain consistent across both Green and conventional bonds. Social Bonds are excluded due to their predominant issuance during the COVID-19 pandemic, which could introduce bias to the analysis. Only bonds with positive yields are included, reflecting the absence of ESG bonds with negative yields in the market. The dataset further includes only bonds denominated in local currencies (Ghanaian Cedi (GHS), Nigerian Naira (NGN), South African Rand (ZAR)) and hard currencies (Australian Dollar (AUD), Canadian Dollar (CAD), Swiss Franc (CHF), EUR, British Pound (GBP), Japanese Yen (JPY), Norwegian Krone (NOK), New Zealand Dollar (NZD), Swedish Krona (SEK), USD). The local currencies of NGN and GHS are managed floating with no predetermined path for the exchange rate, while ZAR is an independent floating currency ("Classification of Exchange Rate Arrangements and Monetary Policy Frameworks – as of June 30, 2004" 2004). This selection allows for a thorough analysis of yield differentials across currency types while maintaining relevance to the African Green Bond market. The data is cleaned with the help of a z-score threshold, applied to the independent variables Time to Maturity and coupon rate. The

z-score threshold for those variables is set at 3, aligning with industry standards and ensuring that all data points are within three standard deviations of their mean (Nevil 2026). The dependent variable, YTM, is taken as a snapshot at a single point in time, aligning with the cross-sectional nature of the study. All monetary amounts are converted to Euros (EUR), which aligns with DZ Bank’s operational focus and enhances cross-currency comparability. The data, extracted from Bloomberg on November 26, 2024, ensures credibility and accuracy for a robust empirical analysis.

**3.3.2 Definition of Variables**

To ensure clarity and reproducibility, the dependent and independent variables used in the analysis are defined in Table 3 and 4:

*Table 3: Dependent Variable*

<b>Log of YTM</b>	The natural logarithm of the mid-value of the YTM for each bond in the dataset. This represents the return an investor would receive if the bond is held until maturity (Tuckman & Serrat 2022)
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*Table 4: Independent Variables*

<b>ESG Dummy</b>	A binary variable where 1 indicates a Green Bond and 0 indicates a conventional bond. This variable captures the Greenium
<b>Currency Dummy</b>	A binary variable where 1 indicates a bond issued in a hard currency (e.g., USD or EUR) and 0 indicates a bond issued in a local currency. This variable captures the currency premium. Especially in EMDE the currency risk is perceived as higher than in developed markets, this especially applies to local bonds (Jain 2023)
<b>Interaction Term (ESG Dummy × Currency Dummy)</b>	A product of the ESG Dummy and Currency Dummy. This variable measures whether the currency premium is different for Green Bonds relative to conventional bonds

Control variables are included to account for bond-specific characteristics that may influence yields, with a limited selection to mitigate multicollinearity concerns (see Table 5).

*Table 5: Control Variables*

<b>Log of Time to Maturity</b>	The natural logarithm of the remaining time to maturity (in years) of the bond. Longer maturities are associated with higher yields due to increased risk (Tuckman & Serrat 2022)
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<b>Coupon Rate</b>	The annual interest rate paid by the bond issuer to the bondholder. Higher coupon rates are typically associated with lower yields, all else being equal (Tuckman & Serrat 2022). • Liquidity Dummy: A binary variable where 1 indicates low liquidity (absence of bid-ask spread data) and 0 indicates high liquidity. Low liquidity is expected to increase yields due to higher transaction costs (Tuckman & Serrat 2022). EMDE secondary markets are more illiquid (Jain 2023), this implies liquidity risk for all bonds on the market. However, because of their difference characteristics, this might be perceived different for the variety of bonds
<b>Rating Dummy</b>	A binary variable where 1 indicates the bond is unrated and 0 indicates the bond has a rating. Unrated bonds generally have higher yields to compensate for the lack of creditworthiness transparency (Peppe & Unal 2022). Given that 979 out of the 1,490 bonds in the dataset lack ratings from any of the three major agencies—Moody’s, S&P, or Fitch—it is not practical to classify ratings into finer categories (e.g., AAA as 1, AA as 2, etc.). This approach would add limited explanatory value to the model, as the prevalence of unrated bonds diminishes the relevance and statistical contribution of such detailed classifications to the overall explanatory power (R-squared) of the analysis.

### 3.3.3 Measures to Improve Model Accuracy

The measures applied to ensure robust and accurate estimation are displayed in Table 6.

*Table 6: Model-Improvement Measures*

Log-Log Transformation	A logarithmic transformation is applied to the YTM and Time to Maturity variables to address skewness and to align the analysis with a loglog model, capturing proportional relationships more effectively (Manning & Mullahy 2001)
Control for Confounding Factors	Inclusion of bond-specific control variables minimizes omitted variable bias
Heteroskedasticity Correction	Robust standard errors are used to address heteroskedasticity in the residuals
Multicollinearity Check	Variance Inflation Factor (VIF) tests confirmed that multicollinearity is not a significant concern (Akinwande, Dikko, and Samson 2015)
Sample Thresholds	Yield buckets with fewer than five observations are excluded to ensure statistical validity

### 3.4. Estimation Approach

The analysis relies on OLS Regression for its simplicity and effectiveness in capturing linear relationships, as often used in financial studies (Maiti 2018). The Quantile Regression is used to explore how the relationships between variables differ across the distribution of bond yields, as financial data generally has a fat long tail, where the OLS might become ineffective (Maiti 2018). This seems especially reasonable, as the African Bond Market is generally considered illiquid and therefore most likely has heightened noise levels for the yield curve (Karahan & Soykok 2023; Kodongo et al. 2023). To address issues of skewness in both the YTM and time-to-maturity variables, a logarithmic transformation is applied to these two continuous variables

only. Dummy variables, such as ESG and Currency Dummies, remain untransformed as they are binary. Similarly, the coupon variable is not logged due to the absence of skewness in its distribution. This adjustment aligns the analysis closer to a semilog model, which is particularly suitable when only some variables require transformation (Haefen 2002). The choice of regression types is motivated by the following considerations:

*OLS Regression:* OLS provides a baseline understanding of the average relationship between bond yields and independent variables (Burton 2021). This is particularly useful for identifying the Greenium and currency premium in aggregate and within individual yield buckets.

*Quantile Regression:* Quantile Regression is employed to capture potential heterogeneity across the distribution of bond yields, especially when the effect of independent variables may differ significantly at lower (25th percentile), median (50th percentile), and higher (75th percentile) yields (Koenker and Hallock 2001).

### ***3.4.1 Regression Models***

The regression is conducted in two different parts. To get an overall idea of the interaction between both premiums, the first regression model is an aggregated OLS model with an interaction term of both premiums. Next, the data is divided into four buckets and matched into four separate regressions to account for the currency premium and the Greenium separately. For both regression types, with interaction term and bucket-specific, an additional Quantile Regression is conducted to account for the heterogeneity nature of the yield. For each regression, the dependent variable is the *YTM*, and the models focus on either the ESG Dummy, the Currency Dummy, or their interaction term.

### 3.4.2 OLS Regression with Interaction Term

This regression model incorporates both the ESG Dummy and Currency Dummy, along with their interaction term, to test whether the currency premium differs for Green Bonds compared to conventional bonds:

$$\begin{aligned} \log(\text{YTM}_i) = & \beta_0 + \beta_1(\text{ESG Dummy}) + \beta_2(\text{Currency Dummy}) \\ & + \beta_3(\text{ESG Dummy} \times \text{Currency Dummy}) + \gamma(\text{Controls}) + \epsilon_i \end{aligned} \quad (3.1)$$

The interaction term  $\beta_3$  is the key coefficient of interest, capturing how the currency premium differs for Green Bonds relative to conventional bonds.

### 3.4.3 Bucket-Specific OLS Regressions

The dataset is divided into four different buckets, named *LNG*, *LG*, *HNG*, and *HG*. These buckets are matched together to form the four bucket-specific regressions. An Overview of the Bucket-Specific Equations can be found in Table 7:

*Table 7: Bucket-Specific Equation Overview*

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**Local, Non-Green (LNG) vs. Local, Green (LG):**

$$\log(\text{YTM}_i) = \beta_0 + \beta_1(\text{ESG Dummy}) + \gamma(\text{Controls}) + \epsilon_i \quad (3.2)$$

*Focus: Testing the Greenium within local currency (ESG Dummy)*

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**Hard, Non-Green (HNG) vs. Hard, Green (HG):**

$$\log(\text{YTM}_i) = \beta_0 + \beta_1(\text{ESG Dummy}) + \gamma(\text{Controls}) + \epsilon_i \quad (3.3)$$

*Focus: Testing the Greenium within hard currency (ESG Dummy)*

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**Local, Non-Green (LNG) vs. Hard, Non-Green (HNG):**

$$\log(\text{YTM}_i) = \beta_0 + \beta_1(\text{Currency Dummy}) + \gamma(\text{Controls}) + \epsilon_i \quad (3.4)$$

*Focus: Testing the currency premium within conventional bond (Currency Dummy)*

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**Local, Green (LG) vs. Hard, Green (HG):**

$$\log(\text{YTM}_i) = \beta_0 + \beta_1(\text{Currency Dummy}) + \gamma(\text{Controls}) + \epsilon_i \quad (3.5)$$

*Focus: Testing the currency premium within Green Bonds (Currency Dummy)*

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### 3.4.4 Quantile Regression for Distributional Effects

In addition to OLS Regression, Quantile Regression is used to capture the heterogeneity of Greenium and currency premium effects across the yield distribution (Hao & Naiman 2007). The Quantile Regression models are specified with a logarithmic transformation applied to continuous variables (YTM and Time to Maturity), reflecting the semi-log approach described earlier. The Quantile Regression is conducted for OLS Regression with Interaction Term, as well as the Bucket-Specific OLS Regression (see Table 8).

Table 8: Quantile Regression Equation Overview

<b>With Interaction Term</b>	
$Q_q(\log(YTM_i)) = \beta_{0q} + \beta_{1q}(\text{ESG Dummy}_i) + \beta_{2q}(\text{Currency Dummy}_i) + \beta_{3q}(\text{ESG Dummy}_i \times \text{Currency Dummy}_i) + \gamma_q(\text{Controls}_i) + \epsilon_{iq}$	(3.6)
<i>Focus: Assessing whether Green Bonds mitigate the currency premium across quantiles</i>	
<b>Local, Non-Green (LNG) vs. Local, Green (LG):</b>	
$Q_q(\log(YTM_i)) = \beta_{0q} + \beta_{1q}(\text{ESG Dummy}_i) + \gamma_q(\text{Controls}_i) + \epsilon_{iq}$	(3.7)
<i>Focus: Testing the Greenium within Local Currency Bonds for quantile q</i>	
<b>Hard, Non-Green (HNG) vs. Hard, Green (HG):</b>	
$Q_q(\log(YTM_i)) = \beta_{0q} + \beta_{1q}(\text{ESG Dummy}_i) + \gamma_q(\text{Controls}_i) + \epsilon_{iq}$	(3.8)
<i>Focus: Testing the Greenium within Hard Currency Bonds for quantile q</i>	
<b>Local, Non-Green (LNG) vs. Hard, Non-Green (HNG):</b>	
$Q_q(\log(YTM_i)) = \beta_{0q} + \beta_{1q}(\text{Currency Dummy}_i) + \gamma_q(\text{Controls}_i) + \epsilon_{iq}$	(3.9)
<i>Focus: Testing the currency premium within conventional bonds for quantile q</i>	
<b>Local, Green (LG) vs. Hard, Green (HG):</b>	
$Q_q(\log(YTM_i)) = \beta_{0q} + \beta_{1q}(\text{Currency Dummy}_i) + \gamma_q(\text{Controls}_i) + \epsilon_{iq}$	(3.10)
<i>Focus: Testing the currency premium within Green Bonds for quantile q</i>	

$Q_q(\log(YTM_i))$  represents the  $\tau$ -th conditional quantile of the log-transformed YTM. This approach captures variations in the Greenium and currency premium across different parts of the yield distribution, uncovering potential heterogeneity in bond pricing dynamics (Koenker and Hallock 2001). By examining lower (25th percentile), median (50th percentile), and higher (75th percentile) quantiles, the analysis highlights whether the impact of explanatory variables,

such as the *ESG Dummy*, *Currency Dummy*, and their *interaction term*, differs between bonds with lower yields and those with higher yields. A summary of all regression models as well as the Python code applied to conduct the analysis can be found in Appendix A.3 and A.4.

### **3.5 Regression with Interaction Term**

#### **3.5.1 OLS Regression**

The results of the OLS Regression provide a comprehensive overview of the average relationship between the independent variables and the log-transformed YTM ( $\log(YTM)$ ). The detailed findings of the OLS and Quantile Regressions, including the key coefficients and their significance levels, are presented in Table 9. The coefficient for the ESG Dummy (0.050,  $p = 0.322$ ) indicates that there is no statistically significant evidence of a Greenium on average across the sample. This finding suggests that, after controlling for currency and other bond-specific characteristics, Green Bonds do not exhibit consistently lower yields compared to conventional bonds. On the other hand, the Currency Dummy ( $-0.282, p < 0.001$ ) is negative and highly significant, implying that bonds issued in hard currencies have substantially lower yields than those issued in local currencies. This result highlights the presence of a robust and statistically significant currency premium. The interaction term between the ESG and Currency Dummies ( $-0.130, p = 0.097$ ) is marginally significant at the 10% level. While not conclusive, this coefficient suggests that the currency premium may be smaller for Green Bonds compared to conventional bonds. This finding warrants further investigation, particularly in light of its implications for optimizing Green Bond issuance strategies.

#### **3.5.2 Quantile Regression**

Quantile Regression results provide additional nuance by exploring how the relationships observed in the OLS Regression differ across the yield distribution (see Table 9). For the ESG Dummy in the Quantile Regression, the coefficient is not statistically significant across all

quantiles, indicating that there is no evidence to suggest a systematic relationship between the ESG label and the YTM at different points in the yield distribution for this analysis. At the 25th percentile, the Currency Dummy ( $-0.088, p < 0.001$ ) is highly significant, indicating that Hard Currency Bonds have lower yields in the lower quartile of the yield distribution. This relationship strengthens at the median (50th percentile) with a coefficient of  $-0.105$  ( $p < 0.001$ ), consistent with the OLS results. However, at the 75th percentile, the Currency Dummy becomes insignificant ( $p = 0.086$ ), suggesting that the currency premium diminishes for higher-yielding bonds. The interaction term is highly significant at the 25th percentile ( $-0.175, p < 0.001$ ), indicating a substantial reduction in the currency premium for Green Bonds at lower yields. At the median, the interaction term ( $-0.008, p = 0.501$ ) is insignificant, suggesting no measurable interaction effect in the middle of the yield distribution. At the 75th percentile, the interaction term ( $-0.085, p < 0.001$ ) regains significance, indicating that Green Bonds continue to mitigate the currency premium, although to a lesser extent, among higher-yielding bonds. In light of these findings, the results provide mixed support for the hypotheses. The insignificance of the ESG Dummy across both OLS and Quantile Regressions indicates that there is no consistent evidence of a Greenium in the African Bond Market, thereby rejecting the first hypothesis (H1). However, the significant and negative coefficients for the Currency Dummy across OLS and lower quantiles strongly support the existence of a currency premium for Hard Currency Bonds, validating the second hypothesis (H2). The interaction term's significance at the 25th and 75th percentiles suggests that Green Bonds mitigate the currency premium, particularly at the tails of the yield distribution, providing partial support for the third hypothesis (H3). These results collectively underscore the complexity of pricing dynamics in the African Bond Market and highlight the nuanced interplay between sustainability and currency factors.

Table 9: Interaction Term OLS and Quantile Regression Results

Variable	OLS	Q(0.25)	Q(0.50)	Q(0.75)
Constant	1.659***	1.426***	1.602***	1.652***
ESG Dummy	0.050	0.004	0.001	0.005
Currency Dummy	-0.282***	-0.088***	-0.105***	-0.016
Currency × ESG Interaction	-0.130*	-0.175***	-0.008	-0.085***
Log(Time to Maturity)	0.007	0.060***	0.043***	0.010***
Maturity Type Dummy	0.045**	-0.001	0.003	0.001
Coupon Dummy	-0.507***	-0.027***	-0.087***	-0.300***
Coupon	0.104***	0.073***	0.074***	0.090***
Liquidity Dummy	0.086***	0.012***	0.008***	0.013***
Rating Dummy (0 = Rated, 1 = Not Rated)	0.023	0.072***	-0.003	0.078***
Observations	1449	1449	1449	1449
Pseudo $R^2$ (Quantile)	-	0.560	0.420	0.307
Adjusted $R^2$ (OLS)	0.445	-	-	-

**Notes:** The dependent variable is the log-transformed yield to maturity. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Standard errors are robust to heteroskedasticity.

### 3.6 Bucket-Specific Regressions

#### 3.6.1 OLS Regression Analysis

The OLS Regression results for the four bucket-specific analyses are summarized in Table 11. For *LNG vs. LG*, the coefficient for the ESG Dummy is statistically insignificant ( $p = 0.434$ ), indicating that the Greenium is not present within Local Currency Bonds. The adjusted  $R^2$  value of 0.250 suggests that only a modest portion of the variation in yields is explained by the model. For *HNG vs. HG*, the ESG Dummy coefficient ( $-0.046$ ) is also insignificant ( $p = 0.251$ ). This suggests that the Greenium is not evident within Hard Currency Bonds. However, the adjusted  $R^2$  of 0.665 indicates that the model effectively explains yield variations within this category, primarily driven by liquidity and coupon characteristics. For *LNG vs. HNG*, the Currency Dummy coefficient ( $-0.278$ ) is significant ( $p < 0.001$ ), providing strong evidence for the existence of a currency premium. This suggests that bonds issued in hard currencies exhibit lower yields compared to those in local currencies. The adjusted  $R^2$  is 0.423, indicating a moderate explanatory power of the model. Finally, for *LG vs. HG*, the Currency Dummy

coefficient ( $-0.241$ ) is marginally insignificant ( $p = 0.156$ ). This result weakly suggests the presence of a currency premium among Green Bonds, although the evidence is not conclusive. The adjusted  $R^2$  of 0.826 demonstrates strong explanatory power, primarily influenced by coupon and maturity type. To investigate whether Green Bonds mitigate the currency premium, the coefficients for the Currency Dummy from the OLS Regressions comparing Local and Hard Currency Bonds for Green and non-Green Bonds (*LNG vs. HNG* and *LG vs. HG*) are compared (see Table 10). For conventional bonds (*LNG vs. HNG*), the coefficient for the Currency Dummy is statistically significant and negative ( $-0.278, p < 0.01$ ), indicating a substantial currency premium for bonds issued in hard currencies. This implies that investors demand higher yields for conventional bonds issued in hard currencies compared to local currencies. For Green Bonds (*LG vs. HG*), the coefficient for the Currency Dummy is less negative ( $-0.241$ ) and not statistically significant at conventional levels. This suggests that the currency premium is smaller for Green Bonds compared to conventional bonds, aligning with the hypothesis that Green Bonds mitigate currency risk. The comparison of these coefficients ( $-0.278$  for conventional bonds versus  $-0.241$  for green bonds) supports the view that Green Bonds reduce the currency premium. However, the lack of statistical significance in the Green Bond regression may reflect the smaller sample size for Green Bonds, calling for cautious interpretation.

Table 10: Currency Premium Comparison for Green and Non-Green Bonds

Model	LNG vs. HNG (Non-Green)	LG vs. HG (Green)	Difference
<b>OLS Regression</b>	-0.278***	-0.241	0.037
<b>Quantile 0.25</b>	-0.071***	-0.247	-0.176
<b>Quantile 0.50</b>	-0.101***	-0.550***	-0.449
<b>Quantile 0.75</b>	-0.010	-0.472***	-0.462

**Notes:** The coefficients represent the Currency Dummy from the regressions. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The difference reflects the relative size of the currency premium for Green versus non-Green Bonds.

### 3.6.2 Quantile Regression

The Quantile Regression results highlight variations in the Greenium and currency premium across different points in the yield distribution (see Table 11). For *LNG vs. LG*, the ESG Dummy is consistently insignificant across all quantiles ( $p > 0.05$ ), indicating no evidence of a Greenium at any point in the yield distribution. For *HNG vs. HG*, the ESG Dummy is also insignificant across all quantiles, reinforcing the conclusion that a Greenium is absent within Hard Currency Bonds. For *LNG vs. HNG*, the Currency Dummy is highly significant at the 25th and 50th quantiles ( $p < 0.001$ ), confirming the presence of a currency premium for bonds with lower to median yields. However, the coefficient becomes insignificant at the 75th quantile, suggesting that the currency premium diminishes for higher-yielding bonds. For *LG vs. HG*, the Currency Dummy is significant at the 50th quantile ( $p < 0.001$ ) but insignificant at the 25th and 75th quantiles. This implies that the currency premium for Green Bonds is most pronounced for bonds with median yields, while it becomes less relevant at the extremes of the yield distribution. A comparison of the Currency Dummy coefficients in the Quantile Regressions further explores how the currency premium varies for Green and non-Green Bonds across different parts of the yield distribution. For conventional bonds (*LNG vs. HNG*), the Currency Dummy is statistically significant for most and negative across all quantiles ( $Q_{0.25} = -0.071, Q_{0.50} = -0.101, Q_{0.75} = -0.010$ ). This indicates a persistent currency premium, with the magnitude of the premium decreasing at higher quantiles. For Green Bonds (*LG vs. HG*), the Currency Dummy is also negative but smaller in magnitude ( $Q_{0.25} = -0.247, Q_{0.50} = -0.550, Q_{0.75} = -0.472$ ). The coefficients at the median and upper quantiles show heightened currency premiums for Green Bonds, though the premium remains less pronounced than that observed for conventional bonds at higher quantiles. These results suggest that Green Bonds generally reduce the currency premium, particularly at lower

Table 11: Bucket-Specific OLS and Quantile Regression Results

Variable	Local, Non-Green vs. Local Green Bond (LNG vs. LG)				Hard, Non-Green vs. Hard Green Bond (HNG vs. HG)			
	OLS	Q(0.25)	Q(0.50)	Q(0.75)	OLS	Q(0.25)	Q(0.50)	Q(0.75)
Constant	1.567***	1.533***	1.600***	1.741***	1.272***	1.106***	1.209***	1.536***
ESG Dummy	0.042	0.001	0.000	0.003	-0.046	-0.069	-0.053	0.000
Log(Time to Maturity)	0.001	0.066***	0.040***	0.010***	0.017	0.027	0.003	0.017
Maturity Type Dummy	0.057**	0.003	0.005	0.008**	-0.014	-0.042	-0.033	-0.058
Coupon Dummy	-0.499***	-0.008	-0.083***	-0.262***	-0.219*	-0.205*	-0.198*	-0.295*
Liquidity Dummy	0.068**	0.006	0.010**	0.018***	0.462***	0.470***	0.430***	0.636***
Coupon	0.096***	0.064***	0.071***	0.077***	0.132***	0.140***	0.150***	0.113***
Rating Dummy (0 = Rated, 1 = Not Rated)	0.207**	0.027**	0.034**	0.076**	-0.374***	-0.433***	-0.450***	-0.522***
Observations	1189	1189	1189	1189	260	260	260	260
Pseudo $R^2$ (Quantile)		0.382	0.287	0.223		0.492	0.388	0.473
Adjusted $R^2$ (OLS)	0.255				0.665			
Variable	Local, Non-Green vs. Hard, Non-Green Bond (LNG vs. HNG)				Local Green vs. Hard Green Bond (LG vs. HG)			
Variable	OLS	Q(0.25)	Q(0.50)	Q(0.75)	OLS	Q(0.25)	Q(0.50)	Q(0.75)
Constant	1.649***	1.409***	1.592***	1.646***	1.545***	1.401***	2.142***	2.138***
Currency Dummy	-0.278***	-0.071***	-0.101***	-0.010	-0.241	-0.247	-0.550***	-0.472***
Log(Time to Maturity)	0.009	0.061***	0.047***	0.012***	-0.012	-0.017	-0.017	-0.031*
Maturity Type Dummy	0.039	-0.003	0.000	0.000	0.152***	0.072**	0.071***	0.064***
Coupon Dummy	-0.511***	-0.022***	-0.087***	-0.298***	-0.190	-0.109	-0.270***	-0.420***
Liquidity Dummy	0.089***	0.012***	0.009***	0.013***	-0.035	-0.003	-0.003	0.017
Coupon	0.073***	0.073***	0.074***	0.089***	0.101***	0.116***	0.064***	0.064***
Rating Dummy (0 = Rated, 1 = Not Rated)	0.027	0.088***	0.001	0.083***	-0.032	-0.114***	-0.175***	0.006
Observations	1364	1364	1364	1364	85	85	85	85
Pseudo $R^2$ (Quantile)		0.546	0.405	0.291		0.698	0.641	0.6013
Adjusted $R^2$ (OLS)	0.423				0.826			

Notes: The dependent variable is the log-transformed Yield to Maturity. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Standard errors are robust to heteroskedasticity.

quantiles of the yield distribution. However, at higher quantiles, the differences between Green and conventional bonds narrow, indicating that the mitigation effect of Green Bonds on currency risk may be more substantial for lower-yielding bonds.

## **Chapter 4 Discussion**

The findings of this study highlight key dynamics in the African Green Bond market, focusing on Greenium, the currency premium, and the potential for Green Bonds to mitigate currency risks. These results must be understood within the broader African financial environment and insights from key stakeholders, like the DZ Bank and the DBSA (Appendix A.1 and Appendix A.2). This discussion evaluates the empirical analysis alongside these perspectives, emphasizing structural challenges and proposing actionable insights for DZ Bank's engagement in this emerging market.

### **4.1 Hypothesis 1: Greenium in the African Bond Market**

The analysis provided no evidence of Greenium in the African Green Bond market. Both OLS and Quantile Regressions showed insignificant ESG dummy coefficients, indicating that Green Bonds do not consistently offer lower yields than conventional bonds. This aligns with existing literature, which highlights difficulties in achieving pricing advantages due to default risks, illiquidity, and limited investor confidence (Kodongo et al. 2023; MacAskill et al. 2020). The DBSA endorses this finding, emphasizing that default risk remains a significant barrier for African bonds (Appendix A.2).

Craig Bezuidenhout from DBSA noted that perceived default risk dominates investor decisions, reducing the possibility of Greenium in markets with sub-investment-grade ratings (Appendix A.2). Without de-risking measures or improved transparency, attracting sustainability-focused investors will remain a challenge. While DZ Bank's advisory efforts, highlighted by Tim Buchholz (Appendix A.1), are a strong first step, the DBSA emphasized that advisory roles

alone cannot overcome systemic barriers. DZ Bank must complement its services with direct participation, such as acting as an anchor investor or providing co-financing. This could address liquidity constraints, enhance investor trust, and pave the way for achieving Greenium.

#### **4.2 Hypothesis 2: Currency Premium in the African Bond Market**

The empirical results confirm a currency premium, with Hard Currency Bonds showing significantly lower yields than Local Currency Bonds. This aligns with literature attributing higher local currency yields to exchange rate volatility and illiquidity premiums (Ivashkovskaya & Mikhaylova 2020; Jain 2023). The DBSA further emphasized that hard currency issuances are preferred by international investors to minimize currency risks (Appendix A.2).

However, over-reliance on Hard Currency Bonds poses challenges. As Craig Bezuidenhout noted, many African issuers, such as municipalities and state-owned enterprises, are required to issue in local currencies to align debt with domestic revenues (Appendix A.2). Despite their appeal to international investors, Hard Currency Bonds remain limited by African issuers' regulatory and financial constraints in managing foreign currency risks revenues (Appendix A.2).

For DZ Bank, these findings highlight the importance of balancing support for hard currency issuances with addressing risks associated with Local Currency Bonds. By leveraging its expertise, DZ Bank could structure tools like currency swaps or partial credit guarantees to mitigate investor risks while helping African issuers align debt more closely with local revenue streams. Supporting currency diversification strategies could also enable sustainable financing solutions that attract both local and international investors.

#### **4.3 Hypothesis 3: Interaction Between Greenium and Currency Premium**

The hypothesis that Green Bonds mitigate the currency premium found limited support. While OLS Regressions with interaction terms showed marginal significance, Quantile Regressions

indicated that this effect is most pronounced at the lower end of the yield distribution. This suggests that Green Bonds may reduce the currency premium for lower-risk or higher-quality issuers, but the effect is inconsistent.

The DBSA interview contextualized this finding, emphasizing that default risk and market illiquidity remain major barriers for both green and conventional bonds in Africa (Appendix A.2). Without addressing these structural issues, Green Bonds have limited potential to offset currency risks. Tim Buchholz (Appendix A.1) noted that while DZ Bank’s role in structuring Green Bonds to international standards is critical, active risk-sharing measures are essential to enhance market credibility.

By taking initial positions in Green Bond issuances or collaborating with multilateral institutions to share risks, DZ Bank could attract a more diversified investor base. This would help mitigate currency premiums while addressing the broader challenges constraining Africa’s Green Bond market.

**4.4 Addressing Market Needs: Recommendations for DZ Bank**

The African Green Bond market presents both challenges and opportunities. The empirical findings, combined with the insights from DBSA and DZ Bank, highlight several areas where DZ Bank could play a transformative role (see Table 12).

*Table 12: Recommendations for DZ Bank*

<b>Beyond Advisory Services</b>	While DZ Bank has excelled in providing advisory support (Appendix A.1), the DBSA interview (Appendix A.2) stressed the importance of moving beyond advice to direct involvement. Acting as an anchor investor or taking balance sheet risk could significantly enhance market confidence and liquidity
<b>De-Risking the Market</b>	Default risk remains a major concern for African issuers. DZ Bank could collaborate with development finance institutions like the AfDB or the DBSA to provide partial credit guarantees or co-financing arrangements. These measures would address investor concerns and enable issuers to tap into broader pools of capital
<b>Capacity Building</b>	Partnering with issuers to enhance governance, reporting standards, and project transparency would align African Green Bonds with international expectations. This, in turn, could attract sustainability-conscious investors and lay the groundwork for achieving Greenium in the future

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**Regulatory  
Support**

DZ Bank could play a critical role in advocating for harmonized regulatory frameworks across African markets. Providing technical assistance to issuers and regulators could reduce the barriers for smaller entities and first-time issuers to enter the market. The African Green Bond market holds immense potential for bridging the continent's climate finance gap, but structural challenges such as default risk, illiquidity, and currency mismatches must be addressed to unlock this potential. DZ Bank is uniquely positioned to drive progress in this market, but doing so will require a shift from a purely advisory role to active participation in risk-sharing and investment. By combining its technical expertise with strategic investments and partnerships, DZ Bank can play a key role in scaling sustainable finance in Africa while addressing the market's most pressing needs

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## Chapter 5 Conclusion

This thesis explored the role of currency denomination in the African Green Bond market, focusing on yield differentials and the potential for Greenium. Through a combination of empirical analysis, an extensive literature review, and qualitative insights from key stakeholders, including the DBSA and DZ Bank (Appendices A.1 and A.2), the study provides actionable recommendations for advancing sustainable finance in Africa. The findings revealed no significant evidence of Greenium in the African Bond Market, consistent with existing studies that emphasize the challenges posed by heightened default risks, illiquidity, and limited investor confidence in emerging markets (Ivashkovskaya & Mikhaylova 2020; Jain 2023; Tyson 2021). As highlighted by the DBSA, credit risk remains a dominant concern for investors, overshadowing the potential benefits of Green Bonds (Appendix A.2). Achieving Greenium will require addressing these fundamental barriers, with a focus on improving market transparency, certification standards, and liquidity (Cortellini & Panetta 2021; Fatica et al. 2021; MacAskill et al. 2020). Conversely, the analysis confirmed the presence of a robust currency premium, with Hard Currency Bonds consistently yielding lower rates compared to Local Currency Bonds. While Hard Currency Bonds are preferred by international investors for their reduced exchange rate risks, this reliance can exacerbate debt burdens for African issuers during periods of local currency depreciation, as noted by the DBSA (Appendix A.2) and Pilling et al., 2023. Local Currency Bonds, although better aligned with issuer revenue streams, face

persistent challenges, including higher yields and limited liquidity (Jain 2023; Tyson 2021). These findings highlight the need for a tailored approach that balances these trade-offs while addressing issuer-specific objectives, such as sustainability signaling or financing cost optimization. For DZ Bank, the insights from this thesis underscore the importance of offering targeted advice on currency considerations while supporting broader structural reforms. The interaction between Greenium and currency premium demonstrated only limited mitigation effects, reinforcing the need for more in-depth research on how default risk, market maturity, and investor behavior intersect with currency dynamics. Additionally, the limitations of the study, including the small dataset reflective of the nascent stage of Africa's Green Bond market, point to the value of continued research to refine these findings. Engaging with more deeply involved institutions could provide better insights into local market dynamics and help address data constraints. Furthermore, as emphasized by the DBSA (Appendix A.2), DZ Bank's role should ideally extend beyond advisory services to include taking some balance sheet risks, such as acting as an anchor investor, to signal market confidence and attract broader participation. In conclusion, scaling green finance in Africa requires a collaborative effort across stakeholders to address currency-related risks and structural inefficiencies. For DZ Bank, aligning its technical expertise with a nuanced understanding of currency dynamics can help position the bank as a transformative partner in the African Green Bond market, ultimately supporting both the continent's sustainable development and global climate goals.

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## **A.1 Interview with Tim Buchholz, DZ Bank**

**Date of Interview:** October 28, 2024

**Interviewee:** Tim Buchholz, Senior ESG Originator, DZ Bank

**Interviewer:** Rebecca Bianca Meyerhoff

**Rebecca Meyerhoff:** Could you please introduce yourself? What is your role at DZ Bank?

**Tim Buchholz:** My name is Tim Buchholz, and I joined DZ BANK in April 2022 as Senior ESG Originator within the Capital Markets unit. In my role, I am advising our corporate clients with regards to all aspects of Sustainable Finance, with a focus on integrating sustainability in the debt finance structure. As part of my role, I am also structuring Green, Social or Sustainability Bonds or Loans. Before I joined DZ BANK, I worked for SMBC and Commerzbank in Frankfurt.

**Rebecca Meyerhoff:** What motivated DZ Bank to collaborate on this thesis, and what are the key outcomes or insights DZ Bank hopes to gain from it?

**Tim Buchholz:** There are two aspects when it comes to motivation. First of all, as Germany's second largest bank, DZ BANK has a responsibility to support young talents, which we take very serious. We want to support young professionals at very early stages of their career to provide them with the tools they need for their education and career choices. The second motivation is related to sustainability and can also be divided into two aspects. First of all, sustainability is an important topics for us as a bank. We want to be aligned with the 1.5° degrees target of the Paris Agreement. In order to do so, we need more people educated about sustainability. In addition, the scientific research about sustainable finance – the market dynamics, intended and unintended incentives within the market, the targeted and achieved impact, and the

drivers of the market are fields where more research is needed in order to understand the complex nature of this topic. We hence support scientific work, and hope that we can derive actions from the outcomes, or gain new ideas that we can use for innovations or business initiatives.

**Rebecca Meyerhoff:** How does DZ Bank currently collaborate with institutions like AfDB, DBSA, and other partners to support Green Bond issuance in Africa?

**Tim Buchholz:** As DZ BANK, our core business partners are usually located in Western Europe, especially in the German speaking part. Our credit exposure is focused on this area. For specific project finance business, we also have exposure to developing or emerging markets, but usually our main client relationships are more locally. However, we have dialogues and business relationships with African institutions as well, like the AfDB, DBSA, or other public sector issuers like the State Treasury of South Africa, Namibia, or more local treasuries like Cape Town. Here, we provide guidance and best practice cases from Europe when it comes to the structure of Green or Social Bond framework, implementations from regulations, and investor behaviour.

**Rebecca Meyerhoff:** What is DZ Bank's motivation for potentially increasing its support for Green Bond issuance in Africa?

**Tim Buchholz:** First of all, we as DZ BANK are a huge supporter of Sustainable Finance. We were the first German bank that became part of the Executive Committee of the Principles, which administer the Green and Social Bond Principles and are at the forefront of the market. We are active in a number of initiative and promote the significance and importance of the topic wherever we can. Secondly, it is also a chance for us as a bank to differentiate from competitors. In a highly homogenous

market, Sustainable Finance is an area where banks can differentiate from others and gain competitive advantages. As a bank without a big credit exposure in Africa, Sustainable Finance advisory offers new business opportunities in Africa without partner on the ground that we wouldn't have had access to without this topic.

**Rebecca Meyerhoff:** How does involvement in emerging markets like Africa align with DZ Bank's business goals and commitment to global ESG principles?

**Tim Buchholz:** The answer is similar to the question before. First of all, we need to transform economies globally. Climate change is not a local problem and can only be solved on a global scale. On the other hand, Africa has a huge economic potential. In order to leverage this potential, a lot of investments are needed, which should be sustainable at best. And what is also not a secret: the industrialized world has benefitted from a huge growth over the last centuries which came with the cost of high CO2 emissions. Regions like Africa, that would like to experience the same growth, need to take into account CO2 emissions, which makes it even more difficult for them to lever their full potential. On the other hand, the regions offers a lot of potential for renewables, where we as a bank can also support with funding. It is hence key that Africa received sufficient fund to transform to a climate neutral continent, experience economic growth – which also could slow down refugee flows as people do not have an incentive leave their home country anymore – at an affordable price while also being aligned with human rights. As DZ BANK is committed to the UN SDGs as well, we aim to achieve this target on the continent, as these universal goals are part of our strategy.

**Rebecca Meyerhoff:** What unique strengths does DZ Bank bring to the Green Bond market, especially in structuring bonds that attract investor interest?

**Tim Buchholz:** As mentioned before, we were the first German bank that is part of the ExCom of the Principles. We are furthermore the second largest German bank with a strong fundament and strong ties to politics, stakeholders and regulators. We are a universal bank and offer all products along the value chain, and are present in a lot of international regions as well – be it Asia with Singapore and Hong Kong, or the Americas or Europe. To make a long story short: we can provide a lot of guidance and insights from international and European capital markets, but also best practices from smaller or medium sized companies from Germany and how they handled challenges with regards to Sustainable Finance. In addition, our asset manager Union Investment is one of the largest sustainable investors in Europe. Hence we are able to structure Green Bonds in a way that they meet highest market standards and satisfy even the highest demanding sustainable investors. This way, we can assure issuers that the Green debt we structure is credible, impactful, and meeting the highest level of quality.

**Rebecca Meyerhoff:** What are the main challenges DZ Bank encounters when working on Green Bond issuances in emerging markets like Africa and how can the knowledge of the Asian Market get translated to the African Market?

**Tim Buchholz:** As mentioned before, we are particularly strong in Germany, and our main credit exposures are in this area. In addition, we are focused on the Euro currency and do not have sufficient infrastructure for other currencies. While Euro funding play a role in Africa, other currencies are major drivers as well. It is hence challenging to overcome the phase of having just a dialogue with the client that really translates into actual business transactions. However, as we can see from our experience in Africa, Sustainable and Green Finance offers a lot of potential from the Advisory area, where banks can add value and initiate business relationships without

established a formal credit relationship. Especially in Asia, we were quite active in initiating dialogues with stakeholders and issuers on the ground, as well as advising clients in the region. Having said that, we have branches in Asia that we do not have in Africa yet, and a lot of our German clients have subsidiaries in Asia, which makes it easier for us to hold a dialogue with these entities than it would be with pure local player. In Africa, the number of German entities or subsidiaries is significantly lower.

**Rebecca Meyerhoff:** How do these challenges differ from challenges in developed markets?

**Tim Buchholz:** Especially in Europe, regulation is often not fragmented, which makes it easier for us to navigate. Political risks are low, and the operational infrastructure for the main currencies is set up. It is always easier for a bank to do business in the home region, independent of whether it is an emerging or developed market. For us, the main understanding of the market, the dynamics, the assessment of the credit and political risks, are one of the main challenges. In addition, sometimes the lack of knowledge about specific local products and requirements is also a burden. In addition, we very often see regulations or other barriers that are aimed to protect the local market, but make it more difficult for foreign players to enter the market.

**Rebecca Meyerhoff:** What role does DZ Bank envision for itself in fostering sustainable finance growth in Africa?

**Tim Buchholz:** We clearly want to position within the sustainable finance advisory niche. It will be difficult or even impossible for us to establish the typical credit relationships with clients on the ground. But we can keep up regular dialogues about sustainable finance, and offer advise on the structure of sustainable debt, in exchange for fees. We can also use this relationship for upcoming EUR issuance of African

issuer, while this will remain a scarce opportunity.

**Rebecca Meyerhoff:** Perfect, thank you those are all the questions.

## **A.2 Interview with Craig Bezuidenhout, DBSA**

**Date of Interview:** December 12, 2024

**Interviewee:** Craig Bezuidenhout, Principal Funding Desk, DBSA & Muhammed Sayed, Specialist Climate and Environment Finance Unit, DBSA

**Interviewer:** Rebecca Bianca Meyerhoff

**Rebecca Meyerhoff:** I would just briefly start with my interview questions that I have. So the first question would be, could you briefly introduce yourself and your role with the within the DBSA?

**Craig Bezuidenhout:** Sure. I'll start so my name is Craig Bezuidenhout, I am a principal on the funding desk in the treasury unit. So effectively we look after all bilateral funding, syndicated loans, private placements, as well as all our green and sustainability ones and finance. So we were instrumental in working with the ESG units, putting together first Green Bond framework, which is putting together 2020 21 we did our first Green Bond issues on the back of that, a private placement with the European DFR post that in the same year, in 21 we then did a second Green Bond with The American Asset Manager, which was a RAND bond, which was rather, rather unusual for American asset manager, and that was the three year bond, which we've just repaid that bond now. So I mean, really, that's, that's our experience, at least on Green Bonds. We've only got two Green Bonds, or no one repaid both with private placements. We've been going through public markets for various reasons. At the time, public markets, especially for DBSA and other local entities, during that COVID, post COVID period, were pretty much still closed for a large extent. So these we could control pricing through private placements. We currently in the final throws, are getting our second party opinion on my sustainable finance framework, while not

really replacing the Green Bond, it will become this sort of new framework in which all future assurances are done, whether it's Green Bonds or sustainable finance, but kind of the lot broader sectors more in line with the bank, the bank's mandate. So social sector, transport, obviously green being renewable energy and the like and clean energy. So it's a lot broader in terms of allocation and under that framework itself. So we expect to potentially do our first issuance, hopefully quarter 225, so that's briefly what I do in terms of liquidity and fundraising.

**Rebecca Meyerhoff:** Thank you so much. Okay, perfect Muhammed, do you also want to introduce yourself, or do you want me to continue?

**Muhammed Sayed:** Yes, maybe just briefly, I guess while I was on the call. So I guess your focus is more on Green Bonds, but maybe as a matter of interest, we the bank also tries to mobilize climate finance mechanisms, predominantly, you know, your UNFCCC mechanisms, including your clean Climate Fund, as well as your global environment facilities. So my role within the Climate and Environment Facility, or sorry, unit within DBSA, is we kind of, you know, manage the accreditation process with with both those funds, as well as assisting in mobilizing climate finance from this mechanism. So we work closely with various teams within the bank as well as project sponsors in terms of designing programs or facilities, and in some cases, projects where we can access funds from these mechanisms. And then we also, in the green space, manage a local fund called the Green Fund where, you know, we offer a range a suite of instruments at different stages of development to help with South Africa's transition in the green economy. So it's more catalytic pilot scale type of projects. But on the GPF and the Global Environment Facility, we try and focus more on designing programs or facilities such as a climate finance facility or a program focusing on a better generation. Where we try and support both mitigation

and adaptation projects. On the adaptation side, you've got a new water reuse program which is co-funded by or funded by the Green Climate Fund. So that's what we do. On the climate finance side, where we mobilize these mechanisms and obviously working very closely with with with Craig on the Treasury side in terms of seeing how those funds flow to TBSA, whether it's in a form of a credit line or other mechanisms. So we definitely try and, you know, bring in the various teams within the bank in order to see how best those funds flow to TBSA. So it's a combination of concessional finance from GCF as well as grant funding, in some cases, to help with project preparation and other technical assistance that is required. Thank you.

**Rebecca Meyerhoff:** Okay, perfect. Thank you so much. And can you give me also like quick insights on the DBSAs current involvement in the Green Bond market, and what like the key objectives and in issuing and supporting Green Bonds are.

**Craig Bezuidenhout:** Sorry? Rebecca, just repeat the question.

**Rebecca Meyerhoff:** Could you give me insights in the current involvement of the of the DBSA and African Green Bond market, and what the key objectives in issuing and supporting Green Bonds are.

**Craig Bezuidenhout:** Well, I mean, we, we obviously led into the African market. So the DBSA mandate extends beyond South Africa, including Southern Africa, and the Act was amended our founding document back in 2014 to include lending into specific countries in the rest of Africa. So we have got a fair amount of exposure West Africa, East Africa, in terms of lending. But we don't issue Green Bonds into the African continent. Like I said, the Green Bonds we've done was the there was the Euro one and ZAR one, we haven't issued Green Bonds locally. You would, if I'm sure you might be speaking to a lot of the local banks, net bank and Standard Bank are

big issuers in terms of their Green Bonds that, after I've seen at least, that's been announced, but DBSA itself doesn't. We haven't issued bonds. I mean, I can't think of a particular market Africa, we would issue a Green Bond in terms of liquidity and pricing. There wouldn't be any markets attractive at this stage, outside of South Africa and, yeah, and outside of Africa, I guess.

**Rebecca Meyerhoff:** Okay, perfect. Yeah. That also brings me to the next question about like, how would you describe the development of the African Green Bond market over the past decade, maybe like also focusing on South Africa, but also on the overall Green Bond market?

**Craig Bezuidenhout:** I mean, outside of what I've seen in South Africa, I haven't seen, at least in terms of announcements debt wise and bank issuances and the like. I haven't seen many Green Bond issuances itself. It's, it's far behind, say, Europe, where the Green Bonds been established, like you said, Since 2012 I've seen recently, I think it's knowing that even their Green Bonds are sort of tapering off in terms of attractiveness and concerns around greenwashing, concerns around premiums that you're paying versus a conventional bond. No one's really seeing pricing benefits, they never have. From our side, Green Bonds, if we issuing it, we know we're not going to get a pricing benefit. It becomes more of showing your commitment towards various initiatives from a transition perspective, sort of aligning your ... trying to diversify some of your funding resources to different sort of sustainable finance. So the that would be more the motivation in terms of SOEs, other SOEs, I think it was rainwater, did some sort of sustainable bond in 22 or 21 where there were sorts of certain targets to which they agreed to on their pricing supplements in terms of water reduction and those likes but green ones itself. No, I haven't seen Africa issuers, not that ... I mean there probably are, but I'm just not aware of the least amount of I've

seen. Yeah, so I think your research, and that's going to be fairly small sample size.

**Rebecca Meyerhoff:** Yeah, that's true. And what do you think are the main barriers to the growth in the Green Bond African market.

**Craig Bezuidenhout:** So look at Africa credit risk at the end of the day. We spoke to many investors, even during the dark times of COVID where the capital markets shut down at the end of the day, whether it's a Green Bond, blue bond, whatever bond you call it, still a bond. There's still credit risk, and you can't get away from the underlying credit risk of the issue. So if you're trying to package the Green Bond thinking and they attract more investors, but your credit risk remains the fundamental concern for all of these guys you're not going to come right. So yeah, I mean COVID risk, and really, as an S&P have been quite punitive towards Africa issuers, and especially we had quite a few downgrades between 2021 and 2022 we had about two or three downgrades from a sovereign perspective, those, I think S&P now put us on a positive outlook. But, yeah, I mean, I think that's the primary issue, is that your credit risk and issuers wanting to do that, and then the premium they'll charge. I mean, you've seen where the sovereign yields are for countries like Ghana and Senegal. They're really heavy units you're sitting at about 22% yields. I mean, no, no government can issue under those sort of conditions.

**Rebecca Meyerhoff:** That makes sense. Could you also give me a little more insights on the investor appetite for African Green Bonds, for domestic and also international investors?

**Craig Bezuidenhout:** So I can talk about local investors. Now, remember South Africa, whilst the Liquidity Markets are what they always call it deep capital markets, which they are. There's a lot of brand liquidity, but, sorry, a lot of brand liquidity

there. But the number of large institutional asset managers compared to, say, Europe, is a lot smaller, to much smaller sort of pool. You talking maybe 10 asset managers control majority of the sort of fixed income market, whereas in Europe, you've got dedicated asset managers focusing on, say, green or sustainable finance that would be purchasing your sort of paper like that. So I think that's the one difference. Is that is the size of the sort of institutional market. Just so whilst it is deep in terms of liquidity, the variation in terms of number of asset managers is not that large, so and at the end of the day, these guys always be looking at your credit risk as a first port of call before even looking at the instrument duration underneath it. And like I said, we haven't seen much in terms of the Greenium or compression and spreads because of the instruments you may be talking 10-15 bps, at most, from what I've seen here.

**Rebecca Meyerhoff:** Perfect, thank you. And how, in your experience, does the currency of the issuance, like local and hard currency, influence the investor demand for the African Green Bonds?

**Craig Bezuidenhout:** Again, I can, I can't talk about Africa, I can talk for DBSA so for us, like said, we've issued a euro and a zar. But I mean, most likely, the chance of issuing a Green Bond, again in euros or dollars, is probably strong, especially we're going to be doing a Euro bond issuance in the next two years. We probably would do a green tranche, primarily because there's a larger pool of institutional investors outside of SA, and some of them might be more bullish. So I think that might be the one reason other the JC or the journals Book Stock Exchange locally has got a strong focus on trying to grow the Green Bond market as well. So if you want to, I can give you a name of one of the JSE people here locally, you could talk to, and they could probably give you a lot of insight into your research. I don't know if you've spoken to anyone at desktop exchange locally. Well, they probably would be your deepest pool

of information that you could extract. So I'll post this call, I'll send you a name, and I'll see if I can find an email for them as well.

**Rebecca Meyerhoff:** Perfect, thank you so much. And could you maybe also, like, give me some more insights on what the advantages for issuing in a local currency and issuing in a hard currency are, and what the drawbacks are, if, like, not for the Green Bond market, also maybe in general, but like, preferably on the Green Bond market.

**Craig Bezuidenhout:** Well, obviously local currency issuance has always been your first price. Likely for institutions like you, just say we got dollar book. We got a Euro book on the loan side, and we got a rand book. So obviously Rand was the largest constitutes the largest portion. So we tried to sort of natural hedge with between our liabilities and our assets as far as possible. So where we there's a requirement in dollars, we would normally then rate dollar liabilities, whether it's a bond or Green Bond, or bilateral loan or syndicate loan, whatever the case would be, we would do that strike keep the natural hedge in place instead of swapping between currencies. So but for instance, for local it's all institutional issues that don't have dollar book, say corporates, they probably local currency would always be a preferred outcome in terms of currency risk. In fact, a lot of the SOEs, standard enterprises here, locally and municipalities or metros the cities, they cannot actually issue of foreign currency bonds. They're sort of prohibited by the local laws and regulations. They have to keep it local.

**Rebecca Meyerhoff:** Okay, that's good to know. And can you also give me more insights on how the liquidity risk impacts the investor interest in a Green Bond market, in the African Green Book market, and also on the secondary market, because doing my research, I like looked at the yields and they were like, really wide.

**Craig Bezuidenhout:** You mean between the different countries?

**Rebecca Meyerhoff:** Yeah, the yield spread was really wide.

**Craig Bezuidenhout:** I mean, absolutely, if you're looking at depending whether you really got to find the right investors. So for investor wants to put buy and hold that instead of trying to offload it in the secondary market, that makes a big difference where they can invest in us. So we chose investors that were other asset managers that were interested in holding as well as well as the DFI's. I mean, they're doing it for more the impact, rather than trying to sell it off and on the secondary market. Because, I mean, let's be honest, like a DBSA paper secondary market there, there wouldn't be much liquidity there, even our local bonds, we don't, they wouldn't, don't have a big repo book in terms of buying and selling back some of our paper, not like, say, the commercial banks, where they've got active desks doing that. So liquidity would certainly play a role. But I maintain it credit risk. Credit ratings is your is your biggest issue with local issues, because you do get penalized in terms of premium. You get penalized in terms of a new issue premium as well. If you're doing it for the first time, especially if you're looking at the Euro bond market, they do penalize in some extent. And you they always going to look at, doesn't matter, the sort of fundamentals your business, they're going to look at where sovereigns issuing, and obviously add a spread differential on top of that, regardless of your individual credit risk goes the use of captured sovereign ceiling at that pace.

**Rebecca Meyerhoff:** Perfect. Thank you. And you already gave me a lot of insight on this, but maybe like too comprehend it. Do you think like Green Bond issued in local currencies are more likely to stay in the domestic market, while the Hard Currency Bonds appear to the broader global investor base?

**Craig Bezuidenhout:** I can say, we are seeing a more interest in Green Bonds, but I think it's more than that, sustainable bonds. I mean, you'll see ICMA's now more focusing on sustainable finances, the starting of as green now is sustainable, which, like I said, captures green as well. But you know, there is certainly interest that we even are still on the provident fund for the DBSA. And I see even within the fund itself, the underlying institutional asset managers managing our funds, there is a drive towards being more exclusively, looking at focusing on in sustainable funding, looking at ESG type elements on your your funding initiatives and your investments as well. So there certainly is a shift where, ... but I mean that the type of issues are sort of limited currently. But I mean, I probably will see a broader pool of these issues coming to the fore, beyond just the sort of four big banks in South Africa. We certainly are looking at becoming a more regular issue and new sustainable finance framework, so hopefully we'll get traction on that in the next sort of year.

**Rebecca Meyerhoff:** Perfect. Thank you. And more broadly speaking, what do you think might be the role Green Bonds can play in advancing the Africa's agenda 2063 and in achieving the SDG targets?

**Craig Bezuidenhout:** You mean like the DZ bank?

**Rebecca Meyerhoff:** No, in general, the Green Bonds, like, how can they help to achieve the Africa's agenda?

**Craig Bezuidenhout:** Remember, the bond is just a funding instrument. So the biggest issue with Green Bonds is projects and that always comes back to the fact that in Africa specifically, there's no shortage of liquidity and people wanting to fund projects. It's there's lots of liquidity globally and even locally, but the problem is finding bankable projects on which to issue your your Green Bonds against. So that

pipeline of green, green projects is your, your biggest hindrance in terms of getting bankable projects of the ground and trying to find those projects in which you can issue your use of proceeds bonds, like a Green Bond, because obviously you need green projects behind those, those bonds in which to ring fence your funding, and that's always been the sort of biggest impediment on Green Bond issuances is the lack project, specifically in South Africa. We've got the REAP program, the independent renewable energy program. I think they're sitting around six and seven now. We've got embedded generation program, which is looking at sort of corporate trying, bring and reduce their own sort of energy on board with embedded generation itself, we've got battery energy storage as well as another so there are different programs in place. But I mean, with the projects themselves, are still they're not numerous. Especially in the continent, we haven't seen multiple green projects cross border. Rest of Africa. Obviously the need is there African Development Bank. I think you're speaking to them as well, driving the energy and lighting up Africa so but from what we've seen this side, I haven't seen multiple projects. The other projects is, where's the issue. It is bankable projects, which to issue a green funding against.

**Rebecca Meyerhoff:** Perfect thank you so much. And maybe to give like more future outlook, what do you think are the future trends to foresee in the African Green Bond market? And particularly, particularly regarding the currency choice?

**Craig Bezuidenhout:** Well, Africa issues always prefer local currency, but you see where rates on Local Currency Bonds or government treasury bonds, the rates are high. And again, there's liquidity issues in country like Zambia, Ghana, Tanzania, Ethiopia, you see a lot of them under the IMF sort of debt restructure program was Paris Club restructure, impacting a lot of investors as well as lenders. So I think until the situation improves from a credit risk rating, things start turning around there. I

don't think you're going to see many Green Bonds, never mind normal bonds coming to the market. So I think until the fundamentals start improving, unless these individual investors can find sort of credit rating agencies, not credit rating, sorry, credit reps, so you're getting lots of meager or African trade insurance, or afri ExIm or AFC, they can come in at a reasonable cost to credit rep the underlying issuance. Then perhaps you might see some some traction there. But again, those credit providers giving you the wrap, I can still be looking at the credit rating, and then charging you massive premiums behind that, I've seen premiums of nine to 10% for some some credit guarantees. Classic example is the World Bank one with Ghana, where they try to do a bond issuance with a pasture risk guarantee. And as it didn't really work out well for Ghana, and this was back in 2015 or 2014 so partial risk gap credit guarantees don't always work well in terms of what you're trying to achieve. But I mean, that's the only way I can find a reasonably priced credit provider to wrap these instruments for you. The issue is in on the African side, then you must start seeing some traction. I'm not sure anyone's willing to give those reps without charging excessive premiums again because of the credit rating. So you need to start speaking to Moody's, S&P and Fitch and seeing what can be done. Because, I mean, at the end of the day, the other one's providing these, these credit ratings for the issuers on the continent.

**Rebecca Meyerhoff:** Thank you. And what would advice would you give financial institutions like the desert bank, who are looking to enter, like the African Green Bond market, as an advisor or like a participant?

**Craig Bezuidenhout:** It's take balance sheet risk, so if you come in and start getting advanced, no one wins to just your advice. There's hundreds of people that can give you advice you're looking for people that will partner with you, put balance sheet against you, whether you're going to take off a tranche of a bond or first loss or

something along those lines. Are really too sort of proud and non invested. That's the way to do it. I think a lot of issues are tired of just hearing advice. They went ... we weren't partner with people. Just give us advice. We wouldn't partner with people that well, if we're doing a loan, we want you to take a tranche. If you're going to do a bond, sort of take up a position as well. Sort of to be an anchor investor. And that certainly helps grab them additional investors. And it's good to know that there's an anchor investor, especially if it's a new issuer. So those are sort of you need to sort of start taking balance sheet on these issues beyond just advice.

**Rebecca Meyerhoff:** Perfect. Thank you. Is there any additional information or like perspective you would believe is valuable for my thesis and that you would like to give me?

**Craig Bezuidenhout:** I think, speak to the JSE, they could provide some valuable advice. They've got a Green Bond focus, like I said, I'll find, try find the right email address for you, and then if you could reach out to them, and they might be able to assist and give you some more, more insightful insights of the South African Green Bond market coming from the exchange side. Yeah.

**Rebecca Meyerhoff:** Perfect. Thank you so much. That will be also all my questions.

### A.3 Overview of Regression Models

<b>Regression Type</b>	<b>Focus</b>	<b>Specification</b>
OLS Regression	Interaction Term	ESG Dummy, Currency Dummy, Interaction Term
Bucket-Specific OLS Regression	LNG vs. LG	ESG Dummy
	HNG vs. HG	ESG Dummy
	LNG vs. HNG	Currency Dummy
	LG vs. HG	Currency Dummy
Quantile Regression	Interaction Term	ESG Dummy, Currency Dummy, Interaction Term
Bucket-Specific Quantile Regression	LNG vs. LG	ESG Dummy
	HNG vs. HG	ESG Dummy
	LNG vs. HNG	Currency Dummy
	LG vs. HG	Currency Dummy

#### **A.4. Python Code for Empirical Analysis**

```
pip install pandas statsmodels matplotlib numpy

# Import essential libraries

import pandas as pd

import numpy as np

import statsmodels.api as sm

from sklearn.preprocessing import StandardScaler

from scipy.stats import zscore

from scipy.stats import skew

import matplotlib.pyplot as plt

from statsmodels.stats.outliers_influence import
variance_inflation_factor

# Step 1: LOAD DATA

# Load bond data from Excel file and verify its contents

df = pd.read_excel('/content/drive/MyDrive/Master Thesis/All
Bonds2.xlsx')

print("Dataset loaded successfully. First 5 rows:")

print(df.head())

# Step 2: INITIAL OLS REGRESSION

# Define the dependent and independent variables
```

```

X = df[['Currency Dummy', 'ESG Dummy', 'Mty Type Dummy', 'Time to
      Maturity (Years)', 'Coupon Dummy', 'Liquidity Dummy', 'Rating
      Dummy (0 = Rated, 1 = Not Rated)', 'Coupon']]

y = df['Yld to Mty (Mid)']

# Add a constant to the independent variables

X = sm.add_constant(X)

# Fit the OLS regression model

model = sm.OLS(y, X).fit()

# Print the summary of the regression model

print(model.summary())

# Step 3: OUTLIER REMOVAL BASED ON YIELD AND Z-SCORES

# Identify and Include the Yield Outliers Based on Threshold

threshold_yield = 0

yield_outliers = df[df['Yld to Mty (Mid)'] < threshold_yield].copy()

df_cleaned = df[df['Yld to Mty (Mid)'] >= threshold_yield].copy()

# Calculate Z-scores for Independent Variables

independent_vars = ['Time to Maturity (Years)', 'Coupon']

outlier_threshold = 3 # Z-score threshold for independent variables

for var in independent_vars:

    z_col_name = f'{var}_Z'

    df_cleaned[f'{z_col_name}'] = zscore(df_cleaned[var])

```

```

# Identify Outliers in Independent Variables

independent_outliers = df_cleaned[

    (df_cleaned[[f'{var}_Z' for var in independent_vars]] >
     outlier_threshold).any(axis=1) |

    (df_cleaned[[f'{var}_Z' for var in independent_vars]] < -
     outlier_threshold).any(axis=1)

]

# Combine Yield Outliers and Independent Variable Outliers for
Reporting

all_outliers =
pd.concat([yield_outliers,independent_outliers]).drop_duplicates()

# Print number of outliers and stats

print(f"Number of yield outliers: {len(yield_outliers)}")

print("Yield Outliers:\n", yield_outliers[['Yld to Mty (Mid)']])

print(f"\nNumber of independent variable outliers:
{len(independent_outliers)}")

print("Independent Variable Outliers:\n", independent_outliers[['Yld
to Mty (Mid)'] + independent_vars])

print(f"\nTotal unique outliers: {len(all_outliers)}")

print("All Outliers:\n", all_outliers[['Yld to Mty (Mid)'] +
independent_vars])

# Remove Rows with Outliers in Independent Variables

```

```

df_cleaned_final = df_cleaned[

    ~((df_cleaned[[f'{var}_Z' for var in independent_vars]] >
    outlier_threshold).any(axis=1) |

    (df_cleaned[[f'{var}_Z' for var in independent_vars]] < -
    outlier_threshold).any(axis=1))

].copy()

# Drop Z-score Columns as They Are No Longer Needed

df_cleaned_final = df_cleaned_final.drop(columns=[f'{var}_Z' for var
in independent_vars])

# Print final cleaned dataset stats

print(f"Final cleaned dataset contains {df_cleaned_final.shape[0]}
rows and {df_cleaned_final.shape[1]} columns.")

# Define Dependent and Independent Variables for OLS Regression

X = df_cleaned_final[['Currency Dummy', 'ESG Dummy', 'Mty Type
    Dummy', 'Time to Maturity (Years)', 'Coupon Dummy', 'Liquidity
    Dummy', 'Rating Dummy (0 = Rated, 1 = Not Rated)', 'Coupon']]

# Use yield as the dependent variable

y = df_cleaned_final['Yld to Mty (Mid)']

# Add a Constant to the Independent Variables

X = sm.add_constant(X)

# Fit the OLS Regression Model

model = sm.OLS(y, X).fit()

# Print the Summary of the Regression Model

```

```

print(model.summary())

# Step 4: CHECK SKEWNESS AND APPLY LOG TRANSFORMATION

# Define the variables for skewness testing
variables = ['Time to Maturity (Years)', 'Coupon']

# Calculate skewness for each variable and print the result
for var in variables:

    skewness_value = skew(df_cleaned[var])

    print(f"Skewness for {var}: {skewness_value:.2f}")

# Check if the skewness indicates a potential need for log
transformation

    if abs(skewness_value) > 1:

        print(f" {var} might require a log transformation
        (highly skewed).")

    elif 0.5 < abs(skewness_value) <= 1:

        print(f" {var} is moderately skewed.")

    else:

        print(f" {var} has low skewness.")

# Step 5: UPDATED OLS REGRESSION (CLEANED DATA AND LOG
TRANSFORMATION)

# Transform Time to Maturity Variables, as it has a high skewness

```

```

df_cleaned_final['Log_Time_to_Maturity'] =
np.loglp(df_cleaned_final['Time to Maturity (Years)'])

# Ensure there are no NaNs or infs in the independent variables

X = df_cleaned_final[['Currency Dummy', 'ESG Dummy', 'Mty Type
    Dummy', 'Log_Time_to_Maturity', 'Coupon Dummy', 'Liquidity
    Dummy', 'Rating Dummy (0 = Rated, 1 = Not Rated)', 'Coupon']]

X = sm.add_constant(X)

y = df_cleaned_final['Yld to Mty (Mid)']

# Drop rows where X or y contain NaN or inf

X = X.replace([np.inf, -np.inf], np.nan).dropna()

y = y[X.index]

# Fit the OLS regression model

model = sm.OLS(y, X).fit()

# Print the summary of the regression model

print(model.summary())

# Check: Visualize the log transformation, to make sure it had a
positive effect

# List of high-skewness variables

high_skew_vars = ['Time to Maturity (Years)',
'Log_Time_to_Maturity']

# Plot histograms for each variable

plt.figure(figsize=(16, 12))

for i, var in enumerate(high_skew_vars):

```

```

plt.subplot(3, 2, i + 1) # Adjust rows and columns as needed

plt.hist(df_cleaned_final[var], bins=30, color='skyblue',
alpha=0.7, edgecolor='black')

plt.title(f'Distribution of {var}')

plt.xlabel(var)

plt.ylabel('Frequency')

plt.tight_layout()

plt.show()

# Recalculate and print skewness for Log_Time_to_Maturity

log_time_to_maturity_skewness =
skew(df_cleaned_final['Log_Time_to_Maturity'].dropna())

print(f"Skewness of Log_Time_to_Maturity:
{log_time_to_maturity_skewness}")

# Step 6: VARIANCE INFLATION FACTOR (VIF) CHECK FOR
MULTICOLLINEARITY

# Define the features for VIF calculation (exclude the dependent
variable 'y')

vif_features = df_cleaned_final[['Currency Dummy', 'ESG Dummy', 'Mty
Type Dummy', 'Log_Time_to_Maturity', 'Coupon Dummy', 'Liquidity
Dummy', 'Rating Dummy (0 = Rated, 1 = Not Rated)', 'Coupon']]

# Add constant for VIF calculation

vif_features = sm.add_constant(vif_features)

```

```

# Calculate VIF for each independent variable

vif_data = pd.DataFrame()

vif_data['Variable'] = vif_features.columns

vif_data['VIF'] = [variance_inflation_factor(vif_features.values, i)
for i in range(vif_features.shape[1])]

# Print VIF results

print("Variance Inflation Factor (VIF) for Independent Variables:")

print(vif_data)

# Step 7: OLS REGRESSION AND QUANTILE REGRESSION WITH INTERACTION
TERM

# Ensure cleaned data

df_cleaned_final = df_cleaned_final[df_cleaned_final['Yld to Mty
(Mid)'].notna()]

# Create the interaction term

df_cleaned_final['Currency_ESG_Interaction'] = (

    df_cleaned_final['Currency Dummy'] * df_cleaned_final['ESG
    Dummy'])

df_cleaned_final['Log_Time_to_Maturity'] =
np.log1p(df_cleaned_final['Time to Maturity (Years)'])

df_cleaned_final['Log_Yield_to_Maturity'] =
np.log1p(df_cleaned_final['Yld to Mty (Mid)'])

# Define independent and dependent variables

```

```

X_columns = ['ESG Dummy', 'Currency Dummy',
             'Currency_ESG_Interaction', 'Log_Time_to_Maturity', 'Mty Type
             Dummy', 'Coupon Dummy', 'Coupon', 'Liquidity Dummy', 'Rating
             Dummy (0 = Rated, 1 = Not Rated)']

y_column = 'Log_Yield_to_Maturity'

# OLS Regression

X_ols = sm.add_constant(df_cleaned_final[X_columns])

y_ols = df_cleaned_final[y_column]

ols_model = sm.OLS(y_ols, X_ols).fit()

# Print OLS results

print("OLS Regression Results:")

print(ols_model.summary())

# Quantile Regression

quantiles = [0.25, 0.5, 0.75]

quantile_results = {}

print("\nQuantile Regression Results:")

for q in quantiles:

    quant_model = sm.QuantReg(y_ols, X_ols).fit(q=q)

    quantile_results[q] = quant_model

    print(f"\nQuantile {q} Results:")

    print(quant_model.summary())

```

```

# Step 8: PLOT FITTED VALUES TO ENSURE A GOOD MODEL FIT

# Calculate residuals for OLS

ols_residuals = ols_model.resid

# Plot residuals for OLS

plt.figure(figsize=(10, 6))

plt.scatter(ols_model.fittedvalues, ols_residuals, alpha=0.5)

plt.axhline(0, color='red', linestyle='--')

plt.title('Residual Plot for OLS Regression')

plt.xlabel('Fitted Values')

plt.ylabel('Residuals')

plt.grid(alpha=0.3)

plt.show()

# Plot residuals for each quantile regression

for q, quant_model in quantile_results.items():

    quant_residuals = y_ols - quant_model.predict(X_ols)

    plt.figure(figsize=(10, 6))

    plt.scatter(quant_model.predict(X_ols), quant_residuals,
alpha=0.5)

    plt.axhline(0, color='red', linestyle='--')

    plt.title(f'Residual Plot for Quantile Regression (Quantile
{q})')

    plt.xlabel('Fitted Values')

```

```

plt.ylabel('Residuals')

plt.grid(alpha=0.3)

plt.show()

# Combined residuals plot

plt.figure(figsize=(10, 6))

plt.scatter(ols_model.fittedvalues, ols_residuals, alpha=0.5,
label='OLS Residuals')

for q, quant_model in quantile_results.items():

    quant_residuals = y_ols - quant_model.predict(X_ols)

    plt.scatter(quant_model.predict(X_ols), quant_residuals,
alpha=0.5, label=f'Quantile {q} Residuals')

plt.axhline(0, color='red', linestyle='--')

plt.title('Combined Residual Plot (OLS and Quantile Regressions)')

plt.xlabel('Fitted Values')

plt.ylabel('Residuals')

plt.legend()

plt.grid(alpha=0.3)

plt.show()

# Step 9: BUCKET-SPECIFIC OLS REGRESSION AND QUANTILE REGRESSION

# Define the function to perform OLS regression for a given dataset
and variable set

```

```

def perform_ols_regression(data, dependent_var, independent_vars,
analysis_name):

    """

    Perform OLS regression for the given data, dependent variable,
    and independent variables.

    """

    print(f"\nPerforming OLS Regression for {analysis_name}...")

# Prepare the data

    X = data[independent_vars].dropna()

    y = data[dependent_var].dropna()

# Align indices

    X, y = X.align(y, join='inner', axis=0)

# Add a constant to the independent variables

    X = sm.add_constant(X)

# Fit the OLS model

    model = sm.OLS(y, X).fit()

# Print the summary of the results

    print(model.summary())

    return model

# Define dependent and independent variables

# Yield to Maturity as the dependent variable

dependent_var = 'Log_Yield_to_Maturity'

```

```

controls = ['Log_Time_to_Maturity', 'Mty Type Dummy', 'Coupon
           Dummy', 'Liquidity Dummy', 'Coupon', 'Rating Dummy (0 = Rated,
           1 = Not Rated)']

# 1. Greenium in Local Currency Bonds

independent_vars_local_greenium = ['ESG Dummy'] + controls

local_currency_data = df_cleaned_final[df_cleaned_final['Currency
Dummy'] == 0]

local_greenium_model = perform_ols_regression(local_currency_data,
dependent_var, independent_vars_local_greenium, "Greenium in Local
Currency Bonds")

# 2. Greenium in Hard Currency Bonds

independent_vars_hard_greenium = ['ESG Dummy'] + controls

hard_currency_data = df_cleaned_final[df_cleaned_final['Currency
Dummy'] == 1]

hard_greenium_model = perform_ols_regression(hard_currency_data,
dependent_var, independent_vars_hard_greenium, "Greenium in Hard
Currency Bonds")

# 3. Currency Premium in Green Bonds

independent_vars_green_currency_premium = ['Currency Dummy'] +
controls

green_bonds_data = df_cleaned_final[df_cleaned_final['ESG Dummy'] ==
1]

green_currency_premium_model =
perform_ols_regression(green_bonds_data, dependent_var,

```

```

independent_vars_green_currency_premium, "Currency Premium in Green
Bonds")

# 4. Currency Premium in Conventional Bonds

independent_vars_conventional_currency_premium = ['Currency Dummy']
+ controls

conventional_bonds_data = df_cleaned_final[df_cleaned_final['ESG
Dummy'] == 0]

conventional_currency_premium_model =
perform_ols_regression(conventional_bonds_data, dependent_var,
independent_vars_conventional_currency_premium, "Currency Premium in
Conventional Bonds")

# 5. Interaction of Greenium and Currency Premium

independent_vars_interaction = ['ESG Dummy', 'Currency Dummy', 'ESG
Dummy * Currency Dummy'] + controls

df_cleaned_final['ESG Dummy * Currency Dummy'] =
df_cleaned_final['ESG Dummy'] * df_cleaned_final['Currency Dummy']

interaction_model = perform_ols_regression(df_cleaned_final,
dependent_var, independent_vars_interaction, "Interaction of
Greenium and Currency Premium")

# Define quantiles of interest

quantiles = [0.25, 0.5, 0.75]

# Define the analyses

analyses = [

```

```

{"name": "ESG Bonds (Local vs. Hard Currency)", "filter":
(df_cleaned_final["ESG Dummy"] == 1), "exclude_dummy": "ESG
Dummy"}, # Exclude ESG Dummy since all are ESG bonds

{"name": "Non-ESG Bonds (Local vs. Hard Currency)", "filter":
(df_cleaned_final["ESG Dummy"] == 0), "exclude_dummy": "ESG
Dummy"}, # Exclude ESG Dummy since all are non-ESG bonds

{"name": "Local Currency Bonds (ESG vs. Non-ESG)", "filter":
(df_cleaned_final["Currency Dummy"] == 0), "exclude_dummy":
"Currency Dummy"}, # Exclude Currency Dummy since all are
local currency bonds

{"name": "Hard Currency Bonds (ESG vs. Non-ESG)", "filter":
(df_cleaned_final["Currency Dummy"] == 1), "exclude_dummy":
"Currency Dummy"} # Exclude Currency Dummy since all are hard
currency bonds

]

# Initialize dictionary to store quantile regression results

quantile_results = {}

# Loop through each analysis

for analysis in analyses:

    print(f"\nQuantile Regression for {analysis['name']}:")

# Filter the dataset

    analysis_data = df_cleaned_final[analysis["filter"]]

# Define dependent and independent variables

```

```

independent_vars = ['Currency Dummy', 'ESG Dummy',
                    'Log_Time_to_Maturity', 'Mty Type Dummy', 'Coupon Dummy',
                    'Liquidity Dummy', 'Coupon', 'Rating Dummy (0 = Rated, 1
                    = Not Rated)']

# Exclude the irrelevant dummy variable for this analysis

if analysis["exclude_dummy"] in independent_vars:

    independent_vars.remove(analysis["exclude_dummy"])

X = analysis_data[independent_vars]

y = analysis_data['Log_Yield_to_Maturity']

# Add constant for regression

X = sm.add_constant(X)

# Run quantile regression for each quantile

quantile_results[analysis["name"]] = {}

for q in quantiles:

    model = sm.QuantReg(y, X)

    quant_model = model.fit(q=q)

    quantile_results[analysis["name"]][q] = quant_model

# Print summary

print(f"\nQuantile {q}:")

print(quant_model.summary())

```