





“Understanding Thailand’s green bond market: Issuance dynamics, return-risk performance, and their relationship with issuance volume”

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UNDERSTANDING THAILAND'S GREEN BOND MARKET: ISSUANCE DYNAMICS, RETURN-RISK PERFORMANCE, AND THEIR RELATIONSHIP WITH ISSUANCE VOLUME

Abstract

Thailand's green bond market is expanding but remains less developed than in advanced economies, raising questions about issuance patterns and whether return-risk conditions support broader market growth. This study aims to analyze issuance dynamics in Thailand's green bond market, evaluate return and risk performance, assess the relationship between return, risk, and issuance volume, and classify green bonds based on their risk characteristics. The sample included 62 green bonds registered with the Thai Bond Market Association (ThaiBMA) during 2019–2025. Descriptive statistics are used to summarize issuance and performance indicators; return measures include current yield, yield to maturity, holding period return, and annual percentage rate; risk is assessed using seven variables capturing default, liquidity, interest rate, inflation, and reinvestment risks, and hierarchical clustering is applied to classify bonds by risk level. Results show that private-sector issuers dominate the market, accounting for 79% of outstanding green bond value (103.216 billion baht), followed by state-owned enterprises (12%) and foreign issuers (9%). Current yield ranges from 1.62% to 5.55% (mean 3.40%), while yield to maturity ranges from 1.75% to 8.86% (mean 3.20%). Credit spreads range from 0.41% to 3.49% (mean 1.46%), and duration ranges from 0.019 to 10.07 years (mean 3.35), indicating generally moderate risk conditions. SEM analysis further reveals a significant positive relationship between risk and return, while issuance volume is not significantly related to either factor. Cluster analysis identifies four distinct risk groups – low, medium, high, and highest – offering a practical risk classification for investors and policymakers to support sustainable finance development in Thailand.

Keywords

issuance, Thailand, yield, spread, duration, liquidity, risk, clustering, sustainable, finance

JEL Classification

G12, G32, Q56, F65

INTRODUCTION

Thailand faces persistent environmental and climate-related challenges that threaten long-term economic resilience and the country's ability to pursue sustainable growth. In response, sustainable finance has become increasingly important as a mechanism for mobilizing capital toward low-carbon and environmentally beneficial projects. Among sustainable financing instruments, green bonds have gained global attention because they channel debt financing to eligible green projects such as renewable energy, energy efficiency, and climate adaptation, while also supporting transparency through the use-of-proceeds principle and external verification practices. Although Thailand's green bond market has expanded since the first issuance in 2018, it remains smaller and less mature than markets in advanced economies. The market is characterized by a limited number of issuers and bond is-

sues, which raises important questions regarding the sustainability of market growth and the conditions that can attract broader investor participation. In particular, insufficient evidence exists regarding the return–risk characteristics of green bonds and whether their risk profiles exhibit meaningful heterogeneity across issuances. This lack of empirical evidence constitutes a significant scientific problem, as it constrains both academic understanding of emerging green bond markets and the ability of market participants and policymakers to evaluate the financial attractiveness and structural robustness of green bond instruments in Thailand. Addressing this gap is essential for advancing research on sustainable finance in emerging markets and for informing future analytical and policy-oriented investigations of green bond market development.

1. LITERATURE REVIEW AND HYPOTHESES

The global financial landscape has undergone a paradigm shift with the integration of Environmental, Social, and Governance (ESG) criteria into capital allocation mechanisms, positioning green bonds as a pivotal instrument in the transition toward sustainable finance. The global green bond market has reached significant milestones in recent years, with developed economies leading early expansion while emerging markets (EMs), particularly within the Association of Southeast Asian Nations (ASEAN), increasingly adopt green bonds to finance low-carbon development pathways (International Finance Corporation [IFC], 2024; Asian Development Bank [ADB], 2025). Within this regional context, Thailand has demonstrated a strong commitment to sustainable development through its Bio-Circular-Green (BCG) Economy model, with both public and private sectors utilizing green, social, and sustainability (GSS) bonds to fund renewable energy, clean transportation, and social infrastructure projects (Public Debt Management Office [PDMO], 2024; Thai Bond Market Association [ThaiBMA], 2025). Nevertheless, the expansion of green bond markets in EMs is frequently accompanied by structural challenges such as liquidity constraints, issuer concentration, and evolving regulatory frameworks that may influence long-term market depth and stability (Asian Development Bank [ADB], 2022).

A growing body of empirical research investigates the determinants and structural conditions of green bond issuance. Evidence indicates that issuance decisions are shaped not only by financing costs but also by firm-level sustainability strategies and governance characteristics, suggesting that non-financial considerations play a sub-

stantive role in market participation (Fatica et al., 2021). These findings help explain why green bond markets in emerging economies can expand rapidly while still exhibiting institutional frictions. From a pricing perspective, cross-sectional analyses reveal that the so-called “greenium” is heterogeneous and tends to be more pronounced for specific issuer and bond characteristics, implying that cost advantages are concentrated within particular market segments rather than uniformly distributed (Löffler et al., 2021). Complementary evidence highlights the influence of investor clientele effects on both pricing and ownership structures, shaping secondary-market behavior and potentially affecting liquidity over time (Baker et al., 2022). Comparative studies between green and conventional bonds further demonstrate that observed yield differentials are sensitive to matching methodologies, certification standards, and market microstructure conditions, underscoring the importance of analytical rigor when interpreting return performance (Hachenberg & Schiereck, 2020). Large-sample corporate evidence also associates green bond issuance with measurable improvements in environmental performance, thereby strengthening the credibility of use-of-proceeds commitments and supporting continued investor and policy engagement, particularly in developing markets (Flammer, 2021).

Theoretical perspectives provide additional foundations for understanding bond market dynamics and issuer behavior. Expectation Theory posits that long-term interest rates reflect the geometric average of expected future short-term rates, implying that issuers are sensitive to yield curve conditions when determining financing strategies (Estrella & Mishkin, 1996; França & Gaspar, 2024). In this context, lower prevailing yields reduce borrowing costs and may incentivize bond

issuance, an effect potentially amplified for green bonds through yield discounts associated with the greenium (MacAskill et al., 2021; IFC, 2025). Empirical evidence from multiple jurisdictions indicates that bond issuance volumes tend to increase in accommodative monetary environments, as firms seek to secure cheaper funding while investors display a “reach-for-yield” behavior by extending duration rather than accepting lower credit quality (De Santis & Zaghini, 2021; Bruno et al., 2024; Bi et al., 2024; Huang et al., 2025). These patterns suggest an inverse association between prevailing yield levels and issuance activity, although asset-liability matching considerations remain important for long-term green infrastructure financing (ThaiBMA, 2025).

Market uncertainty and liquidity conditions further shape issuance incentives and investor behavior. Liquidity Preference Theory asserts that during periods of heightened uncertainty, investors demand additional yield premiums for holding longer-term and less liquid instruments, increasing the cost of capital for issuers (Papavassiliou, 2021). This mechanism is particularly relevant for EM green bond markets, where secondary-market liquidity may be constrained due to buy-and-hold investment strategies among ESG-focused institutions (Cheng et al., 2024). In contrast, Market Segmentation and Preferred Habitat theories suggest that distinct investor mandates – such as ESG-oriented funds – can create independent demand pockets that support pricing advantages even in the absence of superior liquidity, thereby contributing to the persistence of a greenium (Zerbib, 2019; Löffler et al., 2021). Additional evidence underscores the importance of credibility, measurement quality, and external verification in shaping risk–return perceptions. Differences in ESG rating methodologies can influence investor interpretation of sustainability signals (Larcker & Watts, 2020), while third-party certification has been shown to enhance credibility and potentially enlarge the greenium, especially in markets characterized by higher information asymmetry. Liquidity-based analyses also indicate that trading conditions materially affect the apparent cost advantages of green labels (Yan et al., 2025), and sovereign green bond markets may provide benchmark yield curves that facilitate broader corporate market development in emerging economies (Tomczak, 2024).

Beyond pricing and liquidity considerations, empirical studies consistently explore the interaction between yield dynamics, return performance, and issuance activity. Lower yields are generally associated with higher issuance volumes as financing costs decline, while benchmark yield curve formation – often supported by sovereign or public-sector sustainability issuances – can stimulate corporate participation (IFC, 2025; PDMO, 2024). At the same time, market sentiment and investor attention may influence issuance timing, with positive historical returns and favorable market reactions encouraging additional supply (Aini et al., 2023; Wang et al., 2025). Although return-based metrics such as Holding Period Return (HPR) are more commonly applied in equity contexts (Hovakimian et al., 2001; Eckbo et al., 2007), related evidence from Asia and Thailand suggests that firms tend to access capital markets during periods of strong historical performance and positive investor sentiment (Çelik & Akarim, 2012). Nevertheless, relatively few studies directly examine the relationship between bond-specific return measures and green bond issuance volumes, indicating an area requiring further empirical investigation.

Risk characteristics constitute another central dimension of green bond market analysis. Credit ratings remain a primary determinant of market access in emerging economies, with issuance frequently concentrated in the investment-grade segment due to conservative institutional risk appetites (ThaiBMA, 2025; IFC, 2025). Duration and modified duration capture sensitivity to interest rate fluctuations and influence both issuer tenor choices and investor portfolio strategies, particularly during periods of heightened rate volatility. Complementary metrics such as the Price Value of a Basis Point (PVBP) serve as practical tools for hedging interest-rate exposure and assessing price sensitivity. Collectively, these indicators highlight the multidimensional nature of risk assessment in green bond markets, where financial fundamentals interact with liquidity conditions, credibility signals, and regulatory environments.

Overall, the existing literature demonstrates substantial progress in understanding green bond issuance drivers, pricing mechanisms, and risk characteristics. However, prior studies often ex-

amine these dimensions separately and predominantly focus on developed markets. Integrated empirical evidence that simultaneously evaluates issuance dynamics, return–risk performance, and multivariate risk heterogeneity remains comparatively limited in emerging market contexts such as Thailand.

The purpose of this study is to examine the issuance dynamics of Thailand’s green bond market and to evaluate the return–risk performance of green bonds issued in Thailand. In addition, the study aims to assess the relationships between return, risk, and issuance volume using structural equation modeling, and to classify green bonds into distinct risk groups based on multivariate risk characteristics. The following hypotheses are proposed regarding bond issuance volume:

- H1: Current Yield is negatively related to bond issuance volume.*
- H2: Yield to Maturity is negatively related to bond issuance volume.*
- H3: Holding Period Return is negatively related to bond issuance volume.*
- H4: Annual Percentage Return is negatively related to bond issuance volume.*
- H5: Price Value of a Basis Point (PVBP) is negatively related to Green Bond Outstanding Value.*
- H6: Duration is negatively related to Green Bond Outstanding Value.*
- H7: Modified Duration is negatively related to Green Bond Outstanding Value.*
- H8: Credit Rating is negatively related to Green Bond Outstanding Value.*

2. METHODOLOGY

This study investigates the context of green bonds in Thailand, focusing on four key aspects: (1) analyzing issuance dynamics in Thailand’s green bond market, (2) evaluating return and risk per-

formance, (3) assessing the relationship between return, risk, and issuance volume, and (4) classifying green bonds based on their risk characteristics. The methodological framework was organized into a sequential analytical procedure to ensure transparency, consistency, and replicability.

2.1. Data collection

The empirical dataset was compiled from official and publicly accessible sources, primarily the Thai Bond Market Association (ThaiBMA) and the Public Debt Management Office (PDMO). The observation period spans 2018–2024, commencing from the initial issuance of green bonds in Thailand.

The sample comprises all green bond instruments for which complete information on pricing, yield, maturity structure, credit rating, and outstanding value was available. The study relies exclusively on secondary financial data, thereby ensuring standardization of measurement and comparability across issuers and time periods.

2.2. Variable definition and measurement

The analytical framework classifies variables into three principal dimensions: return indicators, risk indicators, and issuance volume. Variables used in this study are shown in Table 1.

2.3. Descriptive statistical analysis

Descriptive statistical techniques were employed as an initial analytical step to provide an overview of the market structure and distributional characteristics of return and risk variables. The analysis included measures of central tendency (mean), dispersion (standard deviation), and range (minimum and maximum values). This stage serves to establish baseline market conditions prior to inferential and multivariate analyses.

2.3.1. Structural equation modeling (SEM)

To investigate the simultaneous and potentially interdependent relationships among return variables, risk variables, and issuance dynamics, Structural Equation Modeling (SEM) was employed. SEM

Table 1. Variables used and measurement

Category	Variables	Symbol	Measurement	Citation
Dependent Variable	Green Bond Outstanding Value	OSTD	Outstanding Value from ThaiBMA database	-
Explanatory Variable: Return Dimension	1. Current Yield	CY	Measured as the ratio of annual coupon payments to the bond's market price.	Idilbi-Bayaa & Qadan, 2022
	2. Yield to Maturity	YTM	Calculated using the bond valuation formula: $PV_n = \frac{CF_1}{(1+YTM)^1} + \frac{CF_2}{(1+YTM)^2} + \dots + \frac{CF_n + M_n}{(1+YTM)^n}$ where PV_n is the bond purchase price, CF_n is the coupon payment, and M_n is the redemption value	Nesbitt, 2018
	3. Annual Percentage Rate	APR	$APR = \frac{CFIN}{CFOUT \cdot T}$ where $CFIN$ is the cash inflow, $CFOUT$ is the cash outflow, and T is the time in years	Peren, 2023
	4. Holding Period Return	HPR	$HPR = \frac{Income + Ending Value - Beginning Value}{Beginning Value}$	Schaub, 2019
Explanatory Variable: Risk Dimension	1. Time to Maturity	TTM	The remaining time until maturity, calculated as the difference between the maturity date and the current date	Mega & Widayat, 2019; Papavassilio, 2021
	2. Credit Rating	CR	Based on TRIS Rating classifications, ranging from BB to AAA. Bonds rated below BBB are categorized as high-yield, while those rated BBB and above are considered investment grade	Ubarhande and Chandani, 2021
	3. Price Value of a Basis Point	PVBP	$PVBP = \frac{(V-) - (V+)}{2}$ where $(V-)$ is the bond price when yield decreases by 1 basis point and $(V+)$ is the price when yield increases by 1 basis point	ThaiBMA, 2024
	4. Credit Spread	CS	$Credit\ Spread\ (\%) = Bond\ Yield - Benchmark\ Rate$	ThaiBMA, 2024
	5. Duration	DUR	$DUR_{Mac} = \sum_{t=1}^n \frac{t \cdot PVCF_t}{f \cdot PVTCF}$ where n is the number of periods, t is the time of each cash flow, f is the frequency of payments per year, $PVCF_t$ is the present value of cash flow at time t , and $PVTCF$ is the bond price	Hawawini, 1984
	6. Modified Duration	M_DURATION	$MD = DUR / (1 + YTM/n)$ where DUR is Macaulay Duration	Dai et al., 2022

enables the estimation of both direct and indirect effects within a unified structural framework and is particularly suitable for examining latent relationships among multiple financial constructs. Model validity was assessed using standardized fit indices and path coefficient estimations in accordance with established SEM evaluation criteria.

2.3.2. Risk classification through cluster analysis

To identify homogeneous groupings of green bonds according to their risk characteristics, cluster analysis was performed using selected risk indicators, including duration, PVBP, and credit

rating. The hierarchical clustering technique was employed, using a dendrogram analysis. Group validation was performed using two techniques: a two-step algorithm, which considered the AIC value at the elbow point (Wanganusorn et al., 2024), and a comparison of clustering performance based on synergy and separation (Shutaywi & Kachouie, 2021). The clustering procedure facilitates the classification of bonds into distinct risk categories, thereby providing a systematic basis for comparative analysis of investment profiles. The resulting clusters were subsequently interpreted as representative risk tiers within the Thai green bond market.

3. RESULTS

3.1. Objective 1: An overview of issuance dynamics in Thailand’s green bond market

A comprehensive study of Thailand’s green bond market identifies three main issuer categories: state-owned enterprises, foreign entities, and long-term corporate issuers. The private sector dominates the market, accounting for 79% of outstanding green bond value (103.216 billion baht), followed by government bonds (12%) and foreign bonds (9%). This highlights the private sector’s central role in market development. Analysis of bond maturity reveals limited participation from state-owned enterprises, with only Exim Bank and BAAC issuing green bonds – most with maturities under three years. BAAC is the sole issuer with a bond exceeding this term. This suggests that green bonds are not yet a preferred funding mechanism for public entities. Foreign-issued green bonds are even more concentrated, with one company issuing six bonds, only two of which have maturities beyond three years. In contrast, the private sector shows broader engagement, with 18 companies issuing multiple green bonds. For example, Global Power Synergy PCL and RATCH Group PLC have issued seven and six bonds, respectively, with maturities ranging from under one year to over ten years. These patterns reflect the private sector’s leadership and diversity in Thailand’s green bond market, as illustrated in Figure 1.

3.2. Objective 2: Return and risk performance

3.2.1. Return performance

In the Thai context, the return on green bonds – measured by the ratio of interest payments to market price, commonly referred to as the current yield – has been found to be significant. The current yield in the Thai green bond market ranges from a minimum of 1.62% to a maximum of 5.55%, with an average return of 3.40%. When returns are assessed using the yield to maturity (YTM) metric, the lowest observed return is 1.75%, the highest is 8.86%, and the average YTM is approximately 3.2021%. Using the annual percentage rate (APR) as a measure, the returns range from a minimum of 1.59% to a maximum of 249%, with an average APR of approximately 7.1044%. In addition, when returns are calculated using the holding period return (HPR) method, the lowest return is 5.69%, the highest is 67.26%, and the average return is 23.0323%.

These findings, derived from multiple return measurement approaches, as shown in Figure 2, provide a comprehensive understanding of the return structure of green bonds in Thailand. Based on the results, green bond returns can be categorized into three levels (Nesbitt, 2018): (1) low-yield (below 3%), (2) moderate-yield (3%-6%), and (3) high-yield (above 6%).

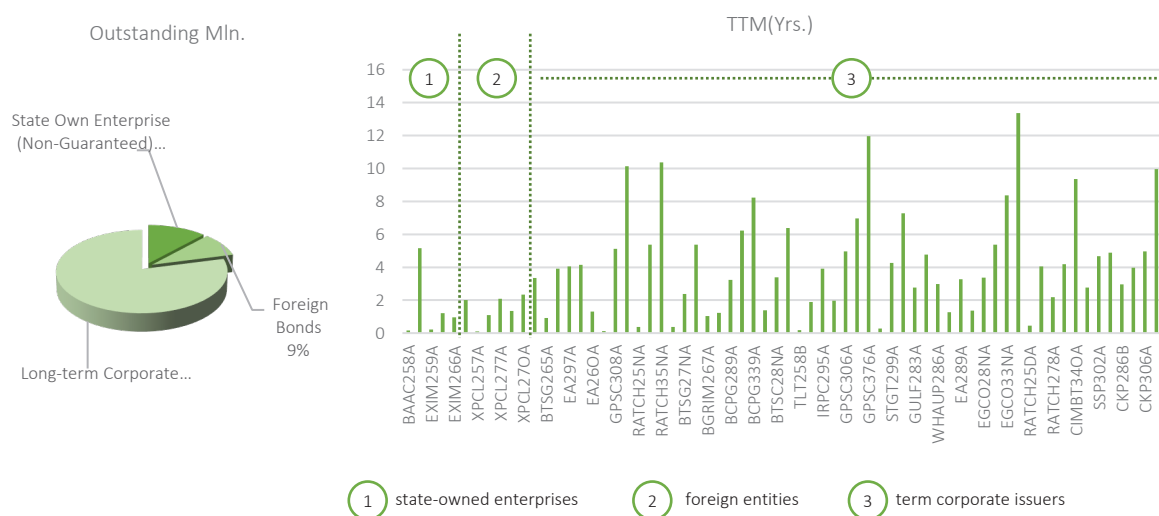


Figure 1. Thai green bond market structure

Table 2. Return descriptive statistics

Variable	N	Descriptive Statistics			
		Minimum	Maximum	Mean	Std. Deviation
CY	62	1.75%	8.86%	3.20%	1.61
YTM	62	1.62%	5.55%	3.40%	0.88
APR	62	1.59%	249.00%	7.10%	31.23
HPR	62	5.69%	67.26%	23.03%	13.16

3.2.2. Risk performance

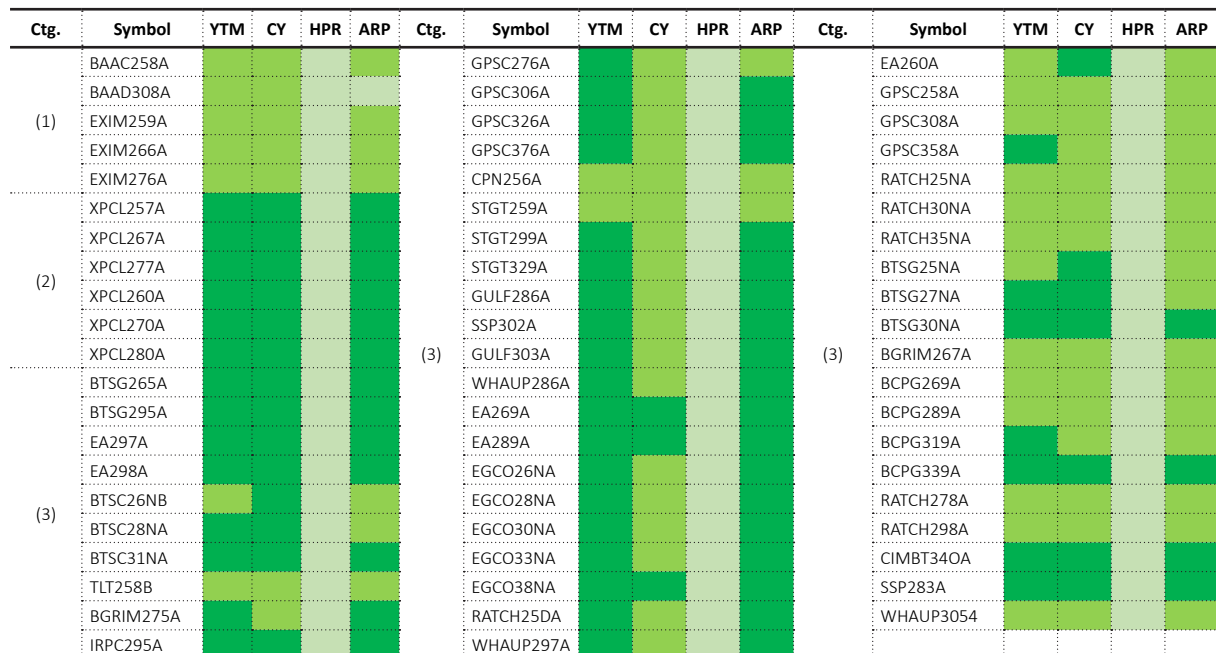
This study evaluates the risks associated with green bonds across five key dimensions: default risk, liquidity risk, interest rate risk, inflation risk, and reinvestment risk. Each of these risk factors can influence the pricing and attractiveness of debt instruments. The details of each risk dimension are outlined in Table 3.

3.2.3. Default risk

Default risk refers to the possibility that the issuer of a green bond may fail to meet its obligations to repay the principal and interest within the agreed timeframe. This risk can be assessed using various financial indicators, including net operating income, debt-to-equity ratio, cash flow generation

Table 3. Risk descriptive statistics

Variables	N	Descriptive Statistics			
		Minimum	Maximum	Mean	Std. Deviation
TTM	62	.0300	13.42	3.73	3.07
PVBP	62	.0002	0.098	0.033	0.025
CS	62	0.41%	3.49%	1.46%	0.86%
DUR	62	0.019	10.07	3.35	2.57
M_DURATION	62	0.018	9.84	3.29	2.53
CONVEX	62	.0097	120.59	20.31	27.01



(1) state-owner enterprises
 (2) foreign entities
 (3) long-term corporate issue

low-yield
 Moderate-yield
 High-yield

Figure 2. Green bond, categorized by yield

capacity, credit ratings, and credit spreads (CS). In this study, credit ratings and credit spreads were employed as proxies for default risk. The findings indicate that a significant proportion of green bonds in Thailand are rated BBB+ (22.6%) and AA- (21.0%), suggesting a moderate to high level of credit risk (see Table 4). When using credit spread as a measure, the risk levels can be categorized as follows: (1) spreads below 100 basis points (bps) indicate very low risk, typically associated with government bonds or AAA-rated issuers; (2) spreads between 100 and 300 bps reflect moderate risk, common among investment-grade bonds; and (3) spreads exceeding 400-500 bps denote high risk, often linked to high-yield or sub-investment-grade bonds (Gilchrist & Zakrajšek, 2012). In the Thai green bond market, credit spreads ranged from 0.41% to 3.49%, with an average of 1.4681%, indicating a predominantly moderate level of default risk.

Table 4. Credit rating descriptive characteristics

Rating	Descriptive characteristics	
	Frequency	Percent
AAA (tha) /FITCH (Thailand)	5	8.1
AAA/TRIS	2	3.2
AA+/TRIS	13	21.0
AA/TRIS	6	9.7
AA-/TRIS	2	3.2
A(tha)/FITCH (Thailand)	1	1.6
A/TRIS	4	6.5
A-/TRIS	9	14.5
BBB+/TRIS	14	22.6
BBB/TRIS	1	1.6
BB+/TRIS	5	8.1
Total	62	100.0

3.2.4. Liquidity risk

Liquidity risk arises from the difficulty of trading a bond without significantly affecting its market price or the proceeds received. Factors contributing to liquidity risk include low trading volume, limited issuer recognition, and the remaining maturity of the bond. Bonds issued by well-known entities, such as governments or large corporations, generally exhibit higher liquidity, whereas those issued by smaller or lower-rated entities may face limited secondary market activity. This study utilized remaining

maturity and credit rating as indicators of liquidity risk. The results show that the remaining maturity of green bonds in Thailand ranges from 0.03 to 13.42 years, with an average of 3.7394 years. Bonds with a remaining maturity of less than 3 years are considered to have low liquidity risk, while those exceeding 5 years are associated with higher risk. These findings align with the observed credit ratings, where a significant portion of bonds are rated BBB+ (22.6%) (see Tables 3 and 4), suggesting a moderate level of liquidity risk.

3.2.5. Interest rate risk and inflation risk

Interest rate risk and inflation risk are closely related, as inflation influences interest rate movements. This study assessed both risks using duration, a measure of a bond's price sensitivity to changes in interest rates. Duration is calculated as the weighted average time to receive the bond's cash flows, discounted to present value. It provides insight into how bond prices may fluctuate in response to interest rate changes. Duration values are typically interpreted as follows: values below 3 indicate low risk, values between 3 and 7 suggest moderate risk, and values above 7 reflect high risk (Intarasupht, 2022; van Binsbergen et al., 2024). The study found that the duration of green bonds in Thailand ranged from 0.0192 to 10.0744, with an average of 3.35426 (see Table 3). These results suggest that green bonds in the Thai market generally exhibit a moderate level of interest rate and inflation risk.

3.2.6. Reinvestment risk

Green bonds, as fixed-income instruments, generate periodic cash flows, primarily through fixed interest payments. Reinvestment risk, which pertains to the uncertainty surrounding the reinvestment of these cash flows, can be assessed using Modified Duration (MD). The literature review supports the use of MD as a measure of reinvestment risk. The study identified MD values ranging from a minimum of 0.0189 to a maximum of 9.8455, with a majority of bonds exhibiting an MD of approximately 3.299194. These findings, presented in Table 3, indicate a moderate level of reinvestment risk associated with green bonds in the Thai market.

3.3. Objective 3: Green bond volume, return, and risk

3.3.1. Return and risk analysis

This study examined the return and risk characteristics of green bonds through descriptive statistical methods, aiming to elucidate the variables associated with bond performance. To evaluate the construct validity and explanatory power of these variables, Confirmatory Factor Analysis (CFA) was employed, as illustrated in Figure 3. The analysis identified Yield to Maturity (YTM), Current Yield (CY), Holding Period Return (HPR), and Average Periodic Return (APR) as key components contributing to green bond returns. The model demonstrated a satisfactory fit to the data, as evidenced by the following fit indices: Chi-square (χ^2) = 0.901, degrees of freedom (DF) = 2, p-value = 0.637, CMIN/DF = 0.450, Goodness-of-Fit Index (GFI) = 0.993, Adjusted Goodness-of-Fit Index (AGFI) = 0.964, Comparative Fit Index (CFI) = 1.000, and Root Mean Square Error of Approximation (RMSEA) = 0.000. These results affirm the robustness of the model and the relevance of the selected return variables in the context of green bond performance. The variables Present Value of a Basis Point (PVBP), Duration, Modified Duration (M_Duration), and Credit Rating were identified as components of the risk factor model, as illustrated in Figure 4. To assess the validity of this construct, Confirmatory Factor Analysis (CFA) was conducted. The model demonstrated a strong fit with the observed data, as indicated by the following fit indices: Chi-square (χ^2) = 0.246, degrees of freedom (DF) = 2, p-value = 0.876, CMIN/DF = 1.32, Goodness-of-Fit Index (GFI) = 0.998, Adjusted Goodness-of-Fit Index (AGFI) = 0.989, Comparative Fit Index

(CFI) = 1.000, and Root Mean Square Error of Approximation (RMSEA) = 0.000. These results confirm the appropriateness of the selected variables in representing the risk dimensions of green bonds.

3.3.2. The relationship between returns and risks affecting the volume of green bond issuance

The relationship between green bond returns, associated risks, and the volume of green bonds issued was examined using Structural Equation Modeling (SEM), as illustrated in Figure 4. The results indicated that the proposed model demonstrated a satisfactory fit to the empirical data. This is supported by the following fit indices: Chi-square (χ^2) = 31.280, degrees of freedom (DF) = 22, p-value = 0.091, CMIN/DF = 1.422, Goodness-of-Fit Index (GFI) = 0.909, Comparative Fit Index (CFI) = 0.993, and Root Mean Square Error of Approximation (RMSEA) = 0.08. These values meet the recommended thresholds for model adequacy as outlined by Hair et al. (2010), thereby confirming the validity of the structural relationships among the variables.

3.3.3. Hypothesis testing results

The structural equation modeling (SEM) analysis was conducted to examine the relationships between return variables, risk indicators, and green bond issuance volume. The hypothesis testing results are summarized based on the estimated path coefficients and their statistical significance. The results indicate that the relationships between return indicators (Current Yield, Yield to Maturity, Holding Period Return, and Annual Percentage Rate) and green bond issuance volume are not sta-

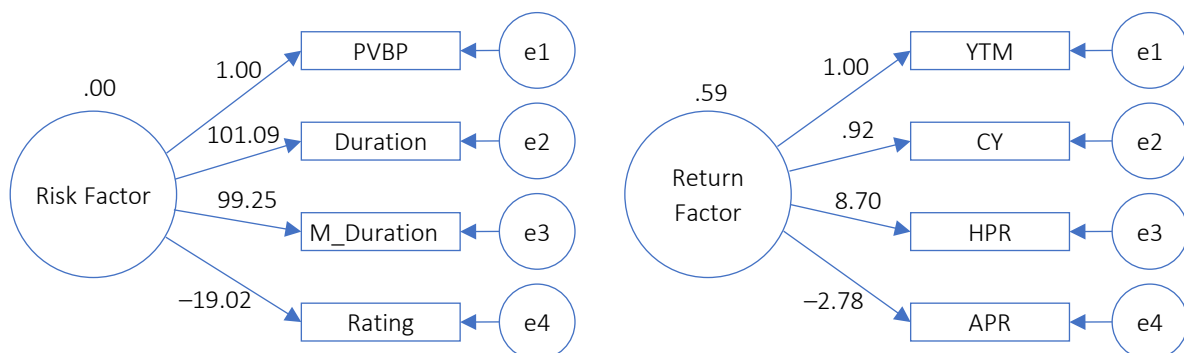


Figure 3. Confirmatory factor analysis

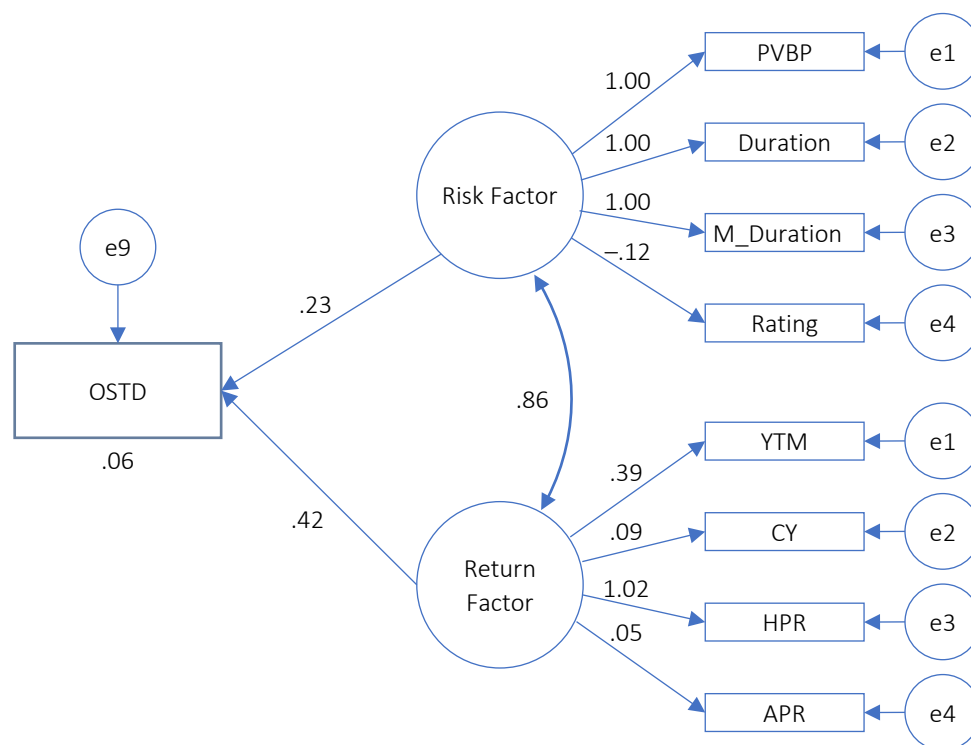


Figure 4. SEM

tistically significant. Therefore, H1, H2, H3, and H4 are not supported. Similarly, the estimated paths between risk indicators – including Price Value of a Basis Point (PVBP), Duration, Modified Duration, and Credit Rating – and green bond outstanding value do not exhibit statistically significant effects. Consequently, H5, H6, H7, and H8 are also not supported. These findings suggest that the volume of green bond issuance in Thailand is not primarily driven by conventional financial return or risk indicators. Instead, issuance decisions may be influenced by broader strategic and sustainability-related considerations, which is consistent with recent literature emphasizing the role of ESG commitments and institutional participation in emerging sustainable bond markets.

3.4. Objective 4: Classification of green bonds by their return and risk characteristics

3.4.1. Return-based classification

Building upon the findings from Objective 2, which established the structure of return and risk for Thai green bonds using multiple measurement approaches, this section aims to categorize green

bonds based on their return and risk profiles. The variability in return metrics arises from the distinct dimensions and assumptions inherent in each method. For instance, Current Yield (CY) reflects the interest income relative to the bond’s current market price, making it suitable for investors focused on short-term income. However, it does not account for capital gains or losses. In contrast, Yield to Maturity (YTM) incorporates both interest payments and price differentials, assuming reinvestment at a constant rate, thereby offering a more comprehensive but complex measure of return. To ensure a robust and multidimensional classification of green bond returns and risks, this study employed clustering techniques. Specifically, hierarchical clustering was applied using CY, YTM, Holding Period Return (HPR), and Average Periodic Return (APR) as representative variables. The dendrogram generated via the Between-Group Linkage method was used to determine the optimal number of clusters. Subsequently, the Two-Step Algorithm was utilized to validate the clustering structure, with the Akaike Information Criterion (AIC) guiding the selection of the optimal number of clusters. Both methods converged on five distinct clusters, representing varying levels of return: very high, high, moderate, relatively

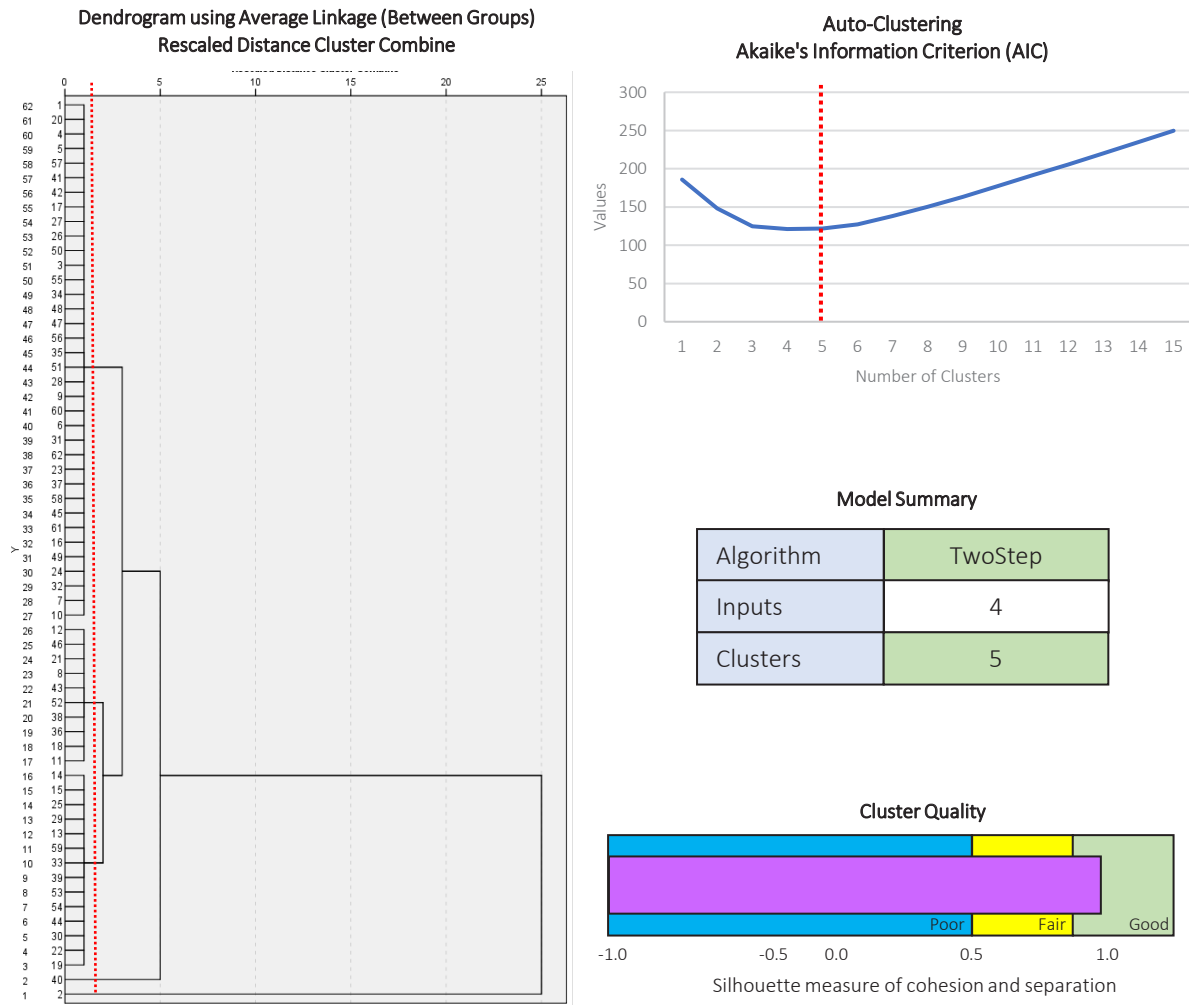


Figure 5. Dendrogram AIC and clustering efficiency for return

low, and low (Thomas et al., 2013). The clustering efficiency was evaluated based on intra-group cohesion and inter-group separation, as illustrated in Figure 5

The classification yielded five distinct groups of green bonds, each with clearly interpretable return characteristics. Figure 6 presents the bond codes corresponding to each return category.

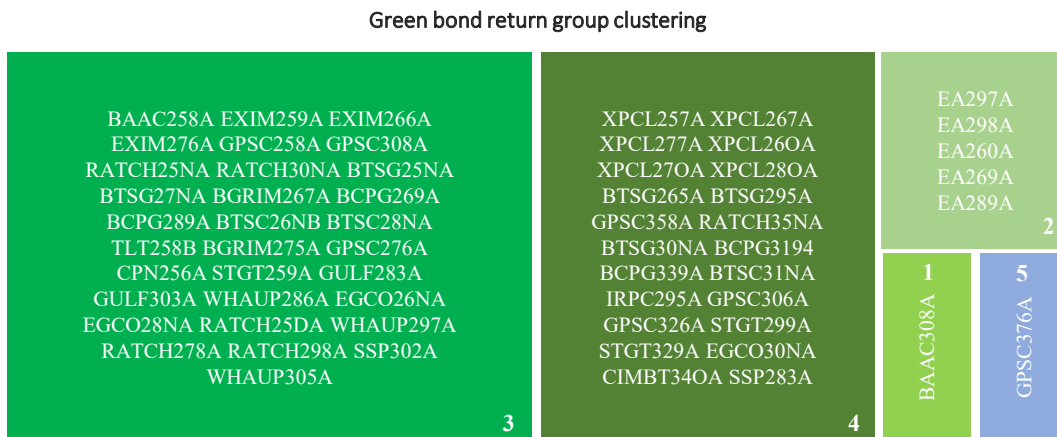


Figure 6. Green bond return group clustering

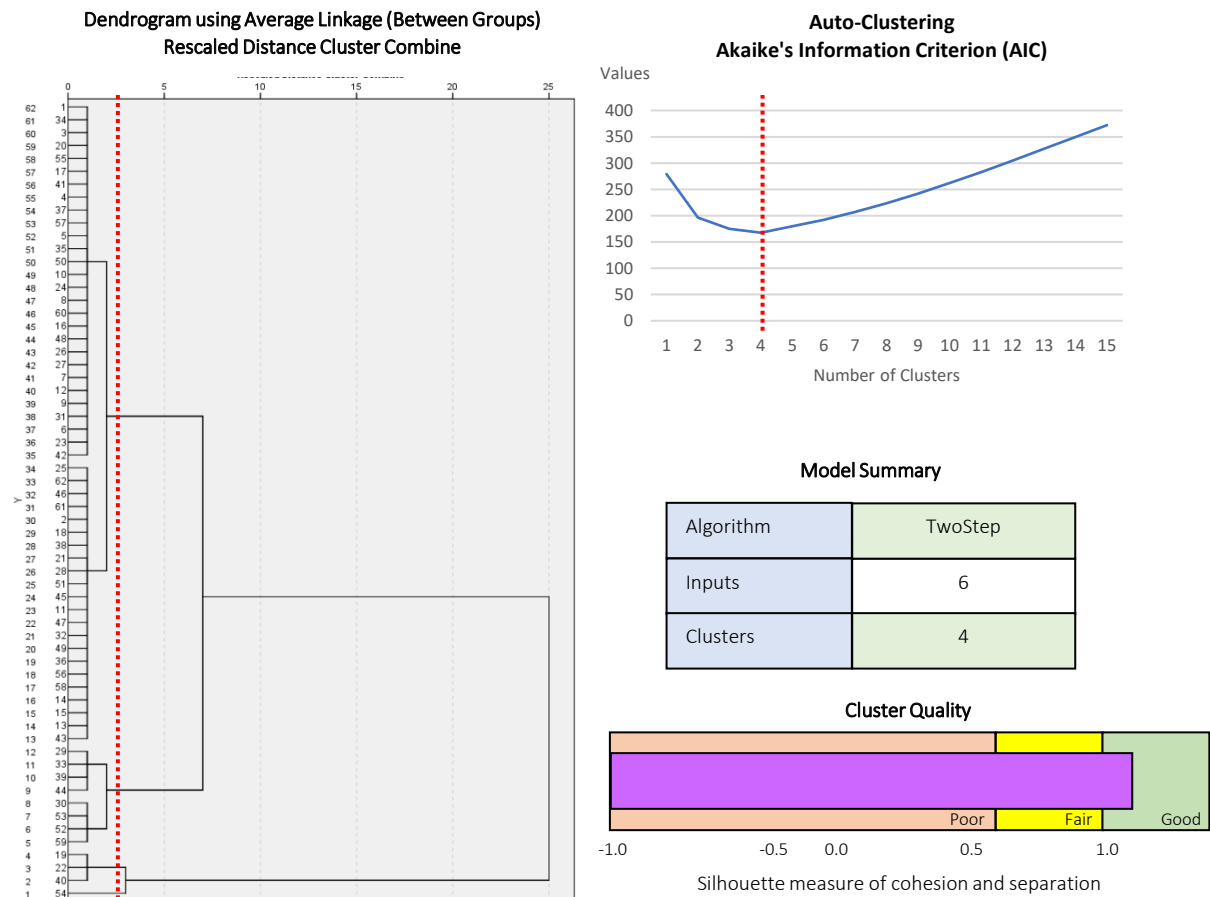


Figure 7. Dendrogram AIC and clustering efficiency for risk

3.4.2. Risk-based classification

In parallel, green bonds were also categorized according to their risk levels using hierarchical clustering. The variables employed for this analysis included Time to Maturity (T_{TM}), Present Value of a Basis Point (PVBP), Credit Spread (CS), Duration (DUR), Modified Duration (M_{Duration}), and Convexity, which collectively capture various dimensions of bond risk. The dendrogram produced using the Between-Group Linkage method served as the basis for initial cluster identification. The Two-

Step Algorithm, guided by the AIC elbow point, confirmed the optimal number of clusters to be four. These clusters correspond to the following risk levels: highest risk, high risk, medium risk, and low risk (Slovic et al., 1979). The clustering structure demonstrated strong explanatory power, with clear group delineation and interpretability, as shown in Figure 7.

Figure 8 summarizes the green bonds classified under each risk category, providing a comprehensive overview of their distribution across the four risk levels.

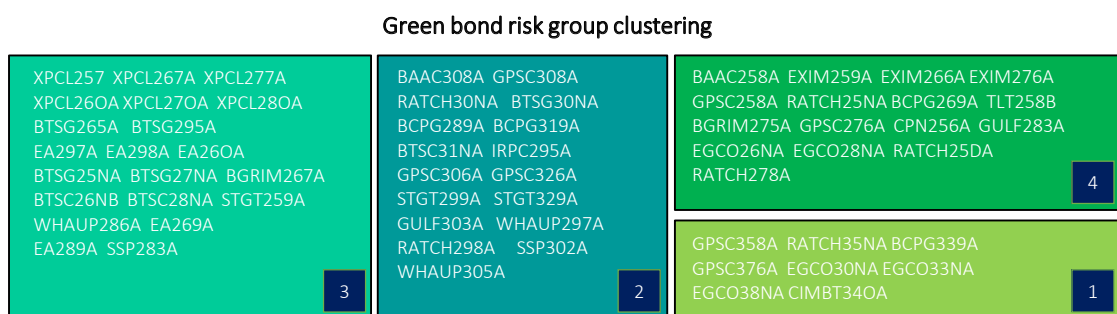


Figure 8. Green bond risk group clustering

4. DISCUSSION

The empirical findings provide several insights into the structural and behavioral characteristics of Thailand's green bond market. First, the dominance of private-sector issuers and the concentration of outstanding value within a limited number of institutions indicate that the market remains issuer-concentrated, a feature commonly observed in emerging market sustainable finance systems. This structural pattern is consistent with prior observations that green bond markets in emerging economies tend to expand under strong institutional participation while still facing liquidity and diversification constraints (Wongaree, 2021; ADB, 2022; IFC, 2024). The results suggest that Thailand's green bond ecosystem is progressing toward maturity, yet its depth and breadth remain dependent on a relatively narrow issuer base. Second, the return indicators reveal moderate yield levels and relatively stable price performance across the observation period, implying that green bonds in Thailand offer competitive but not excessive return profiles. This outcome aligns with the broader international evidence on the "greenium," where yield differentials between green and conventional bonds are present but often modest and heterogeneous rather than uniformly pronounced (Hachenberg & Schiereck, 2020; Löffler et al., 2021; Capital, 2024; Ibric et al., 2024). The findings therefore support the interpretation that the Thai market does not exhibit abnormal pricing distortions; instead, pricing behavior appears to reflect conventional fixed-income fundamentals supplemented by sustainability preferences.

The structural equation modeling results further contribute to the interpretation of return-risk dynamics. The statistically significant positive association between risk and return indicates that green bonds in Thailand largely conform to traditional financial theory, whereby higher risk is accompanied by higher expected compensation. At the same time, the absence of a statistically significant effect of risk and return on issuance volume suggests that issuance decisions are not driven solely by market-based financial incentives. This observation resonates with prior research emphasizing that corporate green bond issuance is influenced by governance strategies, reputational considerations, and sustainability commitments in addition to financing costs (Fatica et al., 2021; Flammer, 2021).

In this context, Thailand's issuance patterns appear to reflect a combination of economic rationality and strategic sustainability positioning rather than pure yield optimization.

Risk-related indicators, particularly duration and credit rating, highlight a preference for moderate risk exposure within the Thai green bond market. The predominance of investment-grade ratings and medium-term maturities indicates a cautious investment climate consistent with the "quality bias" observed in global ESG-oriented fixed-income markets (IFC, 2025; ThaiBMA, 2025). Such behavior may also be associated with liquidity considerations and investor clientele effects, where institutional investors favor stable instruments that align with long-term portfolio mandates (Baker et al., 2022). This pattern reinforces the view that the Thai green bond market functions as a risk-controlled segment rather than a speculative investment domain.

The cluster analysis provides additional evidence that risk characteristics are not uniformly distributed across instruments but instead form distinct tiers of risk exposure. The emergence of clearly differentiated low-risk, medium-risk, high-risk, and highest-risk groups indicates that the market contains sufficient heterogeneity to support portfolio diversification strategies. This segmentation is consistent with theoretical perspectives on market segmentation and preferred habitat behavior, where investor mandates and asset scarcity contribute to differentiated pricing and demand structures (Zerbib, 2019; Löffler et al., 2021). From a policy standpoint, the existence of multiple risk clusters suggests that regulatory frameworks and disclosure standards play a crucial role in enabling transparent risk assessment and investor confidence. Overall, the discussion indicates that Thailand's green bond market reflects a hybrid financial structure in which classical return-risk relationships coexist with sustainability-driven issuance motives and institutional demand patterns. The empirical evidence supports the notion that while financial fundamentals remain influential, non-financial considerations – such as environmental credibility, governance reputation, and policy alignment – constitute an increasingly significant dimension of market behavior. This duality underscores the importance of integrating both economic and sustainability perspectives when evaluating the development trajectory of green bond markets in emerging economies.

CONCLUSION

The purpose of this study was to examine Thailand's green bond market by analyzing issuance dynamics in Thailand's green bond market, evaluate return and risk performance, assess the relationship between return, risk, and issuance volume, and classify green bonds based on their risk characteristics. The empirical investigation provides a comprehensive perspective on how financial and sustainability considerations jointly shape the evolution of the domestic green bond landscape. The findings indicate that Thailand's green bond market operates within a framework where conventional financial principles remain relevant, particularly in the alignment between risk and return, while issuance behavior reflects a broader set of motivations extending beyond purely cost-based considerations. The observed patterns suggest that institutional participation, regulatory support, and sustainability commitments play a complementary role alongside traditional market mechanisms. Furthermore, the differentiation of bonds into distinct risk tiers demonstrates that the market contains sufficient heterogeneity to support diversified investment strategies and structured risk assessment.

From a practical standpoint, the results offer implications for multiple stakeholders. For policymakers, the evidence underscores the importance of maintaining transparent disclosure standards and consistent regulatory frameworks to enhance investor confidence and market depth. For issuers, the findings highlight the strategic value of aligning financial instruments with credible sustainability objectives to attract long-term capital. For investors, the classification of risk characteristics provides a systematic basis for portfolio allocation and comparative evaluation within the sustainable fixed-income segment. Despite these contributions, the study is subject to certain limitations inherent in secondary data analysis and the scope of available market information. Future research may extend the analysis by incorporating cross-country comparisons, longer observation periods, or alternative econometric techniques to further explore the interaction between financial performance, regulatory developments, and environmental outcomes. Such extensions would contribute to a more nuanced understanding of sustainable debt markets and their role in supporting long-term economic and environmental objectives in emerging economies.

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Writing-review & editing: Chirayu Hantrakul, Bhannawat Wanganusorn, Panern Intara.

REFERENCES

1. Aini, A., Sukmadilaga, C., & K Ghani, E. (2023). Green Bonds, Investor Attention and Stock Market Reaction: Evidence from ASEAN Countries. *International Journal of Energy Economics and Policy*, 13, 334-343. <https://doi.org/10.32479/ijeep.15162>
2. Asian Development Bank. (2022). *Green bond market survey for Thailand: Insights on the perspectives of institutional investors and*

- underwriters. Asian Development Bank. Retrieved from <https://www.adb.org/publications/green-bond-market-survey-thailand>
3. Asian Development Bank. (2025, March). *Recent developments in the ASEAN+3 sustainable bond markets*. Asia Bond Monitor. Retrieved from https://asianbondsonline.adb.org/documents/abm/abm_mar_2025_recent_developments_asean3_sustainable_bond_markets.pdf
 4. Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2022). The pricing and ownership of US green bonds. *Annual Review of Financial Economics*, 14, 415-437. <https://doi.org/10.1146/annurev-financial-111620-014802>
 5. Bi, H., Marsh, W. B., & An, P. (2024). *Corporate interest expenses are expected to increase further*. Federal Reserve Bank of Kansas City, KC Fed Economic Bulletin. Retrieved from <https://www.kansascityfed.org/documents/9983/EconomicBulletin24BiMarshAn0202.pdf>
 6. Bruno, V., Dathan, M., & Kitsul, Y. (2024). Corporate bond issuance over financial stress episodes: A global perspective. *International Finance Discussion Papers*, 1390, 1-49. <https://doi.org/10.17016/IFDP.2024.1390>
 7. Capital, G. (2024). *Factors Influencing Green Bonds Pricing*. Retrieved from <https://gunung-capital.com/factors-influencing-green-bonds-pricing/>
 8. Çelik, S., & Akarim, Y. D. (2012). Does Market Timing Drive Capital Structure? Empirical Evidence from an Emerging Market. *International Journal of Economics and Financial Issues*, 3(1), 140-152. Retrieved from <https://www.econjournals.com/index.php/ijefi/article/view/347>
 9. Cheng, G., Ehlers, T., Packer, F., & Xiao, Y. (2024). *Sovereign green bonds: A catalyst for sustainable debt market development?* (IMF Working Paper No. 2024/120). International Monetary Fund. <https://doi.org/10.5089/9798400277030.001>
 10. Dai, Y., Guo, K., Jin, Z., & Wu, Y. (2022). *Extensions for Macaulay Duration, Modified Duration, and Further Study on Immunization Strategy*. <https://doi.org/10.2991/aebmr.k.220307.092>
 11. De Santis, R. A., & Zaghini, A. (2021). Unconventional monetary policy and corporate bond issuance. *European Economic Review*, 135, 103727. <https://doi.org/10.1016/j.euroecorev.2021.103727>
 12. Eckbo, B. E., Masulis, R. W., & Norli, Ø. (2007). Chapter 6 – Security Offerings. In Eckbo, B. E. (Ed.), *Handbook of Empirical Corporate Finance* (pp. 233-373). Elsevier. <https://doi.org/10.1016/B978-0-444-53265-7.50020-2>
 13. Estrella, A., & Mishkin, F. S. (1996). The yield curve as a predictor of U.S. recessions. *Current Issues in Economics and Finance*, 2(7), 1-6. <http://dx.doi.org/10.2139/ssrn.1001228>
 14. Fatica, S., Panzica, R., & Rancan, M. (2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability*, 54, 100873. <https://doi.org/10.1016/j.jfs.2021.100873>
 15. Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, 142(2), 499-516. <https://doi.org/10.1016/j.jfineco.2021.01.010>
 16. França, R., & Gaspar, R. M. (2024). On the Bias of the Unbiased Expectation Theory. *Mathematics*, 12(1), 105. <https://doi.org/10.3390/math12010105>
 17. Gilchrist, S., & Zakrajšek, E. (2012). Credit Spreads and Business Cycle Fluctuations. *American Economic Review*, 102(4), 1692-1720. <https://doi.org/10.1257/aer.102.4.1692>
 18. Hachenberg, B., & Schiereck, D. (2020). Are green bonds priced differently from conventional bonds? A systematic literature review and meta-analysis. *Journal of Asset Management*, 21(5), 371-383. Retrieved from https://ideas.repec.org/a/pal/assmgt/v19y2018i6d10.1057_s41260-018-0088-5.html
 19. Hawawini, G. (1984). On the relationship between Macaulay's bond duration and the term to maturity. *Economics Letters*, 16(3), 331-337. [https://doi.org/10.1016/0165-1765\(84\)90185-X](https://doi.org/10.1016/0165-1765(84)90185-X)
 20. Hovakimian, A., Opler, T., & Titman, S. (2001). The Debt-Equity Choice. *The Journal of Financial and Quantitative Analysis*, 36(1), 1-24. Retrieved from <https://www.cambridge.org/core/journals/journal-of-financial-and-quantitative-analysis/article/abs/debtequity-choice/58D273B51505C6E0383022388C1D09BF>
 21. Huang, J.-Z., Li, P., Wang, Y., Wang, Y., Yao, X., & Zhang, L. (2025). Do investors reach for yield? Evidence from corporate bond mutual fund flows. *Journal of Empirical Finance*, 83, 101625. <https://doi.org/10.1016/j.jempfin.2025.101625>
 22. Ibrić, M., Kozarević, E., & Mešković, A. (2024). *The Rise of Green Bonds: Global Context and European Insights*. <https://doi.org/10.70009/jels.2024.1.1.4>
 23. Idilbi-Bayaa, Y., & Qadan, M. (2022). What the current yield curve says, and what the future prices of energy do. *Resources Policy*, 75, 102494. <https://doi.org/10.1016/j.resourpol.2021.102494>
 24. International Finance Corporation (IFC), & Amundi. (2025). *Emerging market green bonds 2024: IFC-Amundi joint report* (7th ed.). International Finance Corporation. Retrieved from <https://www.ifc.org/content/dam/ifc/doc/2025/emerging-market-green-bonds-2024.pdf>
 25. International Finance Corporation. (2025). *Emerging market green bonds 2024: IFC-Amundi joint report*. Washington, DC: International Finance Corporation. Retrieved from <https://www.ifc.org/content/dam/ifc/doc/2025/emerging-market-green-bonds-2024.pdf>
 26. Larcker, D. F., & Watts, E. M. (2020). Where's the greenium? *Journal of Accounting and Economics*, 69(2-3), 101312. <https://doi.org/10.1016/j.jaccoco.2020.101312>

27. Löffler, K. U., Petreski, A., & Stephan, A. (2021). Drivers of green bond issuance and new evidence on the “greenium.” *Eurasian Economic Review*, 11(1), 1-24. <https://doi.org/10.1007/s40822-020-00165-y>
28. MacAskill, S., Roca, E., Liu, B., Stewart, R. A., & Sahin, O. (2021). Is there a green premium in the green bond market? Systematic literature review revealing premium determinants. *Journal of Cleaner Production*, 280, 124491. <https://doi.org/10.1016/j.jclepro.2020.124491>
29. Mega, A., & Widayat, W. (2019). Effects of bond's interest rate, rating and maturity time toward bond's yields. *Manajemen Bisnis*, 9. <https://doi.org/10.22219/jmb.v9i1.9446>
30. Nesbitt, S. L. (2019). Current yield or yield to maturity? In *Private debt: Opportunities in corporate direct lending*. John Wiley & Sons. <https://doi.org/10.1002/9781119501138.ch4>
31. Papavassiliou, V. (2021). Euro area sovereign bond yields during the Covid19 pandemic: What do they tell us? *European Capital Markets Institute (ECMI), Commentary No. 76*. Retrieved from https://www.ecmi.eu/sites/default/files/euro_area_sovereign_bond_yields_during_the_covid-19_pandemic.pdf
32. Peren, F. W. (2023). Annual Percentage Rate. In F. W. Peren (Ed.), *Financial Math for Business and Economics: Compendium of Essential Formulas* (pp. 29-33). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-67646-2_2
33. Public Debt Management Office. (2024). *Sustainability bond annual report 2024*. Bangkok: Ministry of Finance, Thailand. Retrieved from <https://www.pdmo.go.th/pdmomedia/documents/2024/Dec/Sus%20Bond%20Annual%20Report%202024%20as%20of%2023%20Dec.pdf>
34. Schaub, M. (2019). Holding period returns from NASDAQ traded ADRs. *Applied Economics Letters*, 26(20), 1689-1693. <https://doi.org/10.1080/13504851.2019.1591593>
35. Shutaywi, M., & Kachouie, N. N. (2021). Silhouette Analysis for Performance Evaluation in Machine Learning with Applications to Clustering. *Entropy*, 23(6), 759. <https://doi.org/10.3390/e23060759>
36. Slovic, P., Fischhoff, B., & Lichtenstein, S. (1979). Rating the Risks. *Environment: Science and Policy for Sustainable Development*, 21, 14-39. <https://doi.org/10.1080/00139157.1979.9933091>
37. Thai Bond Market Association. (2025, July 4). *Thai bond market situation summary: Q2 2025* (Press briefing document). Retrieved from <https://www.thaibma.or.th/doc/press/y2025/conQ22025.pdf>
38. ThaiBMA. (2024). *Green, Social, Sustainability Bond & Sustainability-linked Bond (ESG Bond)*. Retrieved from <https://www.thaibma.or.th/EN/BondInfo/ESG.aspx>
39. Thomas, P., Bratvold, R., & Bickel, J. (2013). The Risk of Using Risk Matrices. *SPE Economics & Management*, 6. <https://doi.org/10.2118/166269-MS>
40. Tomczak, K. (2024). Sovereign Green Bond Market: Drivers of Yields and Liquidity. *International Journal of Financial Studies*, 12(2), 48. <https://doi.org/10.3390/ijfs12020048>
41. Ubarhande, P., & Chandani, A. (2021). Elements of Credit Rating: A Hybrid Review and Future Research Agenda. *Cogent Business & Management*, 8(1), 1878977. <https://doi.org/10.1080/23311975.2021.1878977>
42. Van Binsbergen, J. H., Nozawa, Y., & Schwert, M. (2024). Duration-Based Valuation of Corporate Bonds. *The Review of Financial Studies*, 38(1), 158-191. <https://doi.org/10.1093/rfs/hhae054>
43. Wang, J., Wu, C., Yang, X., & Zhou, Y. (2025). Policy uncertainty and corporate bond issuance costs. *Review of Quantitative Finance and Accounting*. <https://doi.org/10.1007/s11156-025-01386-5>
44. Wanganusorn, B., Tulasombat, S., Bangmek, R., & Awirothananon, T. (2024). Working Capital Policy Clustering Technique: A Case Study of Listed Companies in the Industrial Sector, MAI Thailand *Journal of Liberal Art of Rajamangala University of Technology Suvarnabhumi*, 6(3), 713-726. Retrieved from <https://so03.tcithaijo.org/index.php/art/article/view/278009>
45. Wongaree, P. (2021). *The evidence on the green bond premium in Asia-Pacific and Europe markets*. Thammasat University. Retrieved from https://ethesisarchive.library.tu.ac.th/thesis/2021/TU_2021_6302042160_16057_20439.pdf
46. Yan, M., Li, X., Zhao, X., & He, Z. (2025). Liquidity and cost advantage of green bonds. *Finance Research Letters*, 71, 106433. <https://doi.org/10.1016/j.frl.2024.106433>
47. Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, 98, 39-60. <https://doi.org/10.1016/j.jbankfin.2018.10.012>