THE EVIDENCE ON THE GREEN BOND PREMIUM IN ASIA-PACIFIC AND EUROPE MARKETS

BY

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ABSTRACT

Green bond issuance moves toward pro-environmental preferences when it is crucially used to finance environmental projects. This study examines the existence of green bond premium in both primary and secondary bond markets by using 770 green bonds and 16,880 conventional bonds issued from Asia-Pacific and Europe. To find a pair of identical bonds, we employ Propensity Score Matching and Coarsened Exact Matching, as well as Bootstrapping and Synthetic Minority Oversampling Techniques. The result shows that green bond yields are on average 8-120 basis points lower than conventional bonds in Asia-Pacific markets, indicating that a green bond premium exists. However, there is no solid evidence in Europe markets. Our finding explains a potential mismatch in green bond supply and support the view that green bond issuance raises additional issuer's cost of fund while also concerning on information asymmetry that raises a risk of greenwashing.

Keywords: Green Bond Premium, Pro-environmental Preferences, Propensity Score Matching, Coarsened Exact Matching, Asia-Pacific, Europe, Greenwashing

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Parath Wongaree

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Symbols/Abbreviations	Terms
ATT	Average Treatment effect on the Treated
CAGR	Compound Annual Growth Rate
CBI	Climate Bonds Initiative
CEM	Coarsened Exact Matching
CSR	Corporate Social Responsibility
ESG	Environmental, Social, and Governance
ICMA	International Capital Market Association in Zurich
OECD	Organization for Economic Co-operation and Development
PSM	Propensity Score Matching
SRI	Socially Responsible Investment

CHAPTER 1
INTRODUCTION

1.1 Background

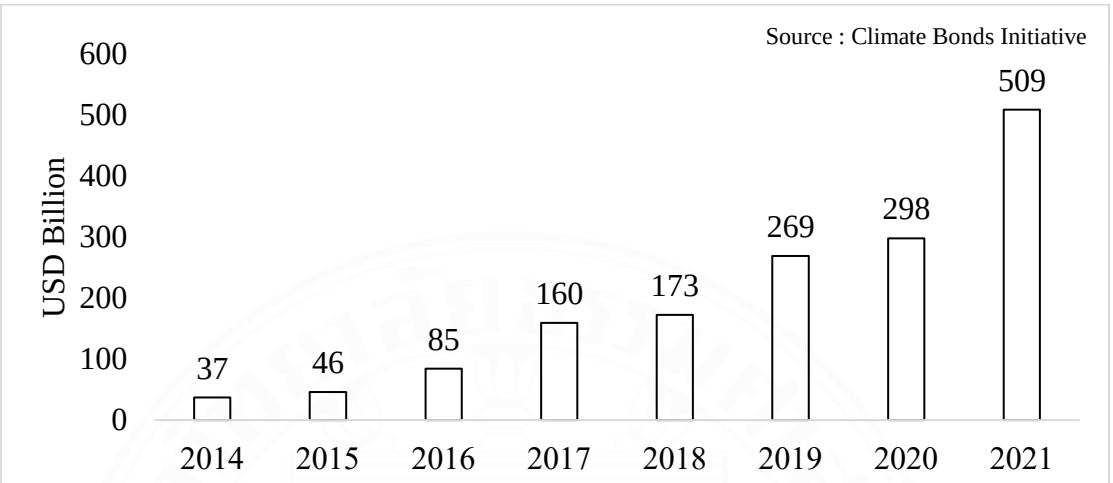
Green bonds are fixed-income securities which dedicated only to projects with environmental advantages such as renewable energy, energy efficiency, pollution prevention and control, sustainable management of natural resources, terrestrial and aquatic biodiversity conservation, clean transportation, and sustainable water management etc. They are a subset of the greater universe of socially responsible investments, including bonds and stocks issued by companies defined by Environmental, Social, and Governance (ESG) norms. According to the Organization for Economic Co-operation and Development (OECD) (2016), green bonds are differed from conventional bonds in that the money obtained will be only used to finance or refinance green initiatives, assets, or business operations.

The first green bond[1] issuance began in June 2007 with the amount of EUR 600 million. Climate Awareness Bond issued by the European Investment Bank, follow by the World Bank which issued its first green bond in 2008 with a SEK 2,300 million. Green bonds have an explosive growth in recent years, with more than USD 1,576 billion in outstanding issues as of December 2021. Figure 1.1 shows the amount issued of global green bonds during 2014 – 2021.

[1] The European Investment Bank (EIB)'s first green bond was a EUR 600 million senior unsecured climate awareness bond issued on 22 May 2007 (pricing date) with a first settlement date on 28 June 2007. It had a 5-year maturity, was fully capital-protected and offered a minimum redemption of 105% at maturity. It was issued as a zero-coupon bond. The EIB linked returns to the then newly set up FTSE4Good Environmental Leaders Europe 40 index. In a special feature, investors were able to use part of the returns towards cutting greenhouse gas emissions via carbon allowances.

Figure 1.1

Amount Issued of Global Green Bonds during 2014 – 2021



This study is mainly focus on Asia-Pacific and Europe markets. From 2014 to 2021, Asia-Pacific markets have the world's highest compound annual growth rate (CAGR) of 118% with the cumulative amount issued of USD 371 billion. Conversely, Europe markets contribute CAGR of only 69% with the world's largest cumulative amount issued of USD 738 billion. Figure 1.2 shows the cumulative size of global green bonds by region during 2014 – 2021 and Figure 1.3 shows the CAGR of global green bonds by region during 2014 – 2021.

Figure 1.2

Cumulative Size of Global Green Bonds by Region during 2014 – 2021

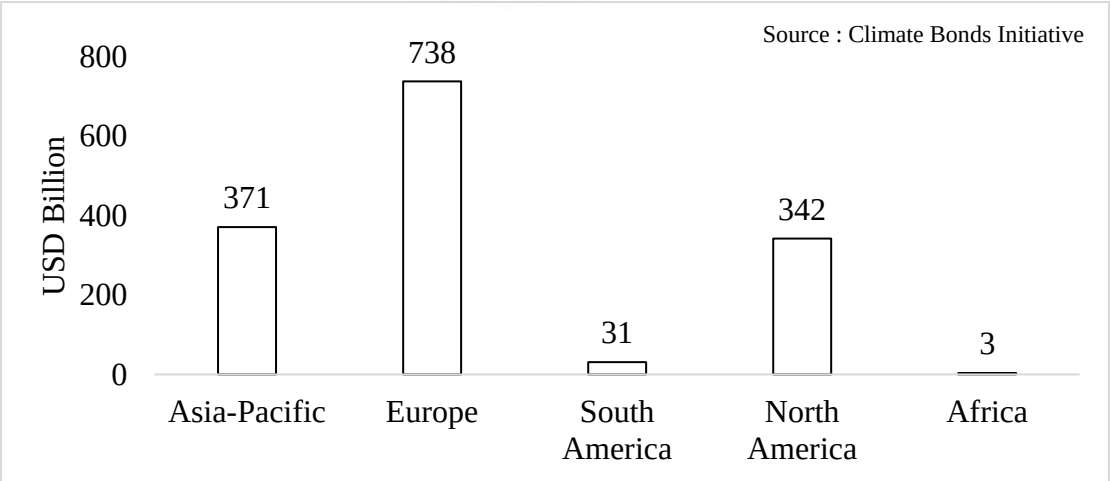
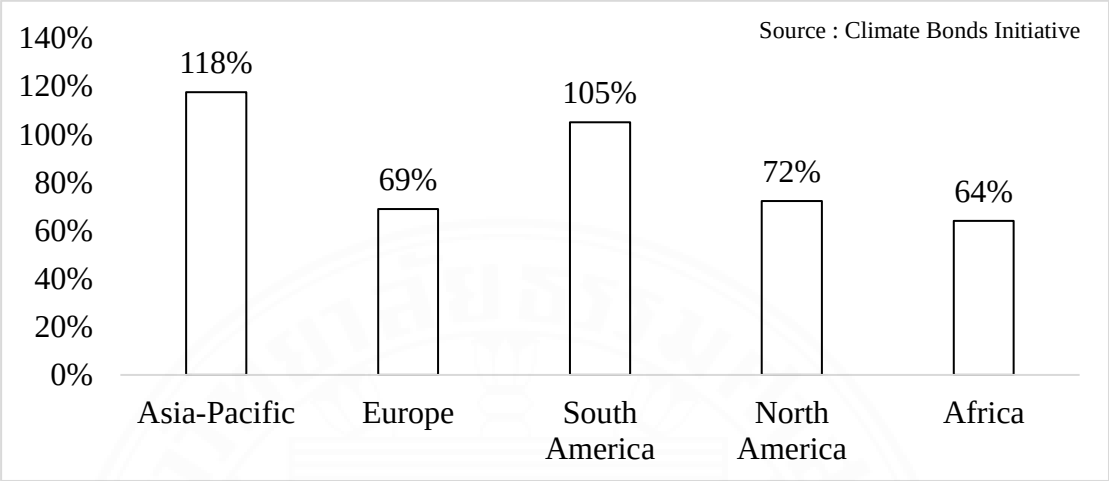


Figure 1.3

CAGR of Global Green Bonds by Region during 2014 – 2021



China has the largest green bond issuance size in Asia-Pacific markets, with USD 199.1 billion, followed by Japan and South Korea with USD 37.7 billion and USD 22 billion, respectively. In Europe, France has the largest green bond issuance with USD 167.2 billion, followed by Germany and the Netherlands with USD 157.1 billion and USD 78.8 billion, respectively. Figure 1.4 and 1.5 shows the cumulative amount issued of green bond by top 10 countries in Asia-Pacific and Europe.

Figure 1.4

Cumulative Amount Issued by Top 10 Countries in Asia-Pacific

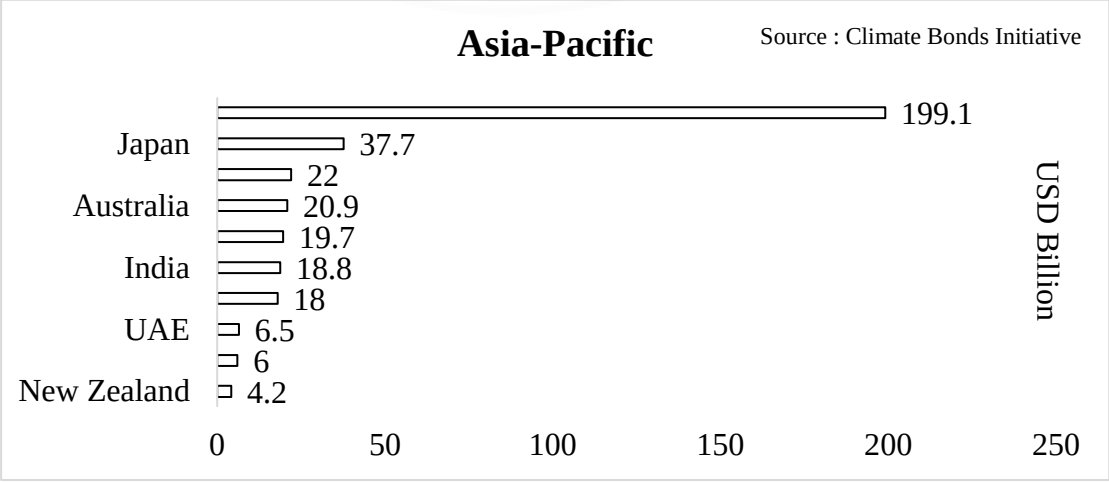
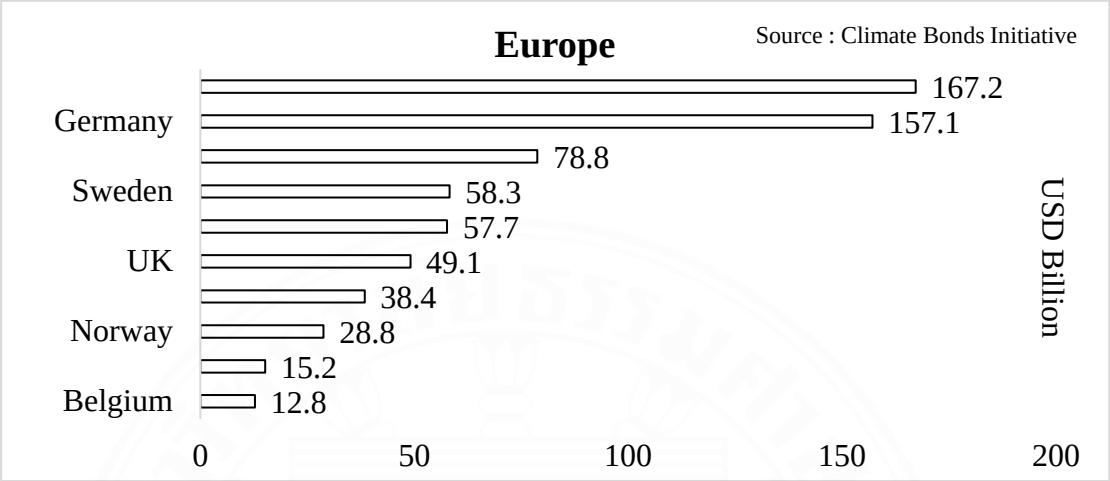


Figure 1.5

Cumulative Amount Issued by Top 10 Countries in Europe



Thanks to the advancements in standards, particularly the introduction of the Green Bond Principles in 2014, Green Bond Principle is the acknowledged standard and is a voluntary procedural guideline created by essential market players and proposed by the International Capital Market Association in Zurich (ICMA). They consist of four basic components that enable transparency and accountability in the development of green bond markets. These components are use of funds, management of proceeds, project appraisal and selection process, and reporting. ICMA specify the topics of the projects sponsored by the funds and the administration of these funds, which should be monitored appropriately via a transparent approach.

Green bond market expansion has revealed a robust movement toward pro-environmental preferences among bond issuers and investors. The “green bond premium” which is defined as the difference between the yields on a green bond and a conventional bond is existed (Agliardi, E & Agliardi, R., 2019). There is an evidence that green bonds are trading at a lower yield (or higher price) than conventional bonds with similar characteristics. This can be implied that an investor is willing to forego their return and ready to accept a lower yield for a “green label” asset. This notion has non-financial benefits for investors, which are obvious for a more in-depth analysis of the determinants of the green premium, which is the focus of this study.

The challenge for investors is whether the green label affects the price at which they are willing to pay for a bond, i.e., whether they are willing to accept a lower yield spread for a green bond compared to a conventional bond with similar characteristics.. Throughout the present study, the word premium to refer to the bond's additional yield due to its green characteristic. There seems to be no fundamental reason for the green label to alter the yield of a green bond because green bonds have the same the default risk of the issuer or a liquidity premium, and the holders of green bonds have no extra rights to the underlying projects and is subject to the same market dynamics.

1.2 Research Questions

Our study is motivated by the ongoing debate about the willingness of investors to pay a premium or accept lower yields for a green bond compared to an otherwise identical conventional bond. Therefore, we design three research questions as follow**;**

1. Is there an existing of negative green bond premium?
2. Does the green bond premium in Asia-Pacific market differs from Europe market due to market structure or environmental preference differences?
3. Do green bonds have a lower risk than conventional bonds? and What are determinants affecting green bond yield?

1.3 Research Objectives

To get a deeper understanding of the yield of green bonds comparing to the conventional bonds and understanding about investors' preferences, this study objectives are as follows;

1. Provides the evidence of a negative green bond premium in the Asia-Pacific markets and Europe markets.
2. Provides the rationale of the difference of the green bond premium between Asia-Pacific and Europe markets regarding market structure or environmental preference.
3. Evaluate the risks of green bonds and conventional bonds and analyze the determinants that affects green bond yield.

1.4 Justification of the study

Menz, K.M. (2010) state that since many firms turn to debt, more research should focus on the debt market rather than the equity market and Junkus, J. & Berry, T.D. (2015) suppose that green bonds are a kind of the alternative investment vehicles that requires more research. The present study findings can provide significant implications for the future development of the green bond markets, particularly for the Asia-Pacific and Europe bond markets. The existing of a green premium in the primary and secondary markets represents that an investor demands for pro-environmental initiatives, resulting in more financing benefits.

In this study, we use green bonds and conventional bonds that issued over the past 6 years during 2016 – 2021 we use a universe of bonds that were issued in Asia-Pacific markets such as China, Japan, Australia, Republic of Korea, Singapore, and others, as well as a universe of bonds that were issued in Europe markets such as France, Germany, the Netherlands, Sweden, and Spain, and others. This study might initiate the bond pricing theory by implying that future bond pricing should consider more about the non-parametric factors.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Green Bond Markets in Asia-Pacific

According to various statistics, more than doubled of Asia Pacific issuers are connected to the ESG in 2020, reaching a record of USD 69 billion, as they tried to improve their sustainability credentials while also tapping into solid investor demand (Anwar, R., & Malik, J. A. (2020); Sustainalytics, (2021)). Bankers predict that the trend will continue, increasing their fee revenue. Some of the world's largest investment banks are increasing the size of their teams to deal with the rising number of ESG-related bond sales (Almeyda, R., & Darmansyah, A. (2021)). For the first time in two years, ESG-related issuances from firms, governments, and other institutions in Asia-Pacific (excluding Japan) have outperformed those from issuers in the United States. Asia-Pacific companies are moving quickly to implement their ESG plans, taking advantage of abundant liquidity and rising demand from global investors eager to increase their exposure to the region as economies recover from the impact of the COVID-19 pandemic, which is being addressed by the increasing rollout of vaccinations (Reuters, 2021). The most prevalent ESG bond issued in the Asia Pacific this year, according to data from Reuters, was the green bond, which accounted for 70%of the transactions and was followed by sustainability-linked bonds which accounted for 20% of the deals. Companies in China accounted for 51.3% of the region's green bond issuance, putting them ahead of South Korea, which accounted for 21.2%.

2.2 Evidence of Green Bond Premium

Due to market maturity, it is now possible for market observers to investigate green bond characteristics, especially with the introduction of green bond indexes that improve the quality and availability of green bond data. The first such index was introduced by the Climate Bonds Initiative (CBI) in 2013, preceded by Bloomberg in 2014.

Several authors indicate their studies regarding the evidence of the existence of green bond premium. The supportive results are, Löffler, K.U., et al., 2021 find that the green bond premium is existed and yield for green bonds is, on average, 15–20 basis points lower than that of conventional bonds in primary markets. MacAskill, S., et al . (2020) find the existence of a green bond premium is 56% of primary market and 70% of secondary market and discover that green bond premium varies widely for the primary market and on average -1 to -9 basis points on the secondary market. Zerbib, O. (2019) finds the yield of green bonds is lower than that of conventional bonds on average -2 basis points. Kapraun, J. & Scheins, C. (2019) find 18 basis points lower yields at issuance for green bonds than conventional bonds. Gianfrate, G. and Peri, M. (2019) (2020) find that green bond premium in the corporate bond sector, estimated between -14.8 and -19.4 basis points and Fatica et al. (2019) find a negative yield spread between global green and conventional bonds between −17 basis points and −29 basis points.

Conversely, there are some argumentative results which, Wensaas, E. & Wist, J.B. (2019) find that there is no statistically significant difference in the yield between green and conventional bonds. Bachelet et al. (2019) find the green bond premium is positive, ranging from 2 bps to 6 basis points. in relation to the sizes of the estimated yield spread on the primary market, however, those on the secondary market are around half that size. Nanayakkara, M. and Colombage, S. (2019) find the green bond premium is 63 basis points as against a comparable corporate bond issue. Finally, Partridge, C. & Medda, F.R. (2020) find a green bond premium that grows to nearly 5 basis points in the secondary market by 2018. While no statistically significant differences in green bond premium were observed in the primary market, they found that during 2017 and 2018, in the cases where paired bonds were issued, there are pricing differences. Table 2.1 summarizes the findings of the evidence of the green bond premium from previous studies.

Table 2.1 Summary of the Evidence of Green Bond Premium

Authors	Data	Methodology	Results
Löffler, K.U., et al., (2021)	Global 2,000 green bonds and 180,000 conventional bonds issued between 2007 and October 2019	Propensity Score Matching and Coarsened Exact Matching	Average negative 15-20 basis points of green bond premium
MacAskill, S., et al . (2020)	Journal articles and industry reports published between 2007-2019	Three-step processes	Varies green bond premium on the primary market and on average negative 1-9 basis points of green bond premium on the secondary market
Zerbib, O. (2019)	Global 1,065 green bonds and 2 synthetic conventional bonds for each green bond issued between July 2013 and 2017	Direct matching method, followed by a two-step regression	Average negative 2 basis points of green bond premium
Kapraun, J. & Scheins, C. (2019)	408,997 ISINs of green bonds and conventional bonds	Yield spread	Average negative 18 basis points of green bond premium
Gianfrate, G. & Peri, M. (2019)	121 European green bonds and 2,815 European conventional bonds issued between 2013 and 2017	Propensity score matching	Average negative 14.8 – 19.4 basis points of green bond premium

Table 2.1 Summary of the Evidence of Green Bond Premium (Cont.)

Authors	Data	Methodology	Results
Fatica et al. (2019)	1,397 green bonds and 271,312 conventional bonds issued between 2007 and 2018	Standard equation for bond yields	Average negative 17 - 29 basis points of green bond premium
Wensaas, E. & Wist, J.B. (2019)	All Nordic 77 green bonds and 154 conventional bonds issued between 2013 and 2016	Direct matching method, followed by a two-step regression	Green bond premium is not existed
Bachelet et al. (2019)	89 bond couples with selected crucial characteristics	One to one matching	Average positive 2 - 6 basis points of green bond premium
Nanayakkara, M. and Colombage, S. (2019)	82 green bonds and 43 conventional bonds issued between 2016 and 2017	Hybrid approach (pure fixed-effects and pure random-effects methods)	Average positive 63 basis points of green bond premium
Partridge, C. & Medda, F.R. (2020)	Green municipal bonds and conventional municipal bonds in US issued in 2014, 2015, and the first half of 2016	Svenson technique	Green bond premium is not existed on primary market and average positive 5 basis points of green bond premium on secondary market

According to our hypotheses, we would like to discover whether there is a negative green bond premium in Asia-Pacific and Europe markets, as well as provide the explanation if the green bond premium in Asia-Pacific markets and Europe markets is difference. Even though many of the previous studies support these hypotheses, it is

unable to draw any conclusions because some arguments claim that there is a positive green bond premium while others claim that there is no green bond premium based on various observations in each study.

2.3 Bond Yield's Volatilities

Several authors reveal their studies regarding to the risk in relevance to the bond's yield. The only supportive result is Bachelet et al. (2019) who discover that green bond yields have higher liquidity and lower volatility compared to conventional bond. While the argumentative results are, Löffler, K.U., et al., (2021) find that the volatility of yields of green bonds is not lower, and potentially even higher, than conventional bond. Zerbib, O. (2019) and Wensaas, E. & Wist, J.B. (2019) find that there is no solid evidence of difference in volatility of in the yield between green and conventional bonds. Pham, L. (2016) finds that the green bonds experience large volatility clustering while the pattern of volatility clustering is weaker for conventional bond and found that a shock in the overall conventional bond market tends to spill over into the green bond market, where this spillover effect is variable over time. Table 2.2 summarizes the findings of the bond yield's volatilities from previous studies.

Table 2.2 Summary of the Bond Yield's Volatilities

Authors	Data	Results
Bachelet et al. (2019)	89 bond couples with selected crucial characteristics	Green bond yields have lower volatility compared to conventional bonds
Löffler, K.U., et al., (2021)	Global 2,000 green bonds and 180,000 conventional bonds issued between 2007 and October 2019	Green bond yields have higher volatility compared to conventional bonds
Zerbib, O. (2019)	Global 1,065 green bonds and 2 synthetic conventional bonds for each green bond issued between July 2013 and 2017	No solid evidence of difference in volatility

Table 2.2 Summary of the Bond Yield's Volatilities (Cont.)

Authors	Data	Results
Wensaas, E. & Wist, J.B. (2019)	All Nordic 77 green bonds and 154 conventional issued between 2013 and 2016	No solid evidence of difference in volatility
Pham, L., (2016)	S&P Green Project Bond Index and US Aggregate Bond Index between April 2010 and April 2015	Green bonds experience large volatility clustering while the pattern of volatility clustering is weaker than conventional bonds

In this study, we intend to identify whether green bonds are less risky than conventional bonds which affected the existing of green bond premium. Due to previous studies, it cannot be concluded that the volatility of yields of green bonds are lower than the conventional bonds.

2.4 Investor's Preference

Generalizing from a broad perspective, the growth of the green bond market corresponds to an increasing trend towards corporate social responsibility (CSR) practices among public and private organizations, as well as increasing demand for socially responsible investment products among investors (Febi, W., et al., 2018). Zerbib, O. (2020) claims that in equilibrium, asset returns decrease for green assets because sustainable investors accept a lower return to hold them, and investors are willing to forgo owing to their non-pecuniary preferences. Agliardi, E & Agliardi, R. (2021) use a modified Epstein-Zin utility function and find the effect of investors' non-pecuniary preferences for environmental quality on portfolio allocation. The introduction of green biases in the utility function may revert the preference in favor of bonds that are less remunerative but more environmental-friendly. Moreover, MacAskill, S., et al. (2020) explain that a portion of investor is willing to pay a higher price for green bonds, and therefore accept a lower yield for a green bond versus a comparable conventional bond and also because green bonds are a relatively new financial construct, investors may be seeking to reduce their risk-profile by focusing on lower risk assets.

Green finance has a variable definition in rich and developing countries, depending on their objectives; for example, coal finance is considered green in China but not in Europe (Gilchrist, D., et al. 2021). In terms of volume, Europe market leads, followed by the Asia-Pacific and North American market (Cheong, C. & Choi, J. 2020). Using network analysis, Halkos, G., et al., (2020) discover that European countries including Germany, Sweden, Luxembourg, the Netherlands, France, and the United Kingdom are the primary suppliers of green bonds in terms of frequency and volume. Emerging market economies issue more green bonds than developed economies (Chiesa, M. & Barua, S. 2019). They also discover that the impact elements of issue size vary across emerging and non-emerging economies, which both economies were influenced by the bond's coupon rate and Euro-currency denomination. In an emerging market, however, the bond's coupon rate has a beneficial impact. China's bond market influence and leadership role in emerging economies, on the other hand, has a negative impact on the non-emerging market. Only non-emerging economies have a substantial impact on the issuer sector, financial indicators, and bond rating. On the other hand, the maturing market is influenced by maturity and pari passu.

Table 2.3 Summary of the Investor's Preference

Authors	Explanation on investor's preference
Febi, W., et al., (2018)	Increasing trend towards corporate social responsibility increase demand for socially responsible investment products among investors.
Zerbib, O. (2020)	Sustainable investors will accept a lower return to hold green assets and willing to forgo owing interest.
Agliardi, E & Agliardi, R. (2021)	Green utility function biases may revert the preference in favor of bonds that are less profitable but more environmentally friendly.
MacAskill, S., et al. (2020)	Some investors are willing to pay a higher price for green bonds, and accept a lower yield compared to conventional bonds.
Gilchrist, D., et al. (2021)	Green finance has a variable definition in rich and developing countries, depending on their objectives for example, coal finance is considered green in China but not in Europe.

Table 2.3 Summary of the Investor's Preference (Cont.)

Authors	Explanation on investor's preference
Cheong, C. & Choi, J. (2020)	In terms of green bond volume, the European market leads, followed by the Asia-Pacific and North American markets.
Halkos, G., et al., (2020)	European countries and the United States are the primary suppliers of green bonds in terms of frequency and volume.
Chiesa, M. & Barua, S. (2019)	Emerging market economies issue more green bonds than developed economies and the impact elements of issue size vary across emerging and non-emerging economies. Both were influenced by the bond's coupon rate and euro denomination.

2.5 Determinants Affecting Green Bond Premium

2.5.1 Social Determinants

Socially responsible investment (SRI) strives to assist socially beneficial firms, which increasingly includes climate change mitigation activities. In the past, publicly lead initiatives by social investors, taking a stance against profit from war, alcohol, tobacco, gambling, and social injustice among others. In 1986, social forces for environmental sustainability have gained strength, coinciding with the Chernobyl nuclear power plant tragedy and the Exxon Valdez oil spill, which is considered one of the greatest environmental disasters in the United States history. Many firms' approach to collect problems regarding a significant to society are being measured using ESG standards, which are connected to CSR and SRI aims.

Recently, government-supported measures in the form of SRI regulatory framework and there is a widespread support among institutional investors. A number of these approaches have been implemented, including expanded product disclosure rules and tax breaks for market players who are pursuing SRI goals (Reneboog, L., et al., 2008). Because they are vulnerable to society norms, investment products that violate the fundamental beliefs of SRI principles, sometimes known as a sin stock have less institutional ownership than other types of investments (Hong, H. & Kacperczyk, M., 2009). According to Gupta, S. (2015), the emergence of ethical consumerism, which manifests in some individuals' proclivity to rationalize purchase

decisions, is linked to these developments, even at the expense of higher costs, to make purchases that are more in line with environmental concerns and personal values. In contrast, Bollen, N.P.B. (2007) finds that investors may have a multi-attribute utility function that is not just based on the conventional risk-reward optimization model but also integrates a set of personal and social values.

Green bonds provide a bridge between issuers for CSR goals and SRI interests, particularly when it comes to environmental concerns. Green bonds could provide market participants with a certain level of community recognition and reputational respect. For both the issuer and the investors, association with green bonds provides a level of social capital. Although social capital as a concept is difficult to quantify, firms that engage in CSR activities have been found to have beneficial economic consequences.

2.5.2 Economic determinants

The economic drivers of the green bond premium have been well documented in the literature, and they have mainly been attributed to a lack of supply of green-labeled investment products, particularly considering growing interest in green issues, which has resulted in a scarcity premium being paid for green securities.

Reboredo, J.C. & Ugolini, A., (2019) and Pham, L., (2016) claim that green bonds provide benefits in terms of diversification and, as a result, reduced risk for bond investors. Preclaw, R., & Bakshi, A., (2015) conclude that green bonds are less hazardous and volatile than conventional bonds, especially when the narrower spreads are compared to risk-adjusted returns. Preclaw, R., & Bakshi, A., (2015) also notice that because long-term investors are substantially represented in the green bond market, their presence may result in lesser liquidity among green bond issuances and, thus, more excellent price stability.

For issuers, Derwall, J., et al., (2005) and Kempf, A. & Osthoff, P., (2007) find that the firms heavily involved in CSR have been proven to have favorable stock returns. Tang, D.Y., & Zhang, Y., (2018) finds that corporate announcements of green bond issuance had beneficial impacts on the stock prices of the company that made the news, resulting in a cumulative anomalous return within ten days of making the announcement.

2.5.3 Environmental determinants

Environmental factors are linked to both the economic and social causes listed above since they are offered on a broader degree of linkage. Green bonds, in theory, provide a framework for establishing a verified and measured impact on environmental concerns through third-party verification, in a form that is consistent with environmental, social, and governance reporting principles

MacAskill, S., et al. (2019) discover the fact that green bonds are invested in a diverse variety of ecologically beneficial assets, ranging from solar power production to "green" affordable housing, means that investors will be better positioned to implement targeted climate change mitigation activities. Baker et al., (2018) and Hyun et al. (2019) conclude that the voluntary non-financial disclosure of proceeds is a key component in determining green bond market prices; the pricing benefits often outweigh the costs. Hyun et al. (2019) finds that green bonds with an independent third-party reviewer have 7 basis point green premium. This green premium is particularly obvious for green bond issuances that have both an independent third-party reviewer and CBI accreditation. Investors and issuers alike place a high value on ESG impact reporting, according to evidence from the support of nonfinancial disclosure.

2.5.4 Cost of Capital

For issuer’s perspective, Chunlian, Z. et. al (2021) indicate that the better the environmental performance of the issuer's region, the lower the financing cost of green bonds, and the third-party certification reduces the financing cost of green bonds. Zerbib, O. (2020) explain that issuer pay a price to mitigate their environmental impact and increase their shareholder base, thereby lowering their cost of capital. Agliardi, E & Agliardi, R. (2021) suggests that issuers’ creditworthiness depends on the correlation of the green project with the core business of the firm allows benefits in the form of a lower cost of capital that firms may obtain.

Table 2.4 Summary of the Determinants Affecting the Green Bond Premium

Factors	Explanation	Authors
Social	Investment products that violate the fundamental beliefs of SRI principles, sometimes known as a sin stock have less institutional ownership than other types of investments.	Hong, H. & Kacperczyk, M., (2009)
	The emergence of the ethical consumerism is related to these developments even at the expense of higher costs, to make purchases that are more in line with environmental concerns following personal values.	Gupta, S. (2015)
	Investors may have a multi-attribute utility function that is not just based on the conventional risk-reward optimization model but also integrates a set of personal and social values.	Bollen, N.P.B. (2007)
Economic	Green bonds provide benefits in terms of diversification and, as a result, reduced risk for bond investors.	Reboredo, J.C. & Ugolini, A., 2019; Pham, L., (2016)
	Green bonds are less hazardous and volatile than conventional bonds, especially when the narrower spreads are compared to risk-adjusted returns.	Preclaw & Bakshi (2015)
	The firms heavily involved in CSR have been proven to have favorable stock returns.	Derwall, J., et al., (2005; Kempf, A. & Osthoff, P., (2007)
	Corporate announcements of green bond issuance had beneficial impacts on the stock prices of the company that made the news.	Tang, D.Y., & Zhang, Y., (2018)

Table 2.4 Summary of the Determinants Affecting the Green Bond Premium (Cont.)

Factors	Explanation	Authors
Environmental	Green bonds are invested in a diverse variety of ecologically beneficial assets, means that investors will be better positioned to implement targeted climate change mitigation activities.	MacAskill, S., et al. (2019)
	The voluntary non-financial disclosure of proceeds is a key component in determining green bond market pricing benefits often outweigh the costs.	Baker et al., (2018) and Hyun et al., (2019)
	Green bonds with an independent third-party reviewer have 7 basis point green premium.	Hyun et al., (2019)
Cost of capital	The better the environmental performance of the issuer's region, the lower the financing cost of green bonds.	Chunlian, Z. et. al (2021)
	Issuer pay a price to mitigate their environmental impact and increase their shareholder base, thereby lowering their cost of capital.	Zerbib, O. (2020)
	Issuers' creditworthiness depends on the correlation of the green project with the core business of the firm allows benefits in the form of a lower cost of capital that firms may obtain.	Agliardi, E & Agliardi, R. (2021)

2.6 Theoretical Framework

We cite two theoretical frameworks which proposed the rationales of the difference of yields of green bonds and conventional bonds. The first framework is related to investor preferences, Fama, E.F. & French, K. (2007) indicate that investors consider both expected payoff and the taste for assets as consumption goods for their investment, Fatica et al. (2019) express that there might be an opportunity that investors prefer to participate in environment friendly investment. Thus, if the investors are in favor of the assets, they will accept the lower yield of the green bonds because of the

"Green Label" of the bond. The second framework is related to the asset pricing theory, Fama, E.F. (1998) explain that market efficiency should concerned on long-term returns of assets are in accordance with reasonable changes in future. It can be implied that green bonds have lower risk than conventional bonds because 1) green bonds are regularly monitoring their use of funds which can minimize default risk and avoided greenwashing and 2) green bonds are mostly issued by investment grade issuers. Thus, green bonds are priced with lower yields.

2.7 Hypothesis Development

In this study, we employ Propensity Score Matching (PSM) approach and Coarsened Exact Matching approach (CEM) which CEM is a more robust non-parametric matching method which can reduce bias of covariates and dependency of model (Löffler, K.U., et al., 2021). CEM is a new powerful method across a wide range of applications to many observational data that can improve the causal effects estimation (Blackwell, M., Iacus, S., King, G. & Porro, G., 2010) and CEM result is much better than the other methods and can solve the issue of model dependence and bias. (Iacus, S., King, G. & Porro, G., 2011). Therefore, CEM is implied to be a better alternative approach than past studies.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Data and Description

In this study, we use Bloomberg, as well as the CBI, to retrieve all available corporate green bond and corporate conventional bonds data in Asia-Pacific markets and Europe markets.

We select the bonds that only issued in Asia-Pacific and Europe markets from January 2016 until December 2021. The bond's characteristics we retrieved comprise of face value, amount issued, year of issuance, currency, tenor, issuer's sector, maturity type, issuer rating, yield to maturity at issuance, annualized ask yield and annualized volatility. Some bonds with missing data are trimmed off. Furthermore, we retrieve external review which is a green-bond verification from an external party from the CBI.

Finally, our sample includes 282 green bonds and 8,729 conventional bonds in Asia-Pacific markets and 488 green bonds and 8,151 conventional bonds in Europe markets. Tables 3.1-3.8 display data descriptive findings of the sample of green and conventional bonds in both markets (GBs = Green bonds and CBs = Conventional bonds).

Table 3.1 Currency of Bond Issuance

Asia-Pacific						
Currency	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
JPY	82	29.1%	1,069	12.7%	1,151	13.2%
USD	49	17.4%	1,242	14.7%	1,291	14.8%
KRW	46	16.3%	1,800	21.3%	1,846	21.1%
CNY	35	12.4%	2,066	24.5%	2,101	24.1%
TWD	22	7.8%	351	4.2%	373	4.3%
EUR	18	6.4%	258	3.1%	276	3.2%
AUD	8	2.8%	413	4.9%	421	4.8%
NZD	7	2.5%	126	1.5%	133	1.5%
INR	6	2.1%	618	7.3%	624	7.1%
HKD	4	1.4%	140	1.7%	144	1.6%
Others	5	1.8%	364	4.3%	369	4.2%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Note: Japanese Yen (JPY), US Dollar (USD), Korea Won (KRW), Renminbi (CNY), Taiwan Dollar (TWD), Euro (EUR), Australian Dollar (AUD), New Zealand Dollar (NZD), Indian Rupee (INR) and Hong Kong Dollar (HKD)

Table 3.1 Currency of Bond Issuance (Cont.)

Europe						
Currency	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
EUR	241	49.4%	4,664	60.9%	4,905	60.2%
SEK	146	29.9%	190	2.5%	336	4.1%
NOK	26	5.3%	114	1.5%	140	1.7%
USD	26	5.3%	1,527	19.9%	1,553	19.1%
AUD	10	2.0%	158	2.1%	168	2.1%
GBP	9	1.8%	521	6.8%	530	6.5%
TRY	7	1.4%	2	0.0%	9	0.1%
CHF	6	1.2%	156	2.0%	162	2.0%
JPY	4	0.8%	202	2.6%	206	2.5%
PLN	4	0.8%	3	0.0%	7	0.1%
Others	9	1.8%	126	1.6%	135	1.7%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Note: Swedish krona (SEK), Norwegian Krone (NOK), Pound sterling (GBP), Turkish New Lira (TRY), Swiss franc (CHF), and Polish Zloty (PLN)

Table 3.2 Sectors of Bond Issuers

Asia-Pacific						
Sector	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Financials	113	40.1%	4,847	57.4%	4,960	56.8%
Utilities	50	17.7%	953	11.3%	1,003	11.5%
Consumer Dist	48	17.0%	839	9.9%	887	10.2%
Industrials	23	8.2%	720	8.5%	743	8.5%
Materials	21	7.4%	264	3.1%	285	3.3%
Others	27	9.6%	824	9.8%	851	9.7%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Europe						
Sector	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Financials	339	69.5%	4,515	58.9%	4,854	59.6%
Utilities	87	17.8%	2,890	37.7%	2,977	36.5%
Industrials	10	2.0%	89	1.2%	99	1.2%
Materials	8	1.6%	59	0.8%	67	0.8%
Consumer Dist	7	1.4%	22	0.3%	29	0.4%
Others	37	7.6%	88	1.1%	125	1.5%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Table 3.3 Ratings of Bond Issuers

Asia-Pacific						
Issuer Ratings	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Prime	1	0.4%	2	0.0%	3	0.0%
High	62	22.0%	1,024	12.1%	1,086	12.4%
Upper-Medium	105	37.2%	3,153	37.3%	3,258	37.3%
Lower-Medium	105	37.2%	3,601	42.6%	3,706	42.5%
Non-Investment	9	3.2%	667	7.9%	676	7.7%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Europe						
Issuer Ratings	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Prime	22	4.5%	776	10.1%	798	9.8%
High	50	10.2%	1,209	15.8%	1,259	15.4%
Upper-Medium	237	48.6%	2,301	30.0%	2,538	31.1%
Lower-Medium	140	28.7%	1,769	23.1%	1,909	23.4%
Non-Investment	39	8.0%	1,608	21.0%	1,647	20.2%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Table 3.4 Maturity Type of Bond Issuance

Asia-Pacific						
Maturity Type	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Straight	254	90.1%	6,879	81.4%	7,133	81.7%
Callable	12	4.3%	710	8.4%	722	8.3%
Puttable	11	3.9%	320	3.8%	331	3.8%
Sinkable	3	1.1%	134	1.6%	137	1.6%
Others	2	0.7%	404	4.8%	406	4.7%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Europe						
Maturity Type	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Straight	328	67.2%	4,263	55.6%	4,591	56.3%
Callable	160	32.8%	3,343	43.6%	3,503	43.0%
Others	-	-	57	0.7%	57	0.7%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Table 3.5 Seniority of Bond Issuance

Asia-Pacific						
Seniority	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Senior	278	98.6%	7,726	91.5%	8,004	91.7%
Subordinated	4	1.4%	614	7.3%	618	7.1%
Junior	-	-	107	1.3%	107	1.2%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Europe						
Seniority	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
Senior	474	97.0%	7,246	94.6%	7,720	94.7%
Subordinated	7	1.5%	26	0.3%	33	0.4%
Junior	7	1.5%	391	5.1%	398	4.9%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Table 3.6 Time to Maturity of Bond Issuance

Asia-Pacific						
Time to Maturity	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
1-5 years	185	65.6%	4,760	56.4%	4,945	56.7%
6-10 years	87	30.9%	2,476	29.3%	2,563	29.4%
11-15 years	3	1.1%	325	3.8%	328	3.8%
16-20 years	2	0.7%	259	3.1%	261	3.0%
>20 years	5	1.8%	321	3.8%	326	3.7%
Perpetuity	-	-	306	3.6%	306	3.5%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Europe						
Time to Maturity	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
1-5 years	183	37.5%	2,052	26.8%	2,235	27.4%
6-10 years	224	79.4%	4,055	52.9%	4,279	52.5%
11-15 years	53	18.8%	890	11.6%	943	11.6%
16-20 years	14	5.0%	310	4.0%	324	4.0%
>20 years	12	4.3%	351	4.6%	363	4.5%
Perpetuity	2	0.7%	5	0.1%	7	0.1%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Table 3.7 Year of Bond Issuance

Asia-Pacific						
Issuer Year	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
2016	4	1.4%	538	6.4%	542	6.2%
2017	28	9.9%	1,095	13.0%	1,123	12.9%
2018	33	11.7%	1,194	14.1%	1,227	14.1%
2019	53	18.8%	2,007	23.8%	2,060	23.6%
2020	56	19.9%	1,849	21.9%	1,905	21.8%
2021	108	38.3%	1,764	20.9%	1,872	21.4%
Total	**282**	**100.0%**	**8,447**	**100.0%**	**8,729**	**100.0%**

Europe						
Issuer Year	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
2016	21	4.3%	881	11.5%	902	11.1%
2017	54	11.1%	1,171	15.3%	1,225	15.0%
2018	66	13.5%	1,348	17.6%	1,414	17.3%
2019	138	28.3%	1,600	20.9%	1,738	21.3%
Europe						
Issuer Year	**GBs**	**%**	**CBs**	**%**	**Total**	**%**
2020	189	38.7%	1,967	25.7%	2,156	26.5%
2021	20	4.1%	696	9.1%	716	8.8%
Total	**488**	**100.0%**	**7,663**	**100.0%**	**8,151**	**100.0%**

Table 3.8 Green Bond Issuance with External Review

External Review	**Sample**	**% of green bonds in region**	**% of total green bonds**
Asia-Pacific	97	34.4%	12.6%
Europe	359	73.6%	46.6%
Total green bonds with External review	**456**	**59.2%**	
Total green bonds	**770**	**100.0%**	

Overall, in Asia-Pacific markets, 40.1% of green bonds are issued by financial sector issuers, whilst 17.7% are issued by utilities sector issuers. JPY (29.1%), USD (17.4%) and KRW (16.3%) contribute majority of the currency. The maturity type and seniority of green bonds are mainly straight and senior, accounting for 90.1% and 98.6% respectively. In term of credit rating, most of green bonds in are Upper-Medium grade (referred to A+, A, and A- of S&P Ratings) (37.2%) and Lower-Medium (referred

to BBB+, BBB, and BBB- of S&P Ratings) (37.2%). On the other hand, conventional bonds have different issuance currencies, with CNY being the most denominated (24.5%) and KRW coming in second (21.3%). Concerning on credit rating, conventional bond issuers have a Lower-Medium grade rating (42.6%), which considerably riskier than green bonds. In term of time to maturity, 65.6% of green bonds will mature within 1-5 years, compared to 56.4% of conventional bonds. However, several characteristics such as issuer's sector, maturity type and seniority are in line with green bond distribution.

For the overview of Europe markets, the issuers in financial sector are prevalent, close to that of Asia-Pacific markets. These findings reflect those financial institutions issue a considerable number of green bonds due to the shift in bank lending toward "green loans," green bond funding for green portfolios, and green issuer transition to less polluting operations (Fatica, S., et al., 2021). EUR (49.4%), SEK (29.9%), NOK (5.3%) are the most common green bond currencies in this region. This coincides to a finding by Maltais, A., & Nykvist, B., (2020) on Swedish issuer's and investor's interest in green bonds as a result of demands to display strong environmental profiles. Straight type (67.2%) and senior class (97.1%) are leading green bond's characteristics. We find that around 48.6% of green bonds are issued from Upper-Medium grade issuers, a quite greater proportion than European conventional bonds as well as Asia-Pacific markets. Another evidence is that the most of green bonds (79.4%) and conventional bonds (52.9%) will mature within 6-10 years, which is considerably longer than Asia-Pacific markets where many bonds will mature in only 1-5 years. Comparing to conventional bonds in Europe markets, the bond's characteristic distribution such as issuer's sector, issuer's ratings, maturity type, seniority is similar to those green bonds. The only distinction is that the major conventional bond currencies are relocated to EUR (60.9%), USD (19.9%) and GBP (6.8%).

In summary, the proceeds of green bond issued by financial sector issuers, are indirectly invested in green projects. Financial sector issuers usually have no incentive to engage in greenwashing, but they can offer green credit to support green projects and have a significant motive to lower the cost of raising capital. Moreover, Green bonds are mainly issued by investment-grade issuers than conventional bonds in both the Asia-Pacific and Europe markets because most of green bond's issuers are

highly credible in terms of a successful integration or achieving of the green projects financed with the proceeds. For green bond issuers, the validity of the green label by third-party verification is notably important (Kapraun, J., et al., 2021). Mostly in the Europe markets, 73.6% of green bonds is verified by the third parties compared to only 34.4% in Asia-Pacific markets. Furthermore, focusing on the investors' demand and the issuers' supply of green bonds, the demand for green investments by ESG investors is expanding at a rapid rate and the investor's need for green bonds to diversify the risk of investment portfolio, regardless of supply. The supply of green bonds is limited due to the lack of widely accepted green definitions, green projects and the weak policies, standards, and regulations (Slimane, M. B., et al., 2020 and Nanayakkaram M., & Colombage, S., 2019). According to the CBI, As of December 2021, the total accumulated supply of Asia-Pacific green bonds is around 371 USD billion, whereas it is doubled in Europe markets amount of 738 USD billion. This evidence indicates some structural difference exists across these bond markets in the meantime.

3.2. Methodology Flowchart

Figure 3.1

Methodology Flowchart

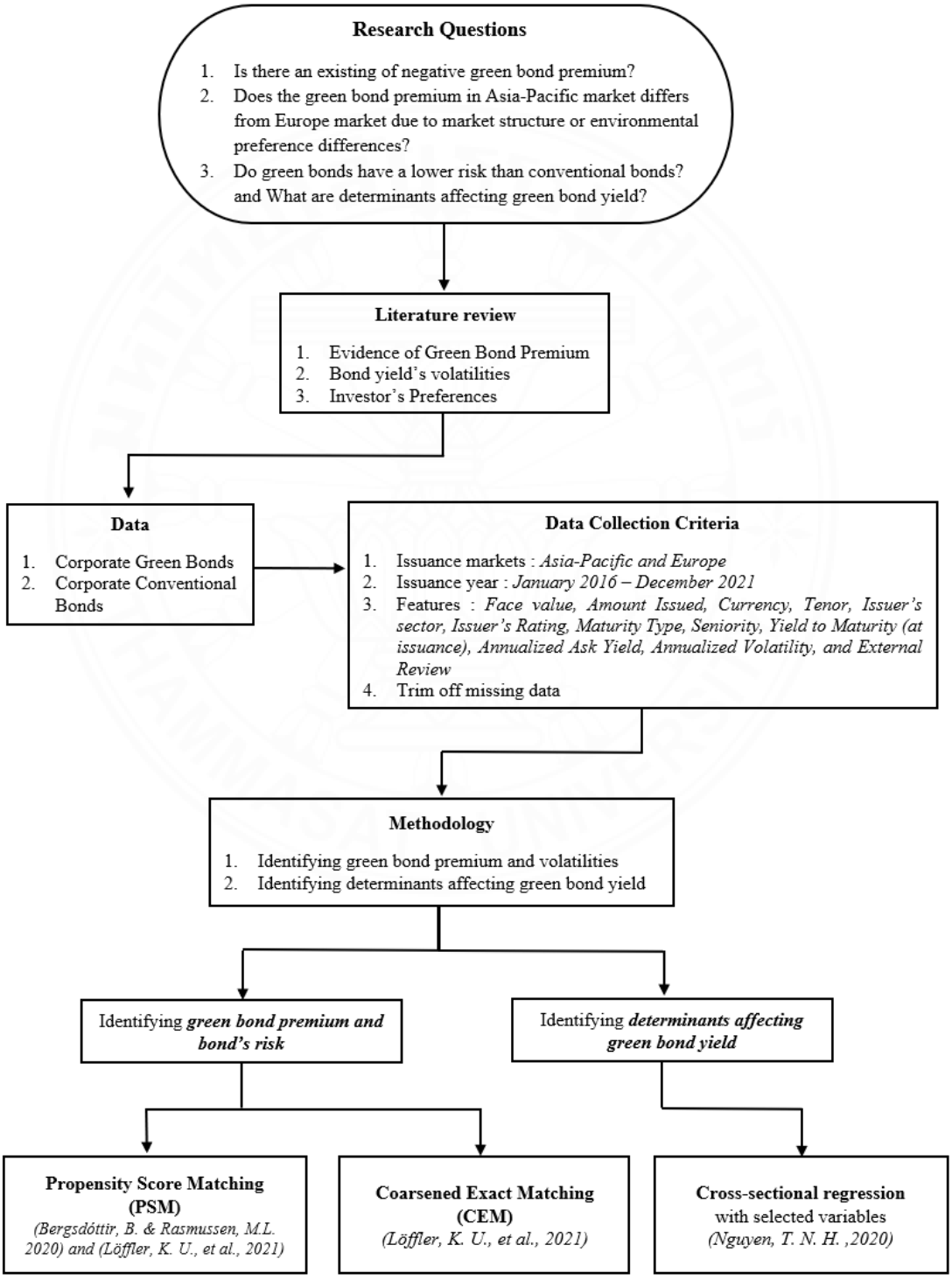
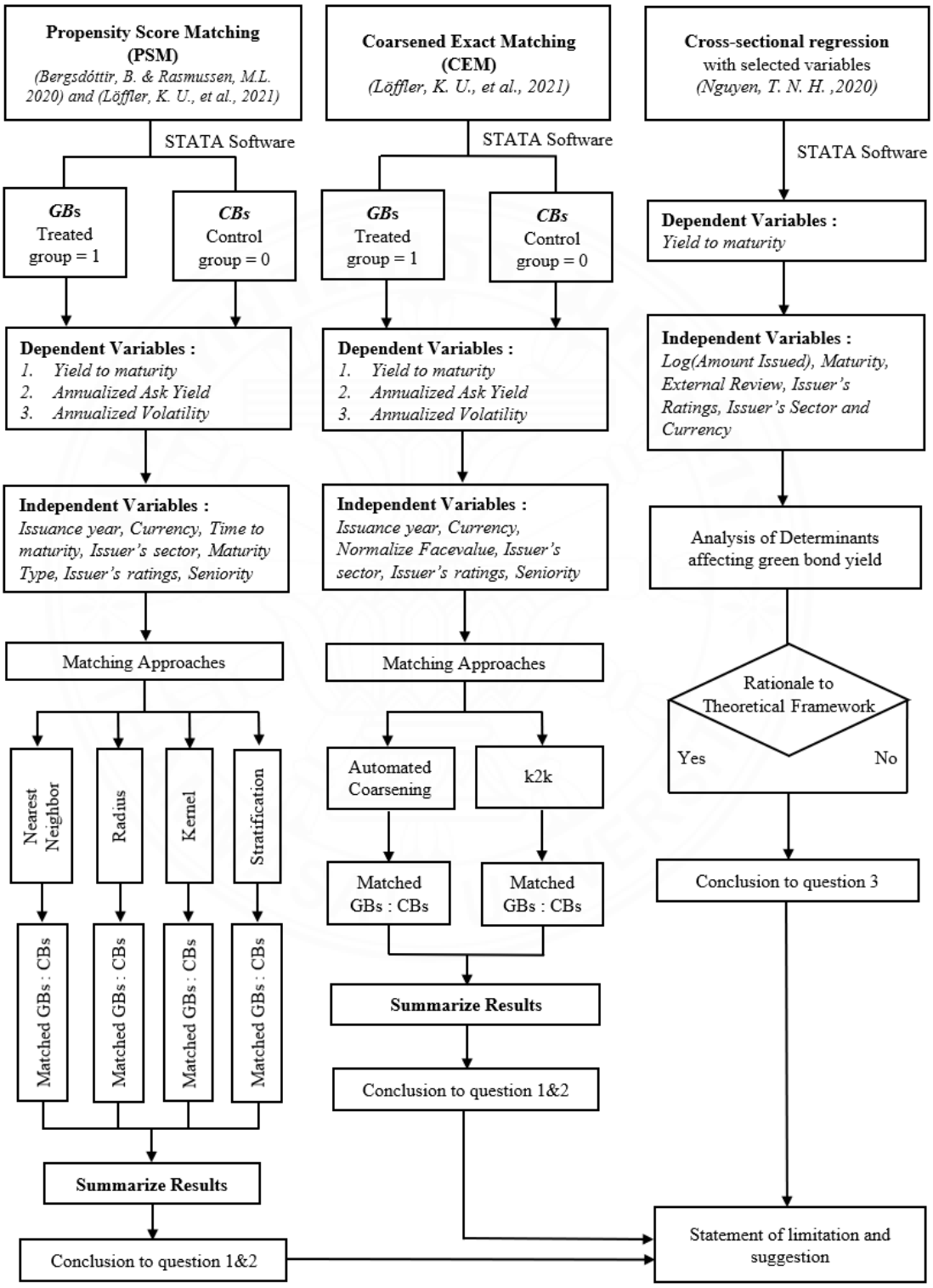


Figure 3.1 (Cont.)

Methodology Flowchart



3.3. Methodology

3.3.1 Matching Approach

Even though green and conventional bonds are issued from the same issuer, there are some differences which are amounted issued, tenor, seniority, face value and coupon rate. We use matching approaches to create comparable samples of green and conventional bonds, expanding on previous study (Zerbib, O., 2019 and Löffler, K.U., et al., 2021). Concerning that the matching approaches can only account for observable factors, non-financial drive such as reputation are not observable, controlled and should be less significant because our sample includes the issuers who issue both type of bonds.

In this study, we employ Propensity Score Matching (PSM) and Coarsened Exact Matching (CEM) to contribute research question 1 and 2. Both approaches provide discrete advantages. For PSM, it is appropriate for empirical settings which there is a treatment effect estimation, a group of treated and a group of control (Gianfrate, G., & Peri, M., 2019). For CEM, previous study (Iacus, S. M., et al., 2012) suggest that CEM is a better alternative to PSM because it eliminates the model dependence of the matching that PSM has and CEM can minimize covariate imbalances between the treated and control groups.

Green bonds are determined as a treated group and conventional bonds are determined as a control group. We need to create a control group that is identical to treated group except the dependent variables which are yield to maturity (at issuance), annualized ask yield and annualized volatility to acquire the best results. However, finding a control group that can match treated group may be a challenge as the number of bond's characteristics selection increases ("curse of dimensionality"). To avoid this problem, we carefully select the key characteristics of the bonds and ensure the adequacy of control group and treated group that can be attributed to those dependent variables.

Specifically, the change in the dependent variables from the treated group is the treatment effect. Therefore, we will estimate the "Average Treatment effect on the Treated" (ATT) for the result.

3.3.1.1 Propensity Score Matching (PSM)

Building on previous study (Bergsdóttir, B. & Rasmussen, M.L., 2020 and Löffler, K.U., et al., 2021), we set up control variables by using issuance year, currency, tenor, issuer's sector, maturity type, issuer's rating, and seniority. Table 3.9 indicates dependent and independent variables used for PSM approach in this study.

Table 3.9 Propensity Score Matching Variables

Dependent Variable (y_i)	Independent Variable (x_i)
1. Yield to Maturity 2. Annualized Ask Yield 3. Annualized Volatility	1. Issuance Year 2. Currency 3. Tenor 4. Issuer's Sector 5. Maturity Type 6. Issuer's Ratings 7. Seniority

The matching approach is based on the propensity score, which is a continuous variable derive through the process of estimating propensity score for green bonds conditional on covariates. After green bonds (treated group) are matched with conventional bonds (control group), The difference between the samples is then estimated by computing the difference of the dependent variables.

To overcome with the curse of dimensionality, for control group, we reclassify some of the bond's characteristic into smaller groups to increase the likelihood of constructing a pair of matched conventional and green bonds. The unmatched characteristics have been eliminated. Table 3.10 represents the reclassification of bond's characteristic for PSM approach.

Moreover, to assess the accuracy of an estimation based on a sample of data from a larger population, we implement bootstrapping, a widely applied effective statistical tool that can be used to quantify the uncertainty associated with a specific estimator (James, G., et al., 2013). Bootstrapping can be used to resample selected dataset, calculate sample statistics and the mean of the sample statistics. Therefore, in our study, we run 100 bootstrap replications in each PSM variable and approach.

Table 3.10 Bond's Characteristic Reclassification for PSM

Asia-Pacific Markets

Characteristic**	Data Distribution	Reclassified Group
Currency	JPY, USD, KRW, CNY, TWD, EUR, AUD, NZD, INR, HKD, SGD, CHF, IDR, SEK*, NOK*, GBP*, CAD*, RUB*, MYR*, ZAR*, KZT*	JPY, USD, KRW, CNY, TWD, Other Currencies
Issuer's Sector	Financials, Utilities, Consumer Discretionary, Industrials, Materials, Technology, Energy, Consumer Staples, Communications, Health Care, Government*	Financials, Utilities, Consumer Discretionary, Other Sectors
Maturity Type	Straight, Callable, Puttable, Sinkable, Call/Sink*, Convertible*, Perp/Call*, Extendible*, Call/Ext*, Sink/Put*, Call/Put*, Conv/Put*	Straight, Callable, Puttable, Sinkable
Issuer's Rating	AAA, AA+, AA, AA-, A+, A, A-, BBB+, BBB, BBB-, BB+, BB, BB-, B+*, B, B-*, CCC+*	Prime (AAA) High (AA+, AA, AA-) Upper-Medium (A+, A, A-) Lower-Medium (BBB+, BBB, BBB-) Non-Investment (Below BBB-)

Note:* Eliminate from sample due to unmatched characteristics between treated group and control group

** No reclassification for Issuance Year, Tenor, Maturity type and Seniority

Table 3.10 Bond's Characteristic Reclassification for PSM (Cont.)

Europe Markets

Characteristic**	Data Distribution	Reclassified Group
Currency	EUR, SEK, NOK, USD, AUD, GBP, TRY, CHF, JPY, PLN, HKD, INR*, IDR*, HUF*, CZK*, RUB, BRL, NZD*, ZAR*, CNY*, CAD*, MXN*, SGD*	EUR, SEK, NOK, USD Other Currencies
Issuer's Sector	Financials, Utilities, Consumer Discretionary, Industrials, Materials, Technology*, Energy, Consumer Staples, Communications, Health Care, Government*	Financials, Utilities, Industrials, Other Sectors
Maturity Type	Straight, Callable, Puttable*, Sinkable*, Call/Sink*, Convertible*, Extendible*, Call/Ext*	Straight, Callable
Issuer's Rating	AAA, AA+, AA, AA-, A+, A, A-, BBB+, BBB, BBB-, BB+, BB, BB-, B+, B*, B-, CCC+*, CCC*, CCC-*	Prime (AAA) High (AA+, AA, AA-) Upper-Medium (A+, A, A-) Lower-Medium (BBB+, BBB, BBB-) Non-Investment (Below BBB-)

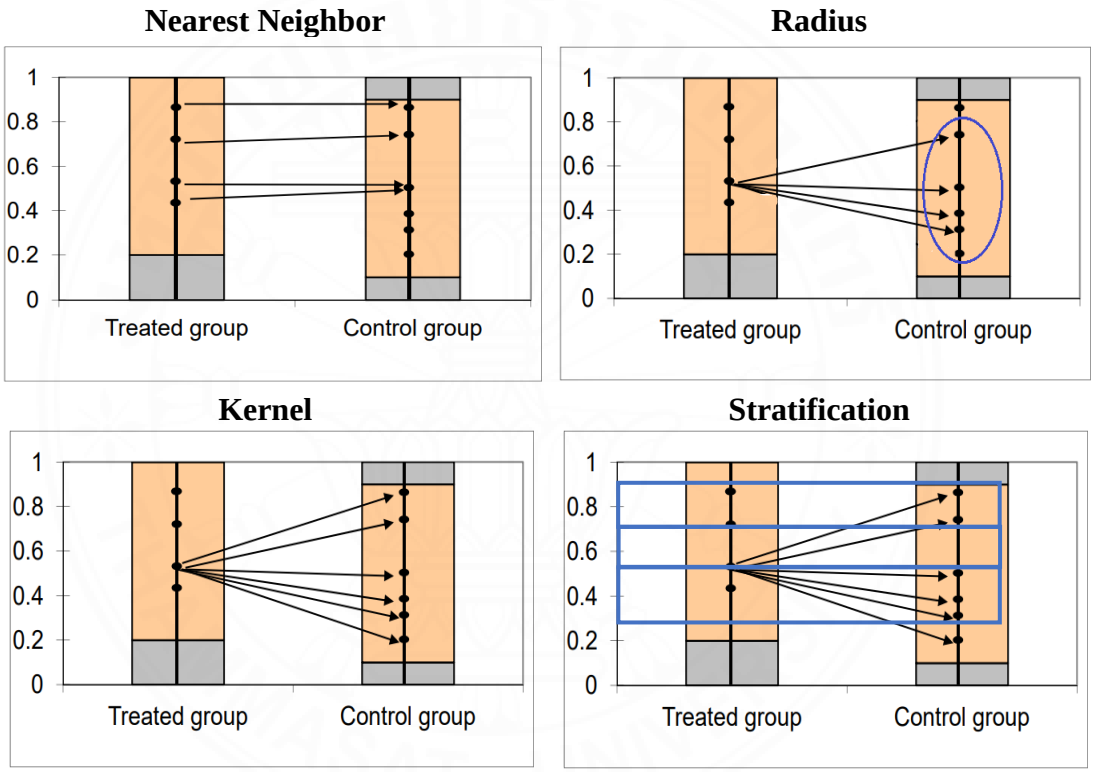
Note:* Eliminate from sample due to unmatched characteristics between treated group and control group

** No reclassification for Issuance Year, Tenor, Maturity type and Seniority

Four matching approaches consisted of Nearest Neighbor, Radius, Kernel, and Stratification (Katchova, A., 2013) are employed. To ensure greater comparability of matched units, a common support of the treated and control group is applied in all estimations.

Figure 3.2

Propensity Score Matching Approaches Framework



(1) Nearest Neighbor

Nearest Neighbor is the most straight forward one. Several control group units are chosen as matching pair for a single treated unit that is closet in terms of propensity score.

(2) Radius

Since Nearest Neighbor can lead to bias and unsatisfying quality if the distribution of propensity score is quite distinct, Radius is introduced to address to this problem. With Radius, the quality of the matches is improved when treated units are matched to control units only if the latter's propensity scores are within

a specified, pre-determined range as we set the radius, which specifies the permissible distance within which units are matched. Conversely, if the distribution of propensity scores is well-balanced between the treated and control groups, the existence of bad matches rises with radius matching compared to Nearest Neighbor.

(3) Kernel

Kernel constructs the alternative outcome by calculating the weighted averages of all units in the control group; the closer a control unit's propensity score is to that of the treated unit, the higher its weight. When more information is used, the variance is reduced, which is a significant benefit. However, when working with Kernel, the potential of bad matches makes correct imposition of the common support critical.

(4) Stratification

The purpose of Stratification is to separate the propensity score's common support into a group of intervals. Then, using the mean difference in outcomes between intervals of the propensity score, calculate the impact within each interval. This approach is also known as blocking, interval matching, or subclassification.

3.3.1.2 Coarsened Exact Matching (CEM)

We employ CEM by building on previous study (Löffler, K.U., et al., 2021). CEM is a method for finding exact matches on the selected variables between data in the treated group and control group. To perform a specific exact matching, we select and classify the bond's characteristics into 6 classes, comprised of currency, normalized face value, issuer's sector, issuer's ratings, seniority, and issuance year. Table 3.11 indicates dependent and independent variables used for CEM approach in this study.

Table 3.11 Coarsened Exact Matching Variables

Dependent Variable (y_i)	Independent Variable (x_i)
1. Yield to Maturity 2. Annualized Ask Yield 3. Annualized Volatility	1. Currency 2. Normalized Face value 3. Issuer's Sector 4. Issuer's Ratings 5. Seniority 6. Issuance Year

Each bond from treated group and control group is coarsened by its characteristics and changed into a set of binary number which a set of binary number of each bond is represented the bond's signature. After each bond is represented by its characteristic coarsened to discrete values by coarsening, a matching pair of bonds with identical binary signature can be created. In other words, for each green bond, the most similar conventional bond is identified. Treated group and control group are normalized the variance. The unmatched bonds are given a weight of 0 and left out meanwhile the matched treated group is given a weight of 1. The matched control group is given a weight calculated by CEM weight which have a maximum value of 1. The CEM weight is calculated by the following equation ; (Given GB = Green bond, CB = Conventional Bond and BIN = Binary Signature).

$$\text{CEM Weight} = \frac{(No.\ of\ Matched\ GB\ with\ BIN\ signature(i))\ x\ (Total\ \ matched\ CB)}{(Total\ \ matched\ GB)\ x\ (No.\ of\ Matched\ CB\ with\ BIN\ signature\ (i))}$$

The L1 statistic, established by Iacus, S. M., et al., (2011) as a measurement of global imbalance, given the overall imbalance. L1 = 0 indicates perfect global balance (up to coarsening), while bigger values imply a greater imbalance between the groups, with L1 having a maximum value of 1.

Again, with CEM, likewise the PSM, the reclassification of the bond's characteristic is required. Table 3.12 represents the reclassification of bond's characteristic for CEM approach.

Table 3.12 Bond's Characteristic Reclassification for CEM

Asia-Pacific Markets

Characteristic**	Data Distribution	Reclassified Group
Currency	JPY, USD, KRW, CNY, TWD, EUR, AUD, NZD, INR, HKD, SGD, CHF, IDR, SEK*, NOK*, GBP*, CAD*, RUB*, MYR*, ZAR*, KZT*	JPY, USD, KRW, CNY, TWD, Other Currencies
Issuer's Sector	Financials, Utilities, Consumer Discretionary, Industrials, Materials, Technology, Energy, Consumer Staples, Communications, Health Care, Government*	Financials, Utilities, Consumer Discretionary, Other Sectors
Issuer's Rating	AAA, AA+, AA, AA-, A+, A, A-, BBB+, BBB, BBB-, BB+, BB, BB-, B+*, B, B-*, CCC+*	Prime (AAA) High (AA+, AA, AA-) Upper-Medium (A+, A, A-) Lower-Medium (BBB+, BBB, BBB-) Non-Investment (Below BBB-)

Note: * Eliminate from sample due to unmatched characteristics between treated group and control group
** No reclassification for Normalized Face value, Issuance Year, and Seniority

Table 3.12 Bond's characteristic reclassification for CEM

Europe Markets

Characteristic**	Data Distribution	Reclassified Group
Currency	EUR, SEK, NOK, USD, AUD, GBP, TRY, CHF, JPY, PLN, HKD, INR*, IDR*, HUF*, CZK*, RUB, BRL, NZD*, ZAR*, CNY*, CAD*, MXN*, SGD*	EUR, SEK, NOK, USD Other Currencies
Issuer's Sector	Financials, Utilities, Consumer Discretionary, Industrials, Materials, Technology*, Energy, Consumer Staples, Communications, Health Care, Government*	Financials, Utilities, Industrials, Other Sectors
Issuer's Rating	AAA, AA+, AA, AA-, A+, A, A-, BBB+, BBB, BBB-, BB+, BB, BB-, B+, B*, B-, CCC+*, CCC*, CCC-*	Prime (AAA) High (AA+, AA, AA-) Upper-Medium (A+, A, A-) Lower-Medium (BBB+, BBB, BBB-) Non-Investment (Below BBB-)

Note: * Eliminate from sample due to unmatched characteristics between treated group and control group
** No reclassification for Normalized Face value, Issuance Year, and Seniority

In our CEM analysis, Automated Coarsening and k2k matching are used. The CEM weight provided for Automated Coarsening is originated to make the most efficient use of the data by employing as many observations as possible. As a result, each green bond is matched with a weighted group identical conventional bond. Moreover, we also use k2k matching, which is a 1:1 matching approach in which one most identical conventional bond is determined for each green bond.

3.3.2 Synthetic Minority Oversampling Technique (SMOTE)

Imbalance dataset appears to be a problem in our study since the sample of conventional bonds is significantly larger than the sample of green bonds. Only 282 green bonds, compared to 8,729 conventional bonds, exist in Asia-Pacific markets or only 3.2% of green bonds to conventional bonds. Also, in Europe markets, there are only 488 green bonds, compared to 8,151 conventional bonds or only 5.9% of green bonds to conventional bonds.

A way to overcome this problem is to apply Synthetic Minority Oversampling Technique (SMOTE). SMOTE can address imbalanced datasets by synthesize new sample in the minority class in the overall sample to fitting the model without providing any additional information to the model. SMOTE works by selecting samples of green bonds in the feature space that are near together, drawing a line connecting them in the feature space, and drawing a new sample at a position along that line (Chawla, N., et al., 2002). As a result, we can generate synthesized green bonds to balance the overall dataset.

Table 3.13 Summarize Data with Synthetic Minority Oversampling Technique

Markets	**Original Sample**	**Sample after using SMOTE**
Asia-Pacific		
- *Green Bonds*	*282 (3.2%)*	*8,729 (100%)*
- *Conventional Bonds*	*8,729 (100%)*	*8,729 (100%)*
Europe		
- *Green Bonds*	*488 (5.9%)*	*8,151 (100%)*
- *Conventional Bonds*	*8,151 (100%)*	*8,151 (100%)*

3.3.3 Determinants Affecting Green Bond Yields

A cross-sectional regression is used in the next stage of our study to contribute research question 3 (Nguyen, T. N. H. ,2020). The major characteristics of bonds, as well as external review of green bond, are assumed to be potential drivers of green bond yield. The econometric estimation is specifically addressed as follows:

$$YTM_1 = \beta_0 + \beta_1 \log(Amount\ issued_i) + \beta_2\, Tenor_i + \beta_3\, External\ Review_i + \beta_4\, Issuer's\ ratings_i + \beta_5\, Issuer's\ sectors_i + \beta_6\, Currency_i + \varepsilon_i$$

Table 3.14 Determinant Variables Legend

Variable name	Description
1) Amount issued	Amount issued in USD currency
2) Tenor	Bond's tenor in years
3) External Review	Dummy variable which takes 1 if the green bond receives a verification or review from an independent party, and 0 otherwise.
4) Issuer's ratings	Bloomberg Composite Credit Ratings, an equally weighted blend of the ratings of a security by Moody's, S&P, Fitch, and DBRS as published by Bloomberg. Dummy variable which takes 1 if the issuer of green bond achieves investment grade and 0 otherwise.
5) Issuer's sectors	Bloomberg classification level 1 (BCLASS Level 1) is used, which provides 3 main sectors, Financials, Utilities and Other Sectors. Dummy variable which takes 1 if the issuer of green bond is in Financials sector or Utilities sector and 0 otherwise.
6) Currency	The currency of the bond at issuance, classified into 2 categories, local currency, and foreign currency. Local currency refers to a green bond issued in any of Asia-Pacific's or Europe's domestic currencies. While foreign currency refers to a green bond issued in any of Asia-Pacific's or Europe's foreign currencies. Dummy variable which takes 1 if green bond is issued in local currency and 0 otherwise.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Matching Approach

This chapter shows the analysis of comprehensive sample and the results of all matching approaches in Asia-Pacific markets, Europe markets, and the total universe of Asia-Pacific and Europe markets. We aim to evaluate the significance, sign, and size of green bond premium and risk. The variables and results of all used matching approaches are then presented and compared. The primary market is represented by yield to maturity, whereas the secondary market is represented by annualized ask yield. Annualized volatility is used to define the risk of green bonds and conventional bonds.

4.1.1 Asia-Pacific Markets

4.1.1.1 The Existence of Green Bond Premium

Findings in Table 4.1 proves the existence of negative green bond premium in Asia-Pacific markets. On average, green bonds provide investors less interest than their conventional bond counterparts. The estimates of the ATT in the primary market are in the range between (7.58) basis points and (52.52) basis points. In the secondary market, the estimated ATT are in the range between (19.10) basis points and (119.45) basis points. The highest ATT is estimated when applying Kernel matching while the greatest standard error is associated with the radius matching and k2k.

4.1.1.2 Risk Level

The results show that the estimated ATTs of volatility are statistically significant and falls between (24) basis points and (80.58) basis points. Thus, the finding affirms that the risk of green bonds is considerably lower than conventional bonds.

4.1.2 Europe Markets

4.1.2.1 The Existence of Green Bond Premium

Similar to findings in the primary market in Asia-Pacific, the estimated ATTs, as shown in Table 4.2, are significant negative between (30.18) basis

points and (68.93) basis points. While for the secondary market, the green bond premiums are broadly dispersed between 51.29 basis points and (29.40) basis points, so we cannot conclude that a negative green bond premium exists. These results for the secondary market align with the finding in Berland, A.R. & Aass, B. (2020) who find green bond premium is distributed around zero, suggesting that there is no green bond premium.

4.1.2.2 Risk Level

The estimated ATTs of volatility are statistically significant and in the range between (29.19) basis points and (76.45) basis points. It can be implied from the result that even though the average risk of green bonds is lower than conventional bonds, the yield spread is not statistically difference especially in the secondary market.

4.1.3 Asia-Pacific and Europe Markets

4.1.3.1 The Existence of Green Bond Premium

Finally, we analyze the entire Asia-Pacific and Europe markets. The estimated ATTs come up with the negative green bond premium in the primary market which the range is between (8.85) basis points and (84.10) basis points. In contrast, the estimated ATTs cannot be concluded that negative green bond premium exists since the results range from 71.02 basis points and (86.38) basis points. Table 4.3 displays the summary statistics of the entire markets.

4.1.3.2 Risk Level

After we evaluate the volatility differential of green and conventional bonds from the entire markets, we find that the volatility of green bonds is lower than conventional bonds which the estimated ATTs of volatility are in the range of (19.51) basis points and (73.22) basis points. These results support that green bond are less risky than their conventional counterparts, especially in term of market risk.

4.1.4 Specific Markets

4.1.4.1 The Financial Institutional Issuer

Bachelet, M., et al. (2019) states in their study that institutional green bonds have a negative premium and are significantly more liquid than conventional peers, whereas private green bonds have a positive premium and a much smaller liquidity advantage. They also presume that one of the reasons for the rejection

of the bonds from private issuers could be the institutional issuer's stronger reputation. Hence, we would like to analyze and specifically discover the existence of negative green bond premium if the issuers are financial institutions. Therefore, we extract only financial institutions including central bank, commercial bank, securities companies and insurance companies from our sample. As a result, Asia-Pacific markets have 56 green bonds, while Europe markets have 150 green bonds. Table 4.4 shows the summary statistics of financial institution issuers.

Our findings demonstrate that green bond premiums are negative in Asia-Pacific markets, between (45.62) and (121.31) basis points and positive in Europe markets, between 57.47 and 75.67 basis points. Despite the results in Europe markets contradict the previous study, the results from Asia-Pacific markets indicate that the majority of green bonds issued by financial institutions have more acquired external certification and have higher issuer ratings than those bonds issued by other private issuers. Therefore, these characteristics can lower green bond yields and reduce the information asymmetry as a consequence.

4.1.4.2 Exclusion of Nordic Markets

Based on previous findings, Wensaas, E. & Wist, J.B. (2019) conclude that green bonds in Nordic market have no statistically significant green bond premium due to the structural dissimilarities between the Nordic and the global green bond market. Moreover, in comparison to the worldwide green bond market, the Nordic green bond market is dominated to a greater extent by real estate sectors. Thus, to assess the existence of green bond premium in Europe without structural dissimilarities effects, issuers from Nordic countries which are Denmark, Norway, Sweden, Finland and Iceland or such bonds that denominated in SEK and NOK currency are omitted from our sample. Finally, our selected sample consists of 249 European green bonds. Table 4.5 presents summary statistics of Europe markets with the exclusion of the Nordic market.

Interestingly, we cannot discover substantial negative green bond premium in Europe markets, thus our findings may add to the evidence in previous study. The structural dissimilarities could be detected in such developed countries in Europe, rather than only in the Nordic markets. However, we recognize that economic changes and interest rate fluctuations could also lead to variation of the results because

our study collects data from 2016 until 2021 while previous study use data of all Nordic bonds issued between 2013 and 2016.

4.2 Determinants Affecting Green Bond Yields

A linear regression is performed on green bond's characteristics to evaluate the determinants of a green bond yield, which the results show in Table 4.6. In Asia-Pacific markets, the results show a statistically significant negative relationship to green bond yield from investment grade, financial sector, and local currencies. Comparing to Europe markets, amount issued, external review, investment grade, and local currencies have a statistically significant negative relationship with green bond yield.

In both region, issuer's rating is generally negatively correlated with the green bond yield due to most of green bond are issued by Upper-Medium ratings (equivalent to above A- ratings from S&P Ratings). Thus, the higher the credit rating of the green bond, the lower default risk and the lower the average green bond yield.

For external review, green bond certification reduces the yields. It helps ease investor concerns about investing in green bonds that do not provide any long-term value, resulting in increased demand for these bonds and lower yields. These findings are supported by findings from Baker et al., (2018), Kapraun, J. & Scheins, C., (2019) and Slimane, M.B., et al., (2020).

Focusing on local currencies, we obtain the same conclusion as Nanayakkara, M. & Colombage, S., (2019). Resulting in negative relationship to green bond yields, if green bond's yield denominated with local currencies, it can decrease their yields due to the fact that bonds issued in local currencies have no foreign exchange risk and are low-risk securities even when invested globally.

4.3 Discussion

Our findings are consistent with previous studies on the green bond markets. According to Löffler, K.U., et al., (2021) and Slimane, M.B., et al., (2020), green bonds are issued with a negative premium, compared with conventional bonds. Our results indicate that although green bonds are currently a minor part of global bond market,

investors are willing to pay a higher price for the bond's "green label" because they care about the environment regarding to the growing of global ESG trend, which according to Fama and French (2007), as well as they believe the risk related with green bonds is lower than that of conventional bonds which can be used to diversify the risk of their investment portfolio.

Regarding demand and supply paradigm in term structure theory, there is a potential mismatch of demand and supply that can lead to a shortage of green bonds since many of green bond issuers encounter challenges such as a lack of widely accepted green definitions, inadequate policies, standards, regulations, and the higher cost of standardization process. We can imply that the reason why Asia-Pacific green bonds have larger negative green bond premium than European bonds is its supply (371 USD billion) is significantly less than the green bond supply in Europe markets (738 USD billion). Consequently, with limited supply, demand for green bonds will drive up the price and lowering the yield. Therefore, our findings should encourage Asia-Pacific bond issuers to be a first-mover advantage for lower funding cost by offering more green-labeled bonds before the market structure catches up to Europe markets.

Additional issuer's cost of fund is considered as another aspect that contributes to the presence of green bond premium. Due to the need for issuers to pay to third-party opinion verification, green bond issuers may seek financial compensation to at least offset the additional cost of issuance. These additional costs can be classified into two categories: external and internal. Internal costs, such as the costs of developing the necessary internal processes and controls for project evaluation and selection, funds management, and reporting in order to comply with the principle. External costs are related with a third-party certification which is a green bond rating. The approximately external certification fees are 0.1 bps of the bond principal (Huynh, T., et al., 2022). CBI represents around 34.4% of Asia-Pacific green bonds are externally verified while 73.6% of European green bonds are. As a result, European green bond issuers have to pay more for extra cost of fund and should compensate themselves by raising bond yields. The evidence in this study come up with a larger negative green bond premium in Asia-Pacific markets than Europe markets.

Our last aspect is a reduction of information asymmetry. Independent external reviews can eliminate information asymmetry between issuers and investors

since the investors are sensitive to that and their confidence in green assets and the risk of greenwashing are increased if more information on the environmental friendliness of green bonds is made publicly available (Dorfleitner, G., et al., 2021). Information asymmetry in the green bond market raises the risks of greenwashing, exposing investors to reputational risks beyond cashflow concerns in conventional bond markets. It can be reduced by the publication of project data and external certification, which will lower the cost of financing. (Huynh, T., et al., 2022). Our findings support the previous studies by revealing that 59.2% of total green bonds are reviewed by the external third parties and green bonds are less risky than conventional bonds in term of volatility. As a result, a negative green bond premium in both Asia-Pacific and Europe markets exists. Therefore, to reduce information asymmetry between market participants and to develop the green bond market, Dorfleitner, G., et al., 2021 persuade that easier access to third-party reports should be encouraged, as well as support from the government to conduct standardized, affordable, and greenness assessments. Moreover, Huynh, T., et al., 2022 also suggests that policymakers should encourage green bond issuers to continue issuing green bonds by further developing the market ecosystem to minimize information asymmetry.

Table 4.1 Asia-Pacific Markets Summary Statistics

Matching Technique	**Propensity Score Matching**				**Coarsened Exact Matching**	
Approach	**Nearest Neighbor**	**Radius**	**Kernel**	**Strati-fication**	**Automated Coarsening**	**k2k**
Original Data :						
1) Yield to Maturity						
- ATT	(13.42)	(7.58)*	(7.80)*	(4.31)	(16.28)	(20.99)
- Std. Error	13.86	8.91	8.47	9.46	16.09	14.80
- *No. Treated*	*280*	*280*	*280*	*279*	*259*	*253*
- *No. Control*	*1,595*	*7,728*	*7,728*	*7,729*	*3,206*	*253*
2) Ask Yield						
- ATT	(26.22)*	(116.38)*	(119.45)*	(25.77)*	(38.68)*	(33.82)*
- Std. Error	1.03	9.82	9.03	9.74	12.46	15.53
- *No. Treated*	*280*	*280*	*280*	*279*	*259*	*253*
- *No. Control*	*1,595*	*7,728*	*7,728*	*7,729*	*3,206*	*253*
3) Volatility						
- ATT	(24.00)*	(79.24)*	(80.58)*	(11.26)	(47.19)*	(53.55)*
- Std. Error	11.72	13.11	12.64	13.82	21.85	26.59
- *No. Treated*	*280*	*280*	*280*	*279*	*259*	*253*
- *No. Control*	*1,595*	*7,728*	*7,728*	*7,729*	*3,206*	*253*
SMOTE Data :						
1) Yield to Maturity						
- ATT	119.15*	(52.22)*	(52.52)*	(0.17)	(9.03)*	(10.15)
- Std. Error	4.42	4.16	3.28	4.11	4.04	7.55
- *No. Treated*	*7,923*	*7,923*	*7,923*	*2,194*	*2,168*	*1,041*
- *No. Control*	*1,799*	*7,815*	*7,815*	*13,544*	*3,206*	*1,041*
2) Ask Yield						
- ATT	115.19*	(85.90)*	(87.10)*	(19.10)*	(37.58)*	(39.24)*
- Std. Error	2.75	4.50	3.29	3.65	4.07	7.67
- *No. Treated*	*7,923*	*7,923*	*7,923*	*2,194*	*2,168*	*1,041*
- *No. Control*	*1,799*	*7,815*	*7,815*	*13,544*	*3,206*	*1,041*
3) Volatility						
- ATT	125.72*	(40.12)*	(46.37)*	8.87	(25.81)*	(55.71)*
- Std. Error	4.41	6.42	7.01	5.31	8.09	12.94
- *No. Treated*	*7,923*	*7,923*	*7,923*	*2,194*	*2,168*	*1,041*
- *No. Control*	*1,799*	*7,815*	*7,815*	*13,544*	*3,206*	*1,041*

Note: The ATT and Std. Error are expressed in basis points. Columns refer to the different matching methods.* indicates significance at the 5% level. In all estimations, a common probability support of the treated and control units is required to ensure greater comparability of matched units. We generate 100 replicates of bootstrapping.

Table 4.2 Europe Markets Summary Statistics

Matching Technique	**Propensity Score Matching**				**Coarsened Exact Matching**	
Approach	**Nearest Neighbor**	**Radius**	**Kernel**	**Strati-fication**	**Automated Coarsening**	**k2k**
Original Data :						
1) Yield to Maturity						
- ATT	(7.71)	(68.11)*	(68.93)*	(2.49)	(1.60)	(1.19)
- Std. Error	13.33	15.62	15.22	13.82	7.83	18.79
- *No. Treated*	*455*	*448*	*448*	*451*	*417*	*352*
- *No. Control*	*1,491*	*6,805*	*6,805*	*6,809*	*3,787*	*352*
2) Ask Yield						
- ATT	18.85*	(28.19)*	(29.40)*	16.52	17.63*	23.95
- Std. Error	9.34	12.03	10.62	9.81	5.79	13.23
- *No. Treated*	*455*	*448*	*448*	*451*	*417*	*352*
- *No. Control*	*1,491*	*6,805*	*6,805*	*6,809*	*3,787*	*352*
3) Volatility						
- ATT	(13.50)	(76.45)*	(75.63)*	26.28	31.63	16.47
- Std. Error	23.44	22.43	21.82	21.83	16.79	33.57
- *No. Treated*	*455*	*448*	*448*	*451*	*417*	*352*
- *No. Control*	*1,491*	*6,805*	*6,805*	*6,809*	*3,787*	*352*
SMOTE Data :						
1) Yield to Maturity						
- ATT	61.76*	(30.18)*	(54.91)*	(14.49)	(6.10)	5.27
- Std. Error	5.45	4.74	5.08	8.19	4.94	8.45
- *No. Treated*	*7,367*	*7,367*	*7,367*	*3,271*	*4,161*	*1,959*
- *No. Control*	*1,552*	*7,013*	*7,013*	*11,109*	*3,798*	*1,959*
2) Ask Yield						
- ATT	51.29*	2.60	(14.82)*	13.29*	12.25*	2.37*
- Std. Error	3.58	3.45	4.37	4.68	3.36	5.86
- *No. Treated*	*7,367*	*7,367*	*7,367*	*3,271*	*4,161*	*1,959*
- *No. Control*	*1,552*	*7,013*	*7,013*	*11,109*	*3,798*	*1,959*
3) Volatility						
- ATT	149.94*	(29.19)*	(66.92)*	(10.77)	4.01	0.93
- Std. Error	13.80	7.60	7.56	14.64	8.44	14.07
- *No. Treated*	*7,367*	*7,367*	*7,367*	*3,271*	*4,161*	*1,959*
- *No. Control*	*1,552*	*7,013*	*7,013*	*11,109*	*3,798*	*1,959*

Note: The ATT and Std. Error are expressed in basis points. Columns refer to the different matching methods. * indicates significance at the 5% level. In all estimations, a common probability support of the treated and control units is required to ensure greater comparability of matched units. We generate 100 replicates of bootstrapping.

Table 4.3 Asia-Pacific and Europe Markets Summary Statistics

Matching Technique	**Propensity Score Matching**				**Coarsened Exact Matching**	
Approach	**Nearest Neighbor**	**Radius**	**Kernel**	**Strati-fication**	**Automated Coarsening**	**k2k**
Original Data :						
1) Yield to Maturity						
- ATT	(8.19)	(84.10)*	(82.36)*	(11.52)	(3.06)	(2.48)
- Std. Error	9.86	9.14	10.11	9.69	7.72	12.76
- *No. Treated*	*768*	*768*	*768*	*760*	*691*	*620*
- *No. Control*	*3,381*	*15,390*	*15,390*	*15,398*	*7,578*	*620*
2) Ask Yield						
- ATT	4.29	(86.38)*	(85.00)*	(6.57)	1.24	5.15
- Std. Error	7.53	3.95	8.13	6.73	6.30	10.56
- *No. Treated*	*768*	*768*	*768*	*760*	*691*	*620*
- *No. Control*	*3,381*	*15,390*	*15,390*	*15,398*	*7,578*	*620*
3) Volatility						
- ATT	(2.76)	(73.22)*	(70.39)*	(15.18)	(2.90)	(5.83)
- Std. Error	15.60	13.58	15.84	16.27	12.98	21.91
- *No. Treated*	*768*	*768*	*768*	*760*	*691*	*620*
- *No. Control*	*3,381*	*15,390*	*15,390*	*15,398*	*7,578*	*620*
SMOTE Data :						
1) Yield to Maturity						
- ATT	41.61	(38.95)*	(55.60)*	(10.60)*	(8.85)*	7.36
- Std. Error	31.66	2.12	4.06	0.03	3.28	6.27
- *No. Treated*	*15,489*	*15,489*	*15,489*	*5,780*	*7,637*	*3,411*
- *No. Control*	*3,487*	*15,304*	*15,304*	*25,013*	*7,578*	*3,411*
2) Ask Yield						
- ATT	71.02*	(33.17)*	(50.17)*	5.19*	0.66	14.19*
- Std. Error	8.57	2.14	3.08	2.54	2.47	4.84
- *No. Treated*	*15,489*	*15,489*	*15,489*	*5,780*	*7,637*	*3,411*
- *No. Control*	*3,487*	*15,304*	*15,304*	*25,013*	*7,578*	*3,411*
3) Volatility						
- ATT	143.01*	(38.27)*	(59.14)*	(24.68)*	(19.51)*	(13.19)
- Std. Error	13.23	4.15	7.11	5.63	5.54	10.30
- *No. Treated*	*15,489*	*15,489*	*15,489*	*5,780*	*7,637*	*3,411*
- *No. Control*	*3,487*	*15,304*	*15,304*	*25,013*	*7,578*	*3,411*

Note: The ATT and Std. Error are expressed in basis points. Columns refer to the different matching methods. * indicates significance at the 5% level. In all estimations, a common probability support of the treated and control units is required to ensure greater comparability of matched units. We generate 100 replicates of bootstrapping.

Table 4.4 Financial Institution Issuers Summary Statistics

Matching Technique	Propensity Score Matching				Coarsened Exact Matching	
Approach	**Nearest Neighbor**	**Radius**	**Kernel**	**Strati-fication**	**Automated Coarsening**	**k2k**
Asia-Pacific :						
1) Yield to Maturity						
- ATT	(25.71)	(81.87)*	(82.06)*	(22.36)	(33.66)	(42.83)
- Std. Error	15.19	20.82	17.38	14.60	21.75	25.24
- *No. Treated*	*56*	*56*	*56*	*56*	*45*	*45*
- *No. Control*	*553*	*3,424*	*3,424*	*3,424*	*1,049*	*45*
2) Ask Yield						
- ATT	(23.15)	(120.94)*	(121.31)*	(47.88)	(45.62)*	(51.80)*
- Std. Error	14.50	20.76	17.95	13.67	21.10	23.15
- *No. Treated*	*56*	*56*	*56*	*56*	*45*	*45*
- *No. Control*	*553*	*3,424*	*3,424*	*3,424*	*1,049*	*45*
3) Volatility						
- ATT	(28.56)	(60.42)*	(60.37)*	(7.13)	(87.76)	(108.20)
- Std. Error	20.15	27.60	25.45	20.95	51.79	57.31
- *No. Treated*	*56*	*56*	*56*	*56*	*45*	*45*
- *No. Control*	*553*	*3,424*	*3,424*	*3,424*	*1,049*	*45*
Europe :						
1) Yield to Maturity						
- ATT	65.67	43.50	43.16	61.05	57.47*	64.94
- Std. Error	37.49	38.23	40.91	40.85	15.17	42.21
- *No. Treated*	*150*	*150*	*150*	*150*	*144*	*144*
- *No. Control*	*770*	*2,600*	*2,600*	*2,600*	*1,901*	*144*
2) Ask Yield						
- ATT	75.67*	52.03	50.50	67.26*	63.24*	67.23*
- Std. Error	25.80	26.82	27.11	26.49	10.58	28.42
- *No. Treated*	*150*	*150*	*150*	*150*	*144*	*144*
- *No. Control*	*770*	*2,600*	*2,600*	*2,600*	*1,901*	*144*
3) Volatility						
- ATT	127.79*	106.90	108.36	137.40*	115.72*	111.43
- Std. Error	63.36	56.64	68.76	60.18	28.60	68.56
- *No. Treated*	*150*	*150*	*150*	*150*	*144*	*144*
- *No. Control*	*770*	*2,600*	*2,600*	*2,600*	*1,901*	*144*

Note: The ATT and Std. Error are expressed in basis points. Columns refer to the different matching methods. * indicates significance at the 5% level. In all estimations, a common probability support of the treated and control units is required to ensure greater comparability of matched units. We generate 100 replicates of bootstrapping.

Table 4.5 Europe markets exclude Nordic market Summary Statistics

Matching Technique	**Propensity Score Matching**				**Coarsened Exact Matching**	
Approach	**Nearest Neighbor**	**Radius**	**Kernel**	**Strati-fication**	**Automated Coarsening**	**k2k**
Europe Exclude Nordic						
1) Yield to Maturity						
- ATT	(1.54)	(21.40)	(23.20)	12.83	16.38	6.13
- Std. Error	22.59	26.47	23.75	22.54	10.93	27.25
- *No. Treated*	*249*	*249*	*249*	*249*	*230*	*230*
- *No. Control*	*1,166*	*6,029*	*6,029*	*6,029*	*3,323*	*230*
2) Ask Yield						
- ATT	28.54	(2.56)	(4.52)	35.77*	35.63*	36.12
- Std. Error	16.46	18.42	15.79	15.88	8.53	19.07
- *No. Treated*	*249*	*249*	*249*	*249*	*230*	*230*
- *No. Control*	*1,166*	*6,029*	*6,029*	*6,029*	*3,323*	*230*
3) Volatility						
- ATT	(11.21)	27.05	25.92	24.60	42.46	35.83
- Std. Error	40.17	40.64	38.07	36.24	23.06	45.72
- *No. Treated*	*249*	*249*	*249*	*249*	*230*	*230*
- *No. Control*	*1,166*	*6,029*	*6,029*	*6,029*	*3,323*	*230*

Note: The ATT and Std. Error are expressed in basis points. Columns refer to the different matching methods. * indicates significance at the 5% level. In all estimations, a common probability support of the treated and control units is required to ensure greater comparability of matched units. We generate 100 replicates of bootstrapping.

Table 4.6 Predictive Regression the Green Bond Yield

Dependent variable : *Yield to Maturity*

Cross-sectional regressions with robust standard errors

Variables	**Asia-Pacific Markets**	**Europe Markets**
Constant	5.76	19.88
Robust Std. Error	*236.24*	*383.12*
Amount Issued (Log)	(0.10)	(1.67)***
Robust Std. Error	*25.36*	*45.48*
Tenor	0.05***	0.00***
Robust Std. Error	*1.06*	*0.00*
External Review	0.15	(0.34)**
Robust Std. Error	*15.97*	*14.66*
Investment Grade	(2.87)***	(3.61)***
Robust Std. Error	*60.73*	*44.44*
Financial Sector	(0.77)***	(0.07)
Robust Std. Error	*17.82*	*20.52*
Utilities Sector	0.28	0.60***
Robust Std. Error	*24.10*	*19.16*
Local Currencies	(0.53)**	(0.98)***
Robust Std. Error	*24.47*	*34.74*
Observations	282	488
R^2	0.24	0.18
Adjusted R^2	0.22	0.16
Residual Sun of Squares	488.79	3,449.39
F stat	14.56	18.61

Note: ∗p < 0.1; ∗∗p < 0.05; ∗∗∗p < 0.01. The Robust Std. Error are expressed in basis points. The amount issued is the amount of green bonds issued expressed in log. Tenor is the maturity of the bond expressed in years. External review is a qualitative variable, of which green bond is verified by third-party. The issuer's rating is a qualitative variable, the only one modality of investment grade. Sector is a qualitative variable, of which the two modalities are Financials and Utilities. Currency is a qualitative variable, of which the modality of regional local currency.

CHAPTER 5
CONCLUSION

Green bonds have become the key financial instrument that the proceeds are only used for green projects with environmental advantages. After the first issuance in 2007, green bond market expansion has revealed a strong shift toward pro-environmental preferences among both issuers and investors. In this study, we only focus on Asia-Pacific and Europe markets because of their outstanding growth and amount issued. We investigate the effect of pro-environmental preferences using a green bond premium, which is defined as the yield differential between a green bond and identical conventional bonds issued by the same issuers, as well as the risk and determinants that influence green bond yields.

The sample in our study includes a total of 770 green bonds and 16,880 conventional bonds which issued from January 2016 to December 2021. The data descriptive shows that most of green bond issuers are in financial and utilities sector, with Upper-Medium grade ratings. Green bonds are more likely to be straight and senior debt. Asia-Pacific green bonds are mainly denominated in JPY, USD, and KRW. European green bonds are mainly denominated in EUR, SEK, and NOK. Interestingly, around 59.2% of green bonds in our sample receive external verification by third parties.

Following previous studies by matching the sample of green bonds with conventional bonds that have similar characteristics. We employ both Propensity Score Matching (PSM) and Coarsened Exact Matching (CEM) to evaluate the comparison groups. We analyze yields to maturity (at issuance) for the primary market, as well as annualized ask yields achieved on secondary markets and annualized volatilities.

Our findings indicate that the green bond yields are statistically significantly lower than conventional bonds in the primary market, ranging from (8.85) basis points and (84.10) basis points. However, because the results for the secondary market range from 71.02 basis points to (86.38) basis points, we cannot conclude that negative green bond premium exists. More specifically, European green bond investors are reluctant to forego their returns in secondary market but are willing in the primary market, while Asia-Pacific investors are more willing sacrifice their yields. In term of

volatilities, we find that green bonds are less risky than conventional bonds, ranging between (19.51) basis points and (73.22) basis points. Furthermore, the findings also highlight that investment grade issuers, financial sector issuers and local currency green bonds reduce the green bond yields since they mostly have a better reputation, higher credit ratings, and no foreign exchange risk. Notably in Europe markets, the presence of external review significantly induces a lower green bond premium because it increases the credibility of the bond issuance.

Three aspects are implied to explain our findings. According to demand and supply theory, a potential mismatch between demand and supply might raise the price while reducing the yield, resulting in a negative green bond premium. We suggest that Asia-Pacific bond issuers can take advantage from the region's scarcity of green bond supply. Another explanation is the additional cost of fund for issuers, external and internal cost associated with green labeling and third-party verification may encourage issuers to compensate by raising their bond yields. Furthermore, a reduction of information asymmetry from information publication and external certification can reduce the risks of greenwashing and the risk from exposing investors to reputational risks beyond cashflow concerns, resulting in a lower green bond premium.

The major limitation of this study emerges from the data incompleteness and program efficiency. Some less frequently traded corporate bonds do not accurately reflect their current value. Some required bond data is unavailable. Due to the capacity limit of Bloomberg, we are unable to retrieve the entire universe of bond data. Furthermore, if we use too many bootstrap replicates in the study, our matching approach will take much longer. Thus, we only set up 100 bootstrapping replications.

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