Environmental Risk Neutrality on Corporate Green Bond Pricing

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Abstract.

Corporate green bond is a novel sustainable finance instrument promising environmental risk neutrality impacts. Being a new area of research, the issue of environmental risk neutrality on green bond pricing remains new to industry practitioners and has been largely ignored in existing research. This research aims to advance this field by examining the impacts of environmental risk and controlling common risk factors in an asset pricing context of green bonds. This research analyses 135 corporate bonds issued by corporations from 12 countries representing both the developed and developing Asia markets, covering data from 2015 to 2019. The analysis performed using panel regression methods considering baseline and robustness analysis confirmed the impact of environmental risk neutrality on corporate green bond pricing (positive significant or positive insignificant or negative insignificant), in addition to bond's common risk factors. This evidence supports the validity of green bonds as a sustainable finance instrument that could minimise environmental risk, offering dual benefits of financial returns and impact climate neutrality.

Keywords: Environmental risk, green bonds, green bonds valuation, responsible investment, sustainable finance.

JEL: G1; G12; N2; O16; Q01

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INTRODUCTION

The finance industry sustainability transition is in the making by practising sustainability in business models and financial product offerings to mitigate environmental, social, and governance risks (ESG risks), supporting the United Nations Sustainable Development Goals (UN SDGs) agenda to realise a sustainable world. Among the three emerging sustainability risks, environmental risk is more serious and requires system-wide action to mitigate its economy-wide effects (Kelly *et al.,* 2015). Investors and financial regulators are increasingly aware of climate-change risk impacts on financial assets and corporations (Dietz *et al.,* 2016).

Thanks to the sustainability transition that raised innovation in green, social, and sustainability bonds (GSS) instruments (i.e., green, social, sustainability, transition, and sustainability-linked bonds), with green bonds leading the issuance, intended to facilitate the transition towards a low-carbon economy (Climate Bonds Initiative, 2022). In sustainable finance literature, this is known as climate neutrality (Schütze and Stede, 2021). Green bonds are seen as a key instrument to unlock climate finance (Karpf and Mandel, 2018). Green bonds are debt instruments issued under the debt's capital markets, which identify the assets and projects to be financed to deliver a low carbon economy and require GHG emissions screening criteria to be consistent with the 2^{o} global warming target set by the Conference of the Parties 21 Paris Agreement (Climate Bonds Initiative, 2021). Transition to sustainable finance, awareness of climate-related risks growing, and gains attraction among prudent asset owners. Accordingly, asset managers are beginning to question how global environmental trends will influence investment portfolios and ways to mitigate environmental risks (Kelly *et al.,* 2015). So far, the theoretical premises of environmental risk neutrality of corporate green bonds remain to be proven. Hence, understanding the mechanisms of green investment financing has attracted scholars, practitioners, and policymakers (Bachelet, Becchetti, and Manfredonia, 2019).

The first green bond was issued in 2007 by the European Investment Bank and World Bank with an AAA rating[4]. The green bond market is expanding, and renewable energy and other projects that address high-priority emissions reduction targets received greater proportions of green bond proceeds (Tolliver, Keeley, and Managi, 2019). The GSS bond issuance is presented in Figure 1. By 31 December 2022, the GSS plus debt instruments reached the cumulative volume of USD3.7tn, with Green remaining the dominant theme. The bonds are

[4] https://www.climatebonds.net/market/explaining-green-bonds

issued largely by financial and non-financial corporations. The projects financed, as presented in Figure 2, are concentrated on energy, buildings, transport, water, waste, land use, industry, ICT, and other unspecified areas. (Climate Bonds Initiative, 2022). The green bond market is still in its infancy, with many challenges that need to be clarified (Deschryver and de Mariz, 2020). In a particular issue addressed by the present research, there needs to be a more conceptual and empirical understanding of the role of green bonds in the corporate transition to carbon neutrality (Tuhkanen and Vulturius, 2020) through the green bonds pricing channel.

Practically, green bonds are issued in strict compliance with green bond principles and framework, ensuring issuers mitigate environmental risks in the project undertaken, and investors invest in climate-friendly instruments (Tiwari *et al.,* 2023). Accordingly, the environmental risk effects on green bond performance are expected to be neutral. However, these benefits seem unclear in practice, with limited evidence for them being a new instrument. As the green bond market grows, it is important to understand the market's risk and return behaviour (Pham, 2016). One key concern is the exposure to environmental risks on green bond pricing. Today, financial assets claim to be affected by environmental risks (Diez *et al.,* 2016). The question of whether green bonds can provide an instrument for investors to hedge against environmentally related financial risks remains open. If these risks materialise, bonds from issuers in polluting sectors may be subject to significant revaluations. To the extent that issuers of green bonds are better shielded against large revaluations, they could serve as an efficient risk management instrument. However, green bonds are more exposed to environmentally related credit risks if poorly executed (Ehlers and Packer, 2017).

The theoretical perspective provides insights into the environmental risk neutrality on corporate bond pricing. Ideally, green bonds are intended to make the economy more sustainable by reducing the threat of climate change through financing environmentally compliant projects only (Bachelet *et al.,* 2019). This is in line with the expected role of green bonds in supporting the UN SDG agenda (Maltais and Nykvist, 2020; Bhutta *et al.,* 2022; Alamgir and Cheng, 2023; Nguyen et al., 2023; Ahmed, Yusuf, and Ishaque, 2024). Research from some countries provides supporting evidence that green bonds issuance is associated with improving environmental quality (Chang *et al.,* 2022; Saha and Maji, 2023; Nguyen *et al.,* 2023). Accordingly, green bond pricing matters to many stakeholders. In an investment context, the damage caused by climate change can lead to portfolio reallocation, affecting declining bond prices. Climate change will cause financial instability, which might adversely affect credit expansion, worsening the situation with the negative impact of climate change on economic activity (Dafermos, Nikolaidi, and Galanis, 2018). In this context, green bonds helping investors to avoid environmental risks (Zhang, Li and Liu, 2021; Wang *et al.,* 2019) and provide a lower-risk investment opportunity for the investor (Nanayakkara and Colombage, 2019). Accordingly, the credit rating agencies consider carbon in bond ratings that will affect the bond price (Jong and Nguyen, 2016). However, the scarcity of evidence leaves the theoretical validity of the environmental risk neutrality benefits of green bonds to be proven empirically.

In terms of common risk factors, earlier researchers indicated that conventional bonds' common characteristics and risk factors apply to green bonds (Weber and Saravade, 2019). In particular, Draksaite, Kazlauskiene, and Melnyk (2018) state that green bonds and non-green bonds have similarities, and the price sensitivity is mostly influenced by coupon rate, time to maturity, and demand. Furthermore, Broadstock and Cheng (2019) state that green bonds are sensitive to macroeconomic factors. The common risk factors for bond investment are interest rate, inflation rate, maturity, and liquidity, as provided in the literature sub-section. In the existing green bond pricing research, researchers' attention has been largely on the greenium puzzle, which is concerned with the valuation premium behaviour of green bonds over conventional bonds (Liaw, 2020; Cheong and Choi, 2020; Immel *et al.,* 2021; Caramichael and Rapp, 2024) and little evidence is available on climate risk neutrality through green bond pricing channel. Evidence of the superiority of green bond performance over conventional bonds is mixed. One research group reports the superiority of green bonds compared to normal bonds. In this context, the green bond is expected to have a relatively higher premium than ordinary bonds due to a lower-risk investment opportunity for investors (Fatica, Panzica, and Rancan, 2021; Nanayakkara and Colombage, 2019). Another group of research documents the lower performance of green bonds in relation to non-green bonds. This performance would be a disincentive for investors to support the expansion of the green bond market (Zerbib, 2019). Given such mixed evidence, it is an open question whether this new asset class also offers attractive risk-return profiles compared to conventional bonds (Hachenberg and Schiereck, 2018). So far, few have documented green bond valuations using the CAPM model for the international green bond market (Tang and Zhang, 2020) and Asset Pricing Theory, which considers bond-specific and macroeconomic variables (Nanayakkara and Colombage, 2019).

This research will focus on green bond valuation and consider environmental risks and common risk factors in the multifactor bond valuation model. It is expected to enhance the finance body of knowledge related to green bond valuation, which would be valuable to practitioners and policymakers. In particular, the results would provide meaningful insights into this new yet very promising market, which would, therefore, have important implications for green bond asset pricing, portfolio management, and risk management applications.

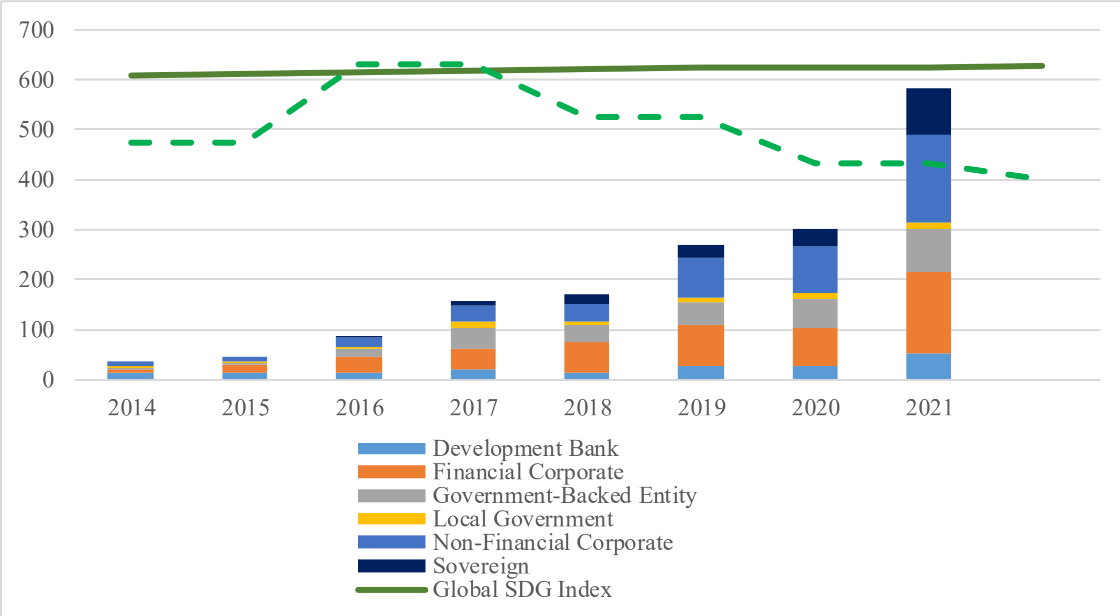

Figure 1: Global green bond total amount issued, global SDG index, and global EPI. The left scale represents the GB issuance in billions of dollars, and the right scale represents the index for SDG and EPI.
Source: Climate Bonds Initiative; Sustainable Development Report; and Socioeconomic Data and Applications Center (SEDAC)

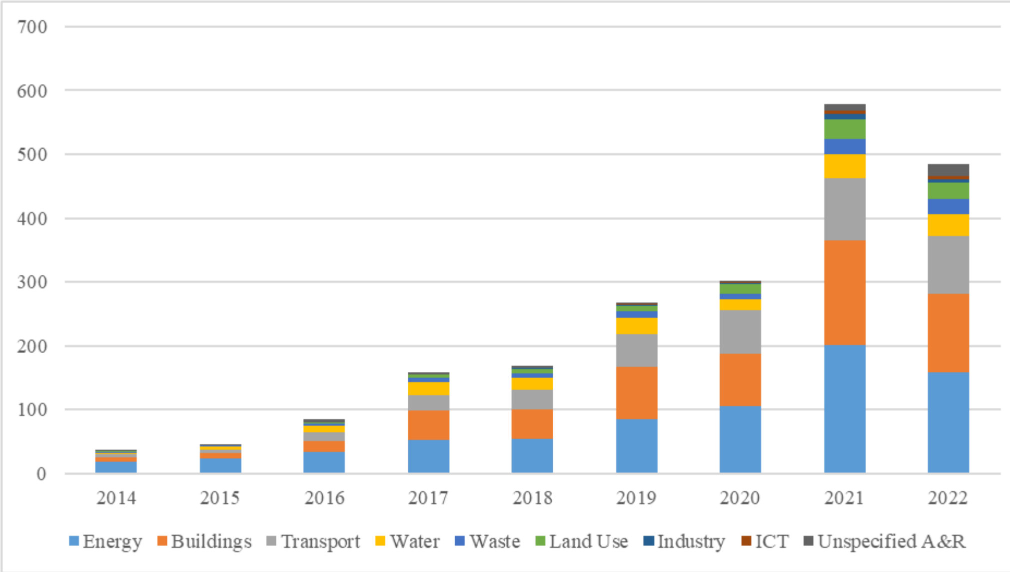

Figure 2: Global green bond total amount issued, use of proceeds
Source: Climate Bonds Initiative; https://www.climatebonds.net/market/data/

LITERATURE REVIEW

Theory

The theoretical foundations for this research are: (i) Efficient market hypothesis and (ii) Bond valuation model.

Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) explains the operating/informational efficiency in three possible states of the financial market (Fama, 1970). The weak form is where the current price of the instruments incorporates all the existing historical financial information at any time. The semi-strong form states that financial asset prices reflect at any time all the information available, including new and old information in the market, and the price changes without any biases. The strong form of EMH states that the price is incorporated with all the available information in the market, including historical information, all available public information, and all private information. The state of sustainable finance market efficiency is important in informing whether the environmental risk is efficiently priced in the financial markets (Schoenmaker and Schramade, 2019).

Bond valuation model

The basic bond valuation model is widely used, where the return is measured by the common factor, including interest rate, coupon payment, maturity, number of periods, and the value of the bond. This model is used to determine the value of a bond, which is involved in calculating the value of a bond's coupon payments or any cash flows and bond value when it is held until maturity. Where C

represents coupon payment, r is rate, F face value of bond, t number of period and T as time to maturity.

$$Bond\ value_i = \sum \frac{C}{(1+r)t} + \frac{FV}{(1+r)T} \tag{1}$$

Based on the arbitrage pricing theory, Ross (1976) introduced the multifactor asset pricing framework with possible risk factors from economic variables affecting asset returns. Accordingly, Francova (2017) used the arbitrage pricing theory in this asset pricing framework to define the relationship between the factors affecting the bond yield. Where the $E(R_{it})$ Is the expected return on the asset i in period t. Then δ_{im} Is the zero mean common factor capturing systematic risk? b_{im} Is the sensitivity of the asset i to the factor m. Lastly, ε_{it} is the random idiosyncratic error term. This equation is used in Fatica, Panzica, and Rancan (2021), Baker *et al.* (2022), and Gozzi *et al.* (2015). This theory also comes with the idea of predicting asset return with a direct relationship between asset expected return and multiple risk variables.

$$E(R_{it}) = \alpha_i + b_{li}\delta_{li} + \cdots + b_{im}\delta_{im} + \varepsilon_{it} \tag{2}$$

The equation below is the general green bond valuation model with environmental and common risk factors. Where $R_{it} - R_f$ refers to the yield of a green bond minus risk-free rates, $Green_{it}$ is the green characteristics or environmental factor. X_{it} is the common factor that may affect the green bond yield. Lastly, ε_{it} is the error term.

$$R_{it} - R_f = \beta_0 + \beta_1\ Green_{it} + \beta_2\ X_{it} + \varepsilon_{it} \tag{3}$$

The factor being selected is based on the systematic risk in the economy. According to Chen, Roll and Ross (1986), they argue that we should consider the factors that will explain changes and influence the expected cash flows. Accordingly, this research considers common economic factors affecting bond returns and environmental risk as a novel risk in green bonds.

Empirical Evidence

Corporate green bonds issuance and investment mechanism

Green bonds are issued in strict compliance with the green bonds' principles and framework, as summarised in Table 1, which would benefit issuers and investors, giving benefits financially and environmentally (Hachenberg and Schiereck, 2018).

On the issuer side, the green bond can be used only as an environmentally friendly product; the difference is that it is marketed as green and only to finance the green project (Ng and Tao, 2016). Another study by Roberedo (2018) states that green bonds are important in meeting the challenges of climate change. The green bond is a bond that is used for climate and environmental projects that could help to reduce climate change and assist the country's climate change adaptation plan (Bachelet *et al.,* 2019). As for the investors' side, green bond issuance is a way for investors to make environmentally friendly investments and improve their environmental, social, and governance activity profiles (Tang and Zhang, 2020). A green bond is ordinarily acknowledged as a place for environmental, social, and governance-focused investors and conventional fixed-income investors looking for green portfolios (Nanayakkara and Colombage, 2019). The usage of green bonds has significant potential to increase the sustainability of the economy by creating value for investors and proceeds of the bonds (Draksaite *et al.,* 2018). The existence of green bonds helps to boost investment in some sectors, which include energy, climate change, water, waste, building, and transportation (Weber and Saravade, 2019). The bond ratings agencies provide rating grades that indicate the level of risk (Livingston and Zhou, 2020). Established market players tend to have higher ratings and a well-known reputation in the bond market. Green bonds are associated with an ESG rating. In particular, a positive ESG rating will reduce financial risk, while a negative rating will raise financial distress (Hsu and Chen, 2015). In industry practice, the issuer's ESG scores are used for green bond ratings, which inform the issuer's creditworthiness and default risk. Accordingly, the issuer's ESG score influences the yield spread of green bonds issued (Polbennikov *et al.,* 2016; Baldi and Pandimiglio, 2022).

Table 1: The process of issuing a green bond

	The Green Bond Framework				
The Green Bond Principles	Use of proceeds	Project Evaluation and Selection Process	Management of Proceeds	Reporting	External Review

GBP 1: Use of Proceeds • Identify eligibility criteria for green projects, • The expected green and/or social impact GBP 2: Project evaluation and selection • Elaborate the internal process/structure to select the eligible green project. GBP 3: Management and proceeds • Explain the measures put in place to track the allocation of proceeds and the temporary use of funds. GBP 4: Reporting • Annual reporting of the selected impact indicator, and • The use of proceeds until its full allocation.	long-term support of environmental and social sustainability transition	• Project identification and eligibility analysis • Commitment decision and confirmation of eligibility • Allocation decision	The Green, Social and Sustainability Bond Committee annually decides, at mid-year, based on the annual accounts for the last two calendar years approved by auditors, whether the disbursements are allocated to the selected projects .	The report's publication informs the issuer's credibility by keeping investors up to date on initial commitments. Key information: • Third-party assurance on effective fund allocation and conformity of the projects • Impact indicators related to the projects	• Second-party opinion – e.g. Moody's Investors or any other party service provider • External Verification – e.g. Moody's ESG or any other party service provider

Source: Developed by the author in reference to Green (2023). Sustainability bonds. Nd Capital Market Association (ICMA) verkkosivu and International Finance Corporation 2020.

Environmental factor effect on green bond valuation

Environmental risk is an important part of sustainability risk (ESG risk) that aimed to be addressed partly using sustainable finance mechanisms transition to a low-carbon economy meeting the UN SDGs 2^{o} global warming target (Wang, Larsen and Wang, 2020; Tao *et al.,* 2022). Accordingly, green bonds are emphasised as an important financial instrument to address environmental risk (Banga, 2019; Schumacher, 2020). In this regard, environmental risk is expected to be neutral for green bonds since the issuance strictly complies with the green bond principles and framework. The fact that bond instruments are affected by environmental risk is a well-known phenomenon in financial markets (Wu and Tian, 2022). However, the impacts are not clear due to limited evidence. Past studies show that the damage caused by climate change can bring a portfolio reallocation that can cause a decline in the price of corporate bonds (Defermos *et al.,* 2018). In reference to Kelly *et al.* (2015), climate change risks will be a significant problem in investment portfolio performance. On the other hand, investors can reduce their portfolio risk from environmental risk by making environmentally friendly investments and reducing climate change risks (Nanayakkara and Colombage, 2019). According to Defermos *et al.* (2018), climate changes increase the green corporate bond yield due to the greenium premium effect. In practice, carbon emissions will significantly affect the issuing company's debt cost and should be material in firm investment decisions (Li, Eddie, and Liu, 2014). In connection, the transition towards a low-carbon economy will increase the demand for investing in green projects, supported by the growing impact of investors' demand and the ESG rating practice in the industry (Nanayakkara and Colombage, 2019). Recent evidence provides support for positive relationships between green bonds and environmental risk (Chang *et al.,* 2022; Ren *et al.,* 2022). In addition, insignificant or negative insignificant of environmental risk also indicates risk neutrality.

H1: Environmental risk will be neutrally affecting the green bond returns

Common risk factor on green bond valuation

Green bonds are for financing green projects (Weber and Saravade, 2019). In terms of pricing factors, green bonds and non-green bonds have similar characteristics, and price sensitivity is mostly influenced by coupon rate, time to maturity, and demand (Draksaite *et al.,* 2018). Accordingly, there is supposed to be sensitivity toward common risk factors for bonds (Litterman and Scheinkman, 1991) that will affect the bond return.

Interest rate – The interest rate affects the discounting value of coupon payments and the bond face value. The bond's interest rate becomes more attractive when the interest rate, in general, falls; this will make the investor bid up the bond's price. The interest rate and bond have an inverse relationship; when the interest rate rises, the bond price will fall. If interest rates rise, people will no longer prefer the lower fixed interest rate paid by a bond, and their prices will fall. According to Bhattacharyay (2013) there is significant relation between interest rate and the bond, which the interest rate will affect the return of the bond. In another supporting evidence, Jalles (2019) includes the interest rate as the factor that affects the bond return; the higher interest rate reflects the higher bond yield. In this study, they stated that when the central bank increases the rates, it will be involved in contractionary monetary policy, and it will lead to a decline in economic activity; the automatic stabilisers will make the budget balance worse and compromise the ability to pay back; this will bring the yields upward.

H2a: Interest rate will be positively influencing the green bond returns

Inflation rate – In an economic sense, inflation reduces the discounting value of coupon payments and the bond face value. The inflation rate can reduce the bond's real value; when inflation increases, the bond price will decrease. An increase in the inflation rate lowers purchasing power as inflation can increase prices. According to Kanas (2014), inflation is important for investors when making decisions about investing in bonds. Accordingly, long-term bonds negatively impact in the short run, as inflation enters the equation with a negative sig (Poghosyan, 2014). Further research indicated that inflation negatively impacts return, whereas US index price growth has a negative impact (Chernov, Creal, and Hordahl, 2019). Kleczyk's (2012) study also used inflation as a change in the consumer price index and found that inflation is negatively related to long-term debt.

H2b: Inflation rate will be negatively influencing the green bond returns

Maturity – Maturity refers to bond tenure. Bond maturity affects bond yields by influencing investors' yield-to-maturity determination. Earlier evidence documented mixed evidence. Elton *et al.'s* 2004 study documented that the role of maturity differs (positive and negative) according to bond ratings. Another study found that the roles of maturity on bond yields vary, with short maturity noted to be more negative and long maturity more positive (Park, 1999; Chiang, 2016). Furthermore, Wang *et al.,* (2019) state that the bond maturity is negatively related to the issue risk premium of green bonds; the longer maturity proves confidence in green bond sales and payment at maturity. Another researcher found that green bonds have an average shorter maturity but have a larger issue amount (Tang and Zhang, 2020). Moreover, maturity has a negative impact on green bonds. Usually, maturity is expected to have a positive impact on investment-grade bonds and not on speculative-grade bonds (Febi *et al.,* 2018).

H2c: Maturity will be negatively influencing the green bond returns

Liquidity – Theoretically, two views have been offered to explain the roles of liquidity on financial instruments, namely, illiquidity of financial instruments i) creates trading costs, and ii) can itself create additional risk (Favero, Pagano and Von Thadden, 2010). Liquidity risk in bond investment refers to two things. First, the bid-ask spread represents how easily the bonds are traded in the marketplace. The bid-ask spread as a proxy for liquidity is based on Amihud and Mandelson (1986). Second, the liquidity ratio informs the issuing firm's repayment capacity. The liquidity ratio in the bond context refers to liquidity ratios used to determine a debtor's ability to pay off current debt obligations without raising external capital. Febi *et al.* (2018) consider liquidity as a factor being tested in their study; they found that green bonds are more liquid than conventional bonds. The liquidity and bid-ask spread have a positive relation to the yield. Moreover, the impact of liquidity risk not being focused may affect the maturity of green bonds. Similarly, Favero *et al. (2009) study documented that liquidity, as a proxy by bid-ask spread, is positively influencing the bond yield for both short-maturity* (5 years) and long-maturity bonds (10 years). Another researcher found that green bonds are more liquid than private bonds (Bachelet *et al.,* 2019). Other than that, Bai, Bali, and Wen (2019) stated that liquidity risk is a serious concern for bond market investors; liquidity risk affects future bond returns. Not only that, previous researcher Wang *et al.,* (2019) found that green bonds that have stronger liquidity tend to be more attractive in trading, which will increase the recognition of green bonds by investors. Accordingly, demand will positively influence bond values.

H2d: Liquidity will positively influence the green bond returns

Table 2: Selected empirical evidence on environmental risk impacts on green bonds

Study	Country/Period	Dependent variable	Independent variable - Environmental factors	Model	Findings
He and Shi, (2023)	China, 2016 to 2021	Green Bond Index	Air pollution	Stepwise regression	Positive and significant
Chang *et al.,* (2022)	10 countries with high green bond issuance	Green bond	Ecological footprint	Quantile cointegration	Green finance improves environmental quality
Liu, Qi, and Wan (2022)	China, 672 green bonds, 2016 to 2019	Green bond issuance	Environment Governance	Structural equation models	Environment Governance is positive and significant
Nanayakkara and Colombage (2022)	1982 GB issues from 52 countries, 2007 to 2019	Bid-ask spread	Moody's classification of credit exposure to environmental risk	Panel regression with robust estimators	Environmental credit risk – Positive and insignificant
Wang *et al.,* (2022)	16 listed firms in TWSE; 2011 to 2020	Green bond issuance	Firms' climate risk concerns	Propensity matching and difference-in-difference regression	the climate risk concerns increase for most firms after the issuance of green bonds
Dan and Tiron-Tudor (2021)	European countries; 2014–2019	Green bond issues	ESG index	Panel regression	ESG index positively influencing

					green bond issues
Flammer (2021)	Global countries 2013–2018	Corporate green bonds return using the market model	Environment rating (ASSET4) Environment materiality (SASB, industry level)	Event study	Environment rating and Environment materiality is positive and significant
Mazzacurati, Paris and Tsiotras (2021)	The European Green Bond, 2009 and 2019	n/a	n/a	Industry review paper	Lower carbon intensity and GHG emission for green bond issuers
Hammoudeh, Ajmi, and Mokni (2020)	The USA, 2014 to 10 February 2020	SP green bond index	CO2 emission allowance price	Time-varying Granger causality	significant time-varying causality from the CO2 emission allowances price to green bonds
Ehlers and Packer (2017)	Global green bond markets	n/a	n/a	Industry review paper	Green bonds low exposure to environmental credit risk

Notes: Selected evidence which concerned about environmental risk on green bond performance

RESEARCH METHODOLOGY

Sample

The data collected from Eikon Thompson Reuters and World Bank, which include the available corporate green bond data from different countries, includes advanced countries: Australia, Germany, New Zealand, Norway, Sweden, United States, and Asia countries; China, India, Indonesia, Malaysia, Singapore, Thailand. The green bond data starts from 2015 to 2019 with monthly frequency. The selection of the corporate green bond is based on the availability of data and is suitable to the time frame.

Table 3: Sample

Countries	Number of Corporate Green Bonds
Advanced countries	
Australia	1

German	1
New Zealand	1
Norway	14
Sweden	89
United States	10
Asia countries	
China	6
India	1
Indonesia	1
Malaysia	9
Singapore	1
Thailand	1
Total	135

Variables

The dependent variable is excess returns, corporate green bond yield minus the risk-free rate, which is the treasury bills rate—the data collected from Eikon Thompson Reuters. Then, the independent variable is environmental risk; this research considers two environmental risk proxies, which are carbon emission per capita and carbon emission metrics tons; the data is collected from the World Bank. Next, the interest and inflation rates are rates from each selected country; both variables are collected from Eikon Thompson Reuters. The last two independent variables are maturity and liquidity, which were collected from Eikon Thompson Reuters. The liquidity variable is based on bid ask spread.

Table 4: Data Description Acronym and Measurement

Variables	Acronym	Measurement	Data sources
Dependent variable			
Green bond return	ER	Country Corporate green bond return – Risk-Free (%)	Eikon Thompson Reuters
Independent variables			
Carbon emission per capita	LogCEPC	Log Country carbon emission per capita (%)	World bank
Carbon emission metrics tons	LogCEMT	Log Country carbon emission metrics tons (%)	World bank
Interest rate	IR	Country Interest Rate (%)	Eikon Thompson Reuters
Inflation rate	INFR	Country consumer price index (%)	Eikon Thompson Reuters
Maturity	LogMAT	Log Corporate green bond maturity (%)	Eikon Thompson Reuters

Liquidity	LIQ	Corporate green bond liquidity (%)	Eikon Thompson Reuters

Empirical Models

Based on the multifactor model, the baseline model in equation 4 measures the common and environmental factors towards the green bond return. The common factors include interest rate, inflation rate, maturity and liquidity, while the environmental risk here is carbon emission. The equation explains the environmental factor, which is CO_2 emission, CE_{it}, which is a proxy by the respective country's carbon emission in metric tons (*CEMT*). The common factors are IR_{it}, the interest rate, INF_{it} Is the inflation rate, MAT_{it} is the maturity; and lastly, LIQ_{it} is liquidity. The excess returns, ER_{it} is calculated based on $R_{it} - R_f$. To address the possibility of the reverse causality concern, the lagged dependent is added as a control independent variable to mitigate the influence of past performance on its future values (Liu, Jin, and Nainar, 2023).

$$ER_{it} = \beta_0 + \beta_1 ER_{it-1} + \beta_2 CE_{it} + \beta_3 IR_{it} + \beta_4 INF_{it} + \beta_5 MAT_{it} + \beta_6 LIQ_{it} + \varepsilon_{it} \quad (4)$$

The empirical model is expanded, considering a series of robustness tests to overcome econometric specification and estimation issues. First, the research considers a different measurement of CO_2 emission proxy by the respective country's carbon emission per capita (*CEPC*). Second, employing a panel robustness estimator, panel weights and Panel-Corrected Standard Errors (PCSE) analysis to mitigate possible error structure due to groupwise heteroscedasticity, autocorrelation, and cross-sectional dependence, which is a common problem for a panel data structure (Beck, 2001). Both of these are estimated using the following equation 5. Where lagged ER and CE are used to reduce concerns about persistency and potential endogeneity problems in the models (Galletta *et al.,* 2023).

$$ER_{it} = \beta_0 + \beta_1 ER_{it-1} + \beta_2 CE_{it-1} + \beta_3 IR_{it} + \beta_4 INF_{it} + \beta_5 MAT_{it} + \beta_6 LIQ_{it} + \varepsilon_{it} \quad (5)$$

Third, the empirical model is estimated using the instrumental variable two-stage least squares (TSLS) method to mitigate endogeneity concerns. In the first stage regression, as in equation 6, the research identifies the respective country’s sustainable development (SDG) index as the instrument variables (IVs) following approaches documented closely related evidence (Liu, Jin, and Nair, 2023). The country sustainable development (SDG) index is expected only to impact CE_{it-1} and is a relevant and strong instrumental variable. The $\sum \beta_i X_{it}$ represents all other common risk factors. CE_{it-1} is the dependent variable in the first stage. $\widehat{CE}_{it-1}$ estimated from the first stage is used as one of the independent variables in the second stage regression as in equation 7.

$$CE_{it-1} = \beta_0 + \beta_1 CE_{it-2} + \beta_1 SDG_{it} + \sum \beta_i X_{it} + \varepsilon_{it} \quad (6)$$

$$ER_{it} = \beta_0 + \beta_1 ER_{it-1} + \beta_2 \widehat{CE}_{it-1} + \beta_3 IR_{it} + \beta_4 INF_{it} + \beta_5 MAT_{it} + \beta_6 LIQ_{it} + \varepsilon_{it} (7)$$

Hypotheses to be tested are;

H_1: $\beta_2 CE \neq 0$, and positive or negative insignificant; H_{2a}: $\beta_3 IR \neq 0$, and positive; H_{2b}: $\beta_4 INF \neq 0$, and negative;
H_{2c}: $\beta_5 MAT \neq 0$, and negative; H_{2d}: $\beta_6 LIQ \neq 0$, and positive.

Model testing procedures

In the preliminary data analyses, a series of basic statistical tests is performed. The empirical models are estimated using the panel regression approach, which considers the pooled OLS model (POLS), random effect model (RE), and fixed effect model (FE). The panel regression model selection is determined based on the Breusch Pagan LM (BPLM) and Hausman tests. The selected models are also subject to diagnostic checks, including the Autocorrelation, Multicollinearity, and Heteroscedasticity tests.

ANALYSIS AND FINDINGS

Preliminary data analysis

The descriptive statistics are presented in Table 5, and elaboration emphasises focus variables. First, the mean of green bond excess returns is about 6 per cent, which is above the global corporate bond portfolio yield, ranging between 2.4 and 4.8 per cent, as analysed by Bekaert and De Santis (2021) employing global corporate bonds data from 1998 to 2018. In the correlation analysis presented in Table 6, the correlations among independent variables are acceptably low, except for the lagged dependent variables, which are normal. Table 7 shows the results of the panel unit-root test. The findings show that all panel variables are integrated at 1%, 5% and 10% levels of significance, indicating that all variables are stationary.

Table 5: Descriptive statistics of mean, median, standard deviation, skewness and kurtosis

Variables	Mean	Median	Std. dev	Skewness	Kurtosis
Return-rf	0.6946	0.5760	1.0178	1.9072	10.1260
Return-rf(-1)	0.6945	0.5760	1.0177	1.9077	10.1285
LogCEMT	2.0593	1.6488	0.7809	1.6322	3.9993
LogCEPC	0.7449	0.6312	0.2106	0.7942	3.1051
IR	0.8037	-0.1458	1.8686	1.3976	4.4523
INFR	1.9169	1.9000	0.6708	0.3693	7.2266
LogMAT	1.8178	1.8751	0.2173	-3.2255	19.3917
LIQ	0.3246	0.2876	0.2661	3.4415	21.2885

Table 6: Correlation analysis

Variables	R-rf	R-rf(-1)	logCEMT	logCEPC	IR	INFR	LogM	L
R-rf	1							
R-rf(-1)	0.9695	1						
LogCEMT	0.4052	0.4092	1					
LogCEPC	0.3313	0.3350		1				
IR	0.3529	0.3506	0.6375	0.3851	1			
INFR	0.0781	0.0808	0.1233	-0.0854	0.1157	1		
LogMAT	0.1789	0.1884	0.1798	0.2057	0.1000	-0.0212	1	
LIQ	0.1996	0.1960	-0.0550	0.1191	0.0133	0.1651	0.3979	1

Table 7: Stationarity tests

Variables	Levin, Lin & Chu	IM, Pesaran & Shin	ADF-Fisher	PP-Fisher	Stationarity
R-rf	-2.7232***	-1.3782*	321.3730	334.3480**	at level
	(0.0032)	(0.0841)	(0.1142)	(0.0444)	
R-rf(-1)	-2.3667***	-0.6104	306.3310	325.6740*	at level
	(0.0090)	(0.2708)	(0.2706)	(0.0853)	
LogCEMT	-13.3762***	-702.5760***	437.3780	275.8120	at level
	(0.0000)	(0.0000)	(1.0000)	(0.7161)	
LogCEPC	-51.8632***	-521.1830***	376.3290***	236.7090	at level
	(0.0000)	(0.0000)	(0.0006)	(0.9923)	
IR	0.0000	0.8493	133.3500	176.6620	at 1st difference
	(1.0000)	(0.8022)	(0.9619)	(0.2362)	
INFR	-1.2978*	-4.5623***	382.8380***	475.0730***	at level

	(0.0972)	(0.0000)	(0.0003)	(0.0000)	
LogMAT	12.5521	-3.5829	1029.4000	4693.82	at 1st difference
	(1.0000)	(0.0002)	(0.0000)	(0.0000)	
LIQ	1.3292	-3.4382***	668.0580***	1603.1700***	at level
	(0.9081)	(0.0003)	(0.0000)	(0.0000)	

Empirical model analysis

The baseline model estimations are presented in Table 8, Model 1, and estimated using the panel RE model to satisfy the panel model selection tests (i.e., BPLM and Hausman tests). The focus environmental variable (CEMT) is positive and significant ($\beta = 2.5057, \rho > 0.05$), which indicates the environmental risk neutrality effects on corporate green bond returns. In other words, the environmental risk does not harm green bonds' valuation but increases instead, which could indicate a green premium in bond valuation by investors. All other controlled common green bond risk factors' coefficients are as theoretically expected and significant, except for liquidity.

First, the robustness tests are presented in Table 8 (Model 2), and the research considers a different measurement of CO_2 emission proxy by the respective country's carbon emission per capita (*CEPC*). The results indicated that the alternate proxy for environmental risk is negative and significant. ($\beta = -5.6097, \rho > 0.01$), which indicates that environmental risk is a positively priced risk that could reduce the value of green bonds. These results do not confirm the expected risk neutrality and contradict the baseline results. However, these results are premature before considering other robustness analyses performed and mentioned in the following paragraphs. All other controlled common green bond risk factors' coefficients are as theoretically expected and significant, except for liquidity.

The second robustness test, as presented in Table 9 (Models 3 and 4), employs a panel robust estimator, panel weights, and Panel-Corrected Standard Errors (PCSE) analysis to mitigate possible error structure due to groupwise heteroscedasticity, autocorrelation, and cross-sectional dependence. Focusing on the environmental risk, both proxies, CEMT ($\beta = 0.0091, \rho < 0.05$)and CEPS ($\beta = 0.0150, \rho < 0.05$), are positive and insignificant, indicating the environmental risk neutrality impacts on corporate green bond returns. All other controlled common green bond risk factors' coefficients are as theoretically expected and significant, except for the inflation rate.

The third robustness test using 2SLS methods is presented in Table 10 (Models 5 and 6). This robustness test is intended to mitigate the possible problem of endogeneity (correlation of environmental variables with the error terms), which influences the effect of environmental risk proxies on green bond values. In the first stage of regression, treating the respective environmental risk proxies (i.e. CEMT and CEPC) as the dependent variables and regressing with the instrument variable, SDG index (logSDG), in addition to other variables in the model. Each model generates an estimate that replaces the environmental variables in the second regression stage. Accordingly, the adjusted environmental variables are free from the influence of SDG factors. Focusing on the environmental risk, CEMT is positive and insignificant, which indicates environmental risk neutrality, and CEPS is negative and significant, failing to show environmental risk neutrality behaviour. The results indicate that environmental risk neutrality impacts on green bond values might vary depending on the choice of environmental proxies. All other controlled common green bond risk factors' coefficients are as theoretically expected and significant, except for the inflation rate.

Table 11 provides a summary of the hypothesis testing. Taking into account all analyses, a general conclusion can be made on the environmental risk neutrality impacts on green bond returns. This evidence supports the validity of H1. In addition, all H2 sub-hypotheses' validity is also supported as theoretically and practically expected.

Table 8: Estimations for baseline panel models

Variables/ Models	Model 1		Model 2		Theoretical Expectation
	FE	VIF	FE	VIF	
C	-4.7535**		4.5594***		
	(0.0286)		(0.0000)		
R-rf(-1)	0.8116***	1.2731	0.7954***	1.2731	+ve & Sig.
	(0.0000)		(0.0000)		
LogCEMT	2.5057**	1.892	-	1.892	+ve & Sig
	(0.0169)				
LogCEPC	-		-5.6097***	1.2952	+ve & Sig
			(0.0000)		
IR	0.0289***	1.7148	0.02128***	1.2940	+ve & Sig
	(0.0000)		(0.0012)		
INFR	-0.0273***	1.0637	-0.0563***	1.0820	-ve & Sig

	(0.0035)		(0.0000)		
LogMAT	-0.1397***	1.0256	-0.0841***	1.2422	-ve & Sig
	(0.0000)		(0.0029)		
LIQ	0.0370	1.2904	0.0436*	1.2398	+ve & Sig
	(0.1520)		(0.0846)		
R-Squared	0.9452		0.9471		
Adj. R-Squared	0.9427		0.9447		
F-statistics	377.5956***		391.7535***		
	(0.0000)		(0.0000)		
Heteroskedasticity test	20.9068***		19.4595***		*Hetero present*
	(0.0000)		(0.0000)		
BPLM Test	5.4418**		5.4572**		H_0: FE (p>0.05)
	(0.0195)		(0.0195)		H_1: *RE (p<0.05)*
Hausman Test	231.1457***		357.7279***		H_0: RE (p>0.05)
	(0.0000)		(0.0000)		H_1: *FE (p<0.05)*

Notes: The FE estimator approach is used to estimate the baseline models (Model 1 and Model 2). Model 1 use logCEMT as a proxy for environmentalk risk. While Model 2 use logCEPC as an alternative proxy for environmental risk.

Table 9: Estimations using the panel robust estimator, PSCE

Variables/ Models	Model 3		Model 4		Theoretical Expectation
	RE-PSCE	VIF	RE-PSCE	VIF	
C	0.1061**		0.1045**		
	(0.0356)		(0.0422)		
R-rf(-1)	0.9540***	1.2765	0.9550***	1.2461	+ve & Sig.
	(0.0000)		(0.0000)		
LogCEMT(-1)	0.0091	1.8980			+ve & Sig.
	(0.3297)				
LogCEPC(-1)			0.0150	1.2908	+ve & Sig.
			(0.5283)		
IR	0.0069*	1.7144	0.0085*	1.2936	+ve & Sig.
	(0.0897)		(0.0617)		
INFR	-0.0074	1.0636	-0.0059	1.0806	-ve & Sig.
	(0.4188)		(0.5055)		

LogMAT	-0.0530*	1.2566	-0.0494*	1.2304	-ve & Sig.
	(0.0515)		(0.0716)		
LIQ	0.0686***	1.2911	0.0627**	1.2398	+ve & Sig.
	(0.0100)		(0.0138)		
R-Squared	0.9403		0.9403		
Adj. R-Squared	0.9402		0.9402		
F-statistics	9058.2463***		9058.2463**		
	(0.0000)		(0.0000)		
Heteroskedasticity test	20.3859***		19.6038***		*Hetero present*
	(0.0000)		(0.0000)		
BPLM Test	5.4457**		5.4112***		H_0: FE (p>0.05)
	(0.0196)		(0.0200)		*H_1: RE (p<0.05)*
Hausman Test	0.0000		0.0000		*H_0: RE (p>0.05)*
	(1.0000)		(1.0000)		H_1: FE (p<0.05)

Notes: The RE-PSCE estimator is used as a robustness approach to estimate Model 3 and Model 4. The PSCE is used to mitigate possible error structure due to groupwise heteroscedasticity, autocorrelation, and cross-sectional dependence.

Table 10: Estimations using TSLS

Variables/ Models	Model 5		Model 6		Theoretical Expectation
	POLS-TSLS	VIF	POLS-TSLS	VIF	
C	0.1121*		0.1098***		
	(0.0620)		(0.0073)		
R-rf(-1)	0.9533***	1.2238	0.9534***	1.2236	+ve & Sig.
	(0.0000)		(0.0000)		
Resid_LogCEMT(-1)	0.0000	1.0014	n/a		+ve & Sig.
	(0.5327)				
Resid_LogCEPC(-1)	n/a		-0.0139***	1.0010	+ve & Sig.
			(0.0099)		
IR	0.0084***	1.1701	0.0083***	1.1702	+ve & Sig.
	(0.0012)		(0.0012)		
INFR	-0.0090	1.0537	-0.0084	1.0543	-ve & Sig.

	(0.1820)		(0.2116)		
LogMAT	-0.0432*	1.2566	-0.0423*	1.2569	-ve & Sig.
	(0.0532)		(0.0581)		
LIQ	0.0638***	1.3021	0.0623***	1.3013	+ve & Sig.
	(0.0051)		(0.0062)		
R-Squared	0.9364		0.9365		
Adj. R-Squared	0.9363		0.9364		
F-statistics	7744.4260***		7760.8920***		
	(0.0000)		(0.0000)		
Heteroskedasticity test	2767.3080***		2716.5470***		*Hetero present*
	(0.0000)		(0.0000)		

Notes: The TSLS method is estimated following the approaches documented by Liu *et al.* (2023). In the first stage regression, the following model is estimated to generate estimates for the respective environmental risk using logSDG as the instrument variable: (i) CEMT c R-rf(-1) LogSDG LogCEMT(-2) IR INF LogMAT LIQ, and (ii) CEPC c R-rf(-1) LogSDG LogCEPC(-2) IR INF LogMAT LIQ. The generated estimates are used in the second stage regression replacing the environmental risk variable; (i) R-rf c R-rf(-1) ResidualCEMT(-1) IR INF LogMAT LIQ, and (ii) R-rf c R-rf(-1) ResidualCEPC(-1) IR INF LogMAT LIQ.

Table 11: Summary of hypotheses testing

Hypotheses/ tests	Baseline models		Robustness models				Findings
	Model 1 FE (CEMT)	Model 2 FE (CEPC)	Model 3 RE-PSCE (CEMT)	Model 4 RE-PSCE (CEPC)	Model 5 POLS-TSLS (CEMT)	Model 6 POLS-TSLS (CEPC)	
H1: Environmental risk → green bond returns	2.505**	-5.609	0.009	0.015	0.000	-0.013***	Generally neutral
H2a: Interest rate → green bond returns	0.028***	0.021***	0.006*	0.008*	0.008***	0.008***	Positive
H2b: Inflation rate → green bond returns	-0.027***	-0.056***	-0.007	-0.005	-0.009	-0.008	Generally Negative
H2c: Maturity → green bond returns	-0.139***	-0.084***	-0.053*	-0.049*	-0.043*	-0.042*	Negative

H2d: Liquidity → green bond returns	0.037	0.043*	0.068***	0.062**	0.063***	0.052***	Generally Positive

Notes: This table summarises the hypothesis testing by collectively reading the baseline models (Table 8—model 1) and robustness analyses (Table 8—model 2, Table 9—model 3 to 4, and Table 10—model 5 to 6).

DISCUSSION

Validity of the regression results

This part provides defenses and clarification to the validity of the regression results. The baseline models (model 1 and model 2) are performed using FE estimator. The estimated models showed the presence of heteroskedasticity issues, which means that the error variances are not all equal. This problem is mitigated in the robustness models (model 3 and model 4), which are performed using PSCE estimators to mitigate possible heteroscedasticity, autocorrelation, and cross-sectional dependence in the panel data structure (Beck, 2001). Further robustness models (model 5 and model 6) were performed based on POLS-TSLS estimations to mitigate endogeneity concerns following Liu, Jin, and Nair (2023). The POLS-TSLS is preferred to be used if no selection of the IV (Semykina and Wooldridge, 2010). In this research, the IV used is the SDG index in reference to Liu, Jin, and Nair (2023), which is practically impacting the environmental quality outcomes.

Of particular concern, the regressions generated a higher R^2, but this is defended to be not a spurious regression case due to multicollinearity, overfitting model, and chance correlation among IVs. The defence clarifications are as follows. First, multicollinearity is not present given all IVs' VIF are smaller than 5. Second, an overfitting model is unlikely since the estimated models are based on the standard multifactor bond pricing model. Noted that the inclusion of lag-dependent variable carries a high coefficient between 0.8 – 0.9 which caused the R^2 and the F-test to be large. However, the inclusion of this lag-dependent variable is to mitigate persistency and endogeneity problems in the model (Galletta *et al.,* 2023). Third, the chance correlation issue is negligible since all IVs' correlations are lower values except for the lag-dependent variable, which is 0.9, but a must-control variable in the model.

The impacts of environmental risks on corporate green bond valuation

Environmental risk (expectation – neutral) - According to theoretical and industry practice expectations, green bonds, a sustainable financial instrument, are expected to be exposed neutrally to environmental risk. This is due to the logical practice that the issuance of green bonds is intended to finance only environmentally friendly projects with strict compliance with the green bonds' principle (Ng and Tao, 2016; Hachenberg, 2018; Weber, 2019). In this analysis, the environmental risks considered are carbon emissions, which are proxied by carbon emissions per capita and carbon emissions in metric tons. Generally, the findings support the validity of the environmental risk neutrality on green bond values, reading from the environmental risk's coefficients as either positive (significant or insignificant) or negative (insignificant). These findings can be synthesised with the theoretical expectation that in an efficient market with significant sustainability practices in financial markets, sustainability risk (in this research case, the environmental risk) should be effectively priced in the sustainable financial instruments since they are incorporated in the design of financial instruments, in the institution, investor, and market practices (Schoenmaker and Schramade, 2019). The findings also align with existing evidence (7 research), as provided in Table 2. To recap, two studies provide evidence of positive perspectives (significant/insignificant) influence of environmental factors on green bond valuations. In particular, He and Shi (2023) provide evidence of air pollution's positive and significant influence on green bond index values in China. At the same time, Nanayakkara and Colombage (2022) show that Moody's environmental risk classifications have positive and insignificant effects on green bonds. In other evidence, five studies provide negative effect perspectives. Briefly, Chang *et al.* (2022) reported that green bond improves environmental quality (low environmental risk). Wang *et al.,* (2022) documented that green bond issuance improves the climate risk concerns of the issuers (low environmental risk). Flammer's (2021) research noted that higher environmental ratings and materiality concerns (low environmental risk) positively influence green bond values. In Mazzacurati *et al.* (2021), it is reported that green bond issuers carry a lower carbon intensity and GHG emissions. In the last piece of evidence, Ehlers and Packer (2017) argued that green bonds should carry a lower exposure to environmental risk.

The findings of environmental risk neutrality on green bond pricing are also in line with recent green bond pricing research. In a closely related study, carbon risk has been documented to be negatively impacting green bond pricing (Duan, Li, and Wen, 2021; Dill, 2024). In another study using sustainability risk, the issuer's ESG performance can influence green bond ratings and impact the yield accordingly (Baldi and Pandimiglio, 2022). Extending the findings to practice, some evidence documented the application of green bonds as a hedging instrument against environmental risk (Jin *et al.,* 2020; Nguyen *et al.,* 2023) that could be deployed in investment portfolio risk management to hedge sustainability-related risk.

The impacts of common risk to corporate green bonds valuation

Interest rate (expectation – positive) – The bond pricing theory predicts that interest rates will positively impact bond values, based on the logic that a higher interest rate will reflect a higher bond yield (Jalles, 2019). The present research confirms these positive and significant effects, aligning with existing evidence. In particular, Viceira (2012) documented that movements in nominal interest rates are positively related to changes in bond risk and return volatility. *Inflation rate* (expectation – negative) – Inflation is expected to be negatively related to the bond yield since inflation reduces the positive effect of interest values on bond yield. In other words, the return on a bond is reduced in real terms and adjusted for inflation. The present findings support the negative role of the inflation rate on bond yield, which is in line with the empirical evidence (Kleczyk, 2012; Poghosyan, 2014). *Maturity* (expectation – negative) – Ideally, bond maturity affects bond yields through its influence on investors' determination of yield to maturity. Earlier evidence documented mixed evidence with the general idea that the influence of maturity on bond yields varies, with short maturity noted to be more negative and long maturity more positive (Park, 1999; Chiang, 2016). This study finds that maturity negatively impacts the valuation of corporate green bonds. The findings are in line with existing evidence which indicates the bond maturity is negatively related to the issue risk premium of green bonds with the justification that the longer maturity proves confidence in green bond sales (Wang *et al.,* 2019). *Liquidity* (expectation – positive) – Liquidity is theoretically expected to be positively related to bond yields. This research finds liquidity is positively related to green bond yield, confirming existing evidence which indicates that liquidity has a positive relation with the yield (Favero *et al.,* 2009; Febi *et al.,* 2018; Bai *et al.,* 2019). In practice, green bonds with strong liquidity will attract investors' demand and consequently affect yields positively (Wang *et al.,* 2019).

CONCLUSION

Common bond risk factors, namely interest rate, inflation rate, maturity, and liquidity, are proven to be priced risk factors in corporate green bonds. In addition, environmental risk, a novel sustainability risk, is confirmed to be neutrally impacting corporate green bonds. This confirms the theoretical, practical, and policy expectations of environmental risk neutrality in sustainable finance instruments that could facilitate the transition towards a low-carbon economy.

Theoretical implication – This research extends the green bond valuation in the context of a multifactor asset pricing model and offers global evidence for validating the impact of environmental risk neutrality on corporate green bond returns. *Practical implication* – In the transition to a sustainable finance industry, ESG is considered a novel risk. In this regard, empirical validation of environmental risk neutrality on corporate green bonds is important to corporate finance managers and investors. Supporting the sustainability transition, corporations would benefit from low environmental risk impacts on the projects undertaken and higher ESG ratings. As for investors, demand for sustainable investment instruments like green bonds is rising, and they are considering environmental risk in investment decisions. The evidence of environmental risk neutrality documented in this research is one possible channel related to the earlier evidence documenting the green premium on green bond pricing. *Policy implication* – Transparency reporting of corporate green bond impacts is important to stakeholders to ascertain the attainment of the targeted environmental benefits to support the logic of environmental risk reduction or neutrality. Sustainability must be strictly in practice on the part of financial instruments, market structure, and investor decision-making to establish the sustainable finance market efficiency.

The present research is limited to several key areas that could be expanded in future research. Firstly, concerning model estimation efficiency. Future research may replicate the green valuation model without lag-dependent variable to go away with the higher R^2 which may leads to suspicion of spurious regression issues. However, the panel GMM estimator is to be used to overcome the endogeneity issues arising from reverse causality. In the case of the TSLS model, if there is no selection bias on the part of the IV instrument, the FE-TSLS estimator is better to be used, as it is robust to any type of correlation between unobserved effects and explanatory and instrumental variables. Furthermore, it does not require specification of the reduced form equations for endogenous variables, and makes no assumptions about the error distribution (Semykina and Wooldridge 2010).

Firstly, in terms of green bond data. The research considered only corporate green bond issuance. At the start of the research in 2019, being a new sustainable financial instrument, not many corporate green bonds were available, and the research was limited to a small sample of 135 green bonds from only 12 countries. Hence, generalization of the findings needs to be taken with care. In recent years, the impact of bond issuance by corporations and nations has been growing and could be investigated in terms of environmental risk proxy. The present research utilises only CO2 proxies. Broader proxies of environmental risks popularly used in the present research are GHG emissions and carbon footprint. Since different proxies might cause variations in the results, the selection of environmental variables that are directly linked to green bond issuance is more appropriate. Hence, the corporate footprint data would be more valuable. Finally, the bond pricing model used is limited to economic multifactor. The corporate green bonds model can be expanded by incorporating firm characteristics as well as green bond issuance characteristics like ratings. Corporations practice full sustainability, and investors investing in sustainable ways are strongly needed to help transition the sustainable finance industry. Green bonds are a good example of sustainable finance instruments that provide financial returns and are equally concerned about ESG risks that must be mitigated in the transition to a sustainable world. Going forward, whether ESG risks are priced and well mitigated in all types of sustainability bonds remains an important issue for stakeholders in the sustainable finance industry.

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