The Impact of Oil Price Fluctuations on Green Bonds

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Abstract

Title: The Impact of Oil Price Fluctuations on Green Bonds

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This dissertation investigates the relationship between oil price fluctuations and green bond returns. A two-step linear regression model is used to test the hypotheses that oil price fluctuations have a significant impact on green bond returns and that green bonds can be used as hedging instruments against oil price fluctuations. Based on daily returns between 2021 and 2022 from a sample of 58 green bonds, the direct impact of oil price fluctuations on green bond returns is first examined. Model 1 shows a significant relationship between oil price fluctuations and green bonds. But this cannot be confirmed in Model 2, taking into account other independent variables, including the returns of WTI crude oil, the stocks of green bond issuers, and the MSCI World index, as well as their volatilities. However, the inclusion of the volatility of WTI proves to have a significant negative effect on the returns of green bonds. By considering other significant variables or directly including the volatility of WTI, the impact of oil price fluctuations on the returns of green bonds may become less significant. Therefore, both hypotheses can only be confirmed indirectly.

Keywords: Green Bonds, Oil Price, Hedging Mechanisms, Sustainable Investments

Resumo

Título: O Impacto das Flutuações do Preço do Petróleo nas Obrigações Verdes

Autor: Jan Pahlke

Esta dissertação investiga a relação entre as flutuações do preço do petróleo e a rendibilidade das obrigações verdes. É utilizado um modelo de regressão linear em duas etapas para testar as hipóteses de que as flutuações do preço do petróleo têm um impacto significativo nos retornos das obrigações verdes e de que as obrigações verdes podem ser utilizadas como instrumentos de cobertura contra as flutuações do preço do petróleo. Com base nos retornos diários entre 2021 e 2022 de uma amostra de 58 obrigações verdes, começa-se por examinar o impacto direto das flutuações do preço do petróleo nos retornos das obrigações verdes. O Modelo 1 mostra uma relação significativa entre as flutuações do preço do petróleo e as obrigações verdes. Mas tal não pode ser confirmado no Modelo 2, tendo em conta outras variáveis independentes, incluindo os retornos do petróleo bruto WTI, as acções dos emitentes de obrigações verdes e o índice MSCI World, bem como as suas volatilidades. No entanto, a inclusão da volatilidade do WTI revela-se um efeito negativo significativo sobre os retornos das obrigações verdes. Ao considerar outras variáveis significativas ou ao incluir diretamente a volatilidade do WTI, o impacto das flutuações do preço do petróleo nos retornos das obrigações verdes pode tornar-se menos significativo. Por conseguinte, ambas as hipóteses só podem ser confirmadas indiretamente.

Palavras-chave: Obrigações verdes, Preço do petróleo, Mecanismos de cobertura, Investimentos sustentáveis

1. Introduction

Climate change poses massive challenges for the entire world. Today, as the effects of climate change become increasingly apparent, the need for sustainable change has become a central issue in all areas of life. This awareness did not develop recently as already in 2015, the international community of 197 countries took significant steps to combat climate change and mitigate its consequences by signing the Paris Agreement. The three main goals of the agreement include reducing global warming to 1.5 degrees Celsius, strengthening the capacity of affected countries to adapt to climate change and reducing CO2 emissions, and aligning financial flows with climate goals. To achieve this transformation, a tremendous amount of capital is needed. According to a study by the Swiss reinsurance company Swiss RE (2022), an average of USD 9.4 trillion per year is needed to achieve a net zero economy by 2050, the target set by the European Union. This leaves a total investment gap of around USD 271 trillion (excluding investments in fossil fuels). Hence, the question of how these massive investments can be supported and promoted arises. One financial instrument can play a special role here, namely green bonds. Green bonds are issued specifically to finance environmentally and climate-friendly projects.

The publication of data on climate change and its political and economic impacts in 2007, prompted a group of Swedish pension funds and the Sandinaviska Enskilda Banken AB to develop a solution for financing that reduces risk for investors and has a positive impact on the climate. In collaboration with the World Bank, the very first green bond was issued in 2008 and the market has grown enormously since then. After the introduction of the Green Bond Principles by the International Stock Market Association in 2014, a voluntary framework for the issuance of green bonds, the market has grown almost exponentially by nearly 1231% as of 2022 (Appendix A). Only in 2022, with an issue volume of USD 487 billion, growth recorded a decrease of 16% compared to the previous year. Initially, the market was dominated by multilateral development banks, but this has changed as companies and governments increasingly search for investments that minimize the risks of climate change and reduce greenhouse gas emissions. As a result, financial institutions are now the largest issuer, accounting for 29% (Appendix B) of green bonds issued. Corporations (25%) and sovereigns (17%) are the second and third largest issuers. Europe dominates the market with a share of 47% (Appendix C) of all newly issued green bonds in 2022, which is why 42% of the volume is priced in euros (CBI, 2023a). However, Asian countries and emerging economies have also experienced rapid growth in recent years.

This impressive growth certainly contributes significantly to the achievement of climate goals, but some challenges affect the advancement of the green bond market, for example the high oil price volatility observed in the wake of the Russia-Ukraine war. After Russia invaded Ukraine, oil prices rose massively. In fact, Russia was hit with tough sanctions, effectively cutting off the supply of the second-largest oil producer. The reduced supply catapulted prices, which peaked at $123.64 per barrel on March 8, 2023 (Appendix D). Although prices subsided somewhat thereafter, the price level remained elevated until well beyond the first half of the year.

The question arises as to what impact such oil price fluctuations will have on green bonds, the supposed instrument for achieving climate targets. How do oil prices correlate with green bonds? Is the volatility dragging investors to a decreased risk profile instrument? How can investors diversify their portfolios to minimize risks from oil price fluctuations? What hedging strategies can Investors use to minimize the risk of oil price fluctuations? Especially for investors interested in investing in green bonds or already holding them in their portfolio, it is important to gain knowledge about the relationship between the oil and green bond markets. The main focus of research so far has been on analyzing the impact of oil prices and, in particular, oil price shocks on green bond issuance. However, some recent academic work also examines the link between these two assets and the utility of green bonds for investors. Some studies show a negative relationship between oil and green bond markets (e.g., Li et al. (2022), or Doğan et al. (2023)). This means that green bond yields tend to rise when oil prices fall. It can be advantageous for investors, as they can then use green bonds as a hedging instrument against oil price fluctuations. On the other hand, some studies show a positive relationship between the two assets (e.g., Kanamura (2020) or Dutta et al. (2021)). This implies that green bonds could become more attractive for investors when oil prices rise. These different results raise important questions about how investors can design their portfolios and use green bonds in times of volatile oil prices.

This work is intended to contribute to the understanding of the relationship between the green bond and oil markets. To this end, I examine the impact of oil price fluctuations, represented by West Texas Intermediate (WTI) crude oil, on green bond returns, as measured by log returns. I consider daily returns between 01.01.2021 and 31.12.2022, a period deliberately chosen because oil prices fluctuated sharply during this period. First, I examine the sole influence of oil price fluctuations on green bonds. In the second step, I extend the model by adding several independent variables, including the returns of WTI crude oil, the stocks of green bond issuers, and the MSCI World index, as well as their volatilities. The inclusion of these variables allows to include other possible influencing factors and to perform a more meaningful analysis. Unlike most papers, the analysis does not use a green bond index, but a sample of green bonds created from the available data in Refinitiv Eikon. Based on the existing literature, I posit two hypotheses. First, oil price fluctuations have a significant impact on green bond returns. And second, green bonds can be used as a hedging instrument against oil price fluctuations.

To investigate the above hypotheses the remainder of this thesis is presented as follows: Section 2 begins with an explanation of the definition and standards of green bonds. Section 3 provides a literature review of the current state of research on the interplay between oil and green bond markets. In section 4 the methodology applied to verify the hypotheses is outlined and it is explained why which variables were included in the models. Section 5 presents the underlying data for the analysis, the methods used to calculate the variables, and the descriptive statistics of these data. Section 6 elaborates on the empirical results and compares both models. Section 7 then examines the robustness of the models, before section 8 finally presents the conclusion of the empirical study.

2. Definition of Green Bonds

The following section provides an overview of the definition of green bonds, as well as the framework that has become the voluntary market standard for issuing green bonds.

There are many definitions and interpretations of green bonds. The European Parliament defines green bonds as follows: "Green bonds are committed to financing or re-financing investments, projects, expenditure or assets helping to address climate and environmental issues" (European Parliament, 2022). Furthermore, there are various initiatives with different definitions and standards for green bonds, such as the Climate Bond Initiative (CBI) and the International Capital Market Association (ICMA), which have emerged as two (voluntary) market standards for green bonds. The ICMA’s Green Bond Principles (GBP) dominate over the CBI’s Climate Bonds Standard and Certification Scheme due to less stringent requirements (European Parliament, 2022). Since the CBI’s standard is based on the ICMA’s GBP, I refer in this paper to the ICMA’s definition of the GBP, which defines green bonds and their standards below.

A green bond is defined as any bond where the proceeds are used solely for the financing or refinancing of green projects and comply with the GBP. The GBP are composed of four principles “Use of Proceeds”, “Process for Project Evaluation and Selection”, “Management of

Proceeds", and "Reporting". The "Use of Proceeds" principle defines for which green projects the proceeds may be used and legal paperwork must include a note on the use. According to the guiding concept, all projects that receive green bond financing or refinancing "should provide clear environmental benefits which will be assessed and, where feasible, quantified by the issuer" (ICMA, 2022). The GBP specifies a number of project categories that are usually supported by the issuance of green bonds. However, these are not limited, and others can be added on an ongoing basis. Eligible projects include projects in the following areas: renewable energy, energy efficiency, pollution prevention and control, environmentally sustainable management of living natural resources and land use, terrestrial and aquatic biodiversity, clean transportation, sustainable water and wastewater management, climate change adaptation, circular economy adapted products, production technologies and processes, and green buildings.

The Process for Project Evaluation and Selection principle states that the issuer of the green bonds should clearly define to investors the sustainable goals and intentions, as well as the affiliation in one of the above-mentioned use of proceeds categories. It should disclose information on the process by which the issuer selects the projects and assesses and manages the social and environmental risks. Furthermore, the issuer is advised to position itself on the disclosed information in terms of the company's overall strategy, policy, and objectives with regard to environmental sustainability.

Various approaches are proposed for the administration and management of the proceeds. In any case, the investors should be informed about the temporary storage of non-allocated proceeds. In addition, the allocation to the projects should be ensured and periodically adjusted over the entire term of the green bond. In general, a transparent presentation and external review are recommended.

The annual report should provide an overview of the funded projects, including a brief description of each project. This should include not only the amount of proceeds used but also the achieved or expected impact of the project. Significant changes in the use of proceeds should be reported on a regular basis. Otherwise, annual reporting is sufficient, but the data should always be kept up to date. Qualitative and quantitative performance measures are recommended to measure and quantify the impact of the project. Their underlying assumptions and methodologies should also be reported.

3. Literature Review

The current section of the dissertation provides a broad review of the current state of academic literature, particularly regarding the connectedness between green bonds and oil markets. In addition, an explanation of how this dissertation differs from the existing literature is provided.

With the increasing awareness of the necessity of environmental protection and the associated link between the environment and finance, this research field is gaining strong attention. Green bonds are proving to be a useful tool for reducing CO2 emissions at the corporate level (Fatica and Panzica, 2020). However, the question arises of how other assets affect green bonds. Therefore, and more importantly due to the reduction in the use of fossil fuels and fluctuating prices, the link between oil and green bond markets is increasingly coming to the forefront of research. Nevertheless, the main research focus so far has been on analyzing how oil prices, and especially oil price shocks affect the issuance of green bonds. But recent studies have provided insights into the link between these two assets and the utility of green bonds for investors.

Kanamura (2020) examines in his study the environmental friendliness and investment performance of green bonds. Proposing a new price model based on the demand and supply of green bonds and energy commodities, he first examines the correlation between the two assets to assess the environmental friendliness of green bonds using various green bond indices. For this purpose, he uses a structural-type model framework (Kanamura, 2020). In the second step, he uses a model based on the expected return, risk, and performance ratio of green bond premiums (defined by the log difference between green and conventional bonds) to measure the performance of green bonds versus conventional bonds. The study shows that different green bond indices are either positively or negatively correlated with WTI or Brent crude prices. On the one hand, it shows a negative correlation between oil prices and the Solactive green bond index, so that the prices move in opposite directions. On the other hand, he can show that both the Bloomberg Barclays MSCI and the S&P green bond index correlate positively with oil prices and therefore rise with them. The difference in the interaction is due to the weighting of the indices and the fact that the Solactive green bond index is not particularly representative of the green bond market (Kanamura, 2020).

In line with Kanamura's (2020) findings, Dutta et al. (2021) also demonstrate a positive, but weak, time-varying correlation between climate bonds[1] and WTI oil prices. In their study, they

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[1] Climate bonds are a subset of green bonds, and they are used for climate change solutions (CBI, 2023b).

examine the dynamic correlations and hedging effectiveness between climate bonds, equities, gold, and oil markets, as well as the linkage between these markets, particularly during the COVID-19 pandemic. For their approach, they use a bivariate asymmetric VAR-DDC-GARCH model. The model is based on Engle's (2002) DCC-GARCH model, which is used to estimate and forecast volatility and time-varying correlation in financial time series (Engle, 2002). The asymmetric version of the model by Cappiello et al. (2006) is applied because financial time series data are often affected by asymmetric effects (Dutta et al., 2019). In addition to the positive correlation between climate bonds and oil prices, they find that they are also positively correlated with gold, but significantly negatively correlated with the S&P 500, which intensified during the COVID-19 pandemic. The analysis of hedging effectiveness revealed a positive hedge ratio for climate bonds and gold. On the other hand, the hedge ratios for climate bonds and oil, and stock fluctuated between positive and negative. Thus, climate bonds proved to be an effective hedge mechanism. During the pandemic, however, the effectiveness is reduced.

A weak relationship between WTI oil and green bond markets was also demonstrated by Braga et al. (2021). The authors argue that investments in innovative renewable energy projects are risky and characterized by higher relative fixed costs and upfront costs (especially in developing countries). As a result, and due to the dynamics in the credit markets, there may be reduced borrowing and a gap in investments in green projects. Therefore, the authors hypothesize that the state and multilateral organizations can play a special role in reducing risks and costs, as issuers or guarantors. To test this, the authors calculate bond yields and beta prices. They find that green bonds issued by governments and multilateral organizations, especially for long maturities, have lower yields and volatilities compared to private bonds. The resulting lower return-risk ratio makes investment more attractive to risk-averse investors. As issuers, governments and multilateral companies can therefore contribute to the increased financing of green projects. In addition, the authors find evidence that green bonds can be used as a good hedging instrument against oil price fluctuations. To do this, they compare the impact of oil price fluctuations on the returns of green bonds (using the S&P 500 Green Bond Index) and energy corporate bonds (using the S&P 500 Energy Corporate Bond Index). The result shows that the volatility of green bond returns is less affected by the oil price than the returns of conventional energy bonds.

In their study, Lee et al. (2021) examine the causal relationship between Brent crude oil prices, geopolitical risks, and the Barclays MSCI green bond index in the United States. They hypothesize that oil price fluctuations can be used to explain green bond price dynamics. To test their hypothesis, they use a Granger-causality in quantile analysis. This method is used to examine the causality between two variables in different qualities of the data distribution (Granger, 1969). It allows to analyze not only the direction but also the strength of the causal relationships. This is particularly important to better interpret the relationships in different market conditions. In addition, compared to a linear estimation of causality, the analysis allows to detect different forms of conditional heterogeneity, giving a better understanding of the causal relationship (Lee et al., 2021). The result of the Granger-causality quantile analysis indicates that there is a causal relationship between oil prices, geopolitical risks, and green bond prices. This changes under different market conditions. Furthermore, they find a significant bi-directional causality between oil prices and green bonds for lower quantiles, so that they influence each other. Because of this mutual interaction, green bonds are a good hedging mechanism in times of bearish markets. On the other hand, the analysis for upper quantiles shows a less strong influence of oil prices on green bond prices. Therefore, green bonds can be used for diversification during bullish oil market conditions.

Pham and Nguyen (2022) investigate the impact of economic policy and financial market uncertainties on green bond markets. They analyze four green bond indices[2] and three uncertainty indices[3] using two different models. First, they apply a Markov switching dynamic regression (MSDR) model of Hamilton (1989) as it allows for the use of state-dependent and time-varying dynamics in the relationships between the different variables (Pham & Nguyen, 2022). Based on the observed data, the MSDR model allows switching between two states representing periods of high and low uncertainty. By including the state variable, the model captures the changing relationship between green bonds and uncertainty and provides a more nuanced analysis than traditional regression models (Pham & Nguyen, 2022). The model provides evidence that the impact of uncertainty on green bonds is dependent on the degree of uncertainty. In periods of low uncertainty, the uncertainty indices show a lower effect on green bond returns than in periods of high uncertainty. As a second approach, they use a time-varying parameter vector autoregression (TVP-VAR) connectedness network. Compared to the MSDR, it estimates coefficients and volatility of time-varying variables in a vector autoregressive framework that allows to analyze dynamic interactions and spillover effects between the variables under study over time. The model demonstrates on average a relatively low level of connectedness between the green bond and uncertainty indices. Consequently, the low

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[2] Solactive Green Bond EUR USD IG Index, S&P Green Bond Index, Bloomberg Barclays MSCI USD Green Bond Index, and Bloomberg Barclays MSCI EUR Green Bond Index.

[3] Baker, Bloom and Davies (2016), CBOE Volatility Index, and CBOE Crude Oil Volatility Index.

connectedness and thus reduced spillover effects suggest limited transmission of shocks between the uncertainty indices and green bond markets. However, during periods of high uncertainty, such as during the COVID-19 pandemic, connectedness increases. The authors thus find a similar result as Dutta et al. (2021) and show a low connection between green bonds and oil markets and hence represent a good hedging instrument for investors.

In order to examine their hypothesis that crude oil investors can use green bonds as an efficient hedging instrument and as a safe haven, Huang et al. (2022) choose an approach similar to that of Dutta et al. (2021). To measure the dynamic correlation between green bond and Crude oil markets, the authors use the DCC-GARCH model of Engle (2002). They find that during the period under consideration, the dynamic conditional correlations between green bonds and crude oil are low. While during the COVID-19 pandemic and the outbreak of the Russia-Ukraine conflict, they find a negative correlation. Furthermore, they discover evidence that green bonds have the highest risk reduction effectiveness compared to precious metals, such as gold or silver. To test the hypothesis that green bonds exhibit safe haven properties for crude oil investors, they follow the model of Baur and McDermott (2010) Therefore, they regress the relationship between green bonds and crude oil markets and implement a dynamic process to capture extreme oil price movements. The regression shows that green bonds act as a safe haven and a strong hedge against Crude oil markets.

Li et al. (2022) study the dynamic relationship between oil prices and green bonds using the Shanghai Stock Exchange green bond index. The authors, like Pham and Nguyen (2022) use a TVP-VAR model to account for time variations. The analysis shows that the oil price has a negative impact on the green bond index in the short and medium term. This result suggests that green bonds are not an effective instrument to hedge against oil price fluctuations.

In their study, Doğan et al. (2023) also examine the causal relationship between crude oil, green bonds, and geopolitical risks using indices. Compared to Lee et al. (2021), they additionally consider policy uncertainties and other commodities and examine the dynamic dependencies of the variables. They test for causality in the first step with the Granger-causality quantiles analysis. Based on this, they use the quantile coherency estimation method of Baruník and Kley (2019) to analyze the dependence and the joint variation between the variables over different frequencies and during calm and turbulent events, i.e., in the different quantiles of the distribution. Furthermore, the authors use the cross-quantilogram model of Han et al. (2016). The model is used to study the dependence between two variables in different quantiles of the distribution (Han et al., 2016). In addition, it allows a detailed analysis of the relationship between variables and can capture aspects such as asymmetries and nonlinear dependencies (Han et al., 2016). This allows the authors to analyze not only the causality between variables but also the strength and direction of dependence in different quantiles of the distribution (Doğan et al., 2023). The analysis revealed that there is a negative relationship between green bonds and oil markets in the intermediate quantiles and during short-term periods. Therefore, green bonds can be considered a safe haven asset. Furthermore, the authors show that changes in oil prices can predict the volatility of green bonds. In particular during, periods of turmoil in the oil market, oil price fluctuations can affect the price changes of green bonds. There is also a bi-directional causality so that green bond price fluctuations also affect oil price developments.

This dissertation makes some contributions to the academic literature on the interplay between green bonds and oil markets. First, unlike most papers, the analysis does not use a green bond index, but a sample of green bonds. By considering only green bonds, the true effect of oil price fluctuations on green bond returns is measured. A bias due to the weighting of an index is thus prevented. Other aspects such as rebalancing or currency hedging, which could have an impact on the performance of the index, are therefore excluded. Furthermore, only corporate green bonds of publicly traded companies are considered. Second, most studies focus solely on the impact of oil prices on green bonds and include few, if any, other variables in the analysis. In this study, several independent variables are included in the second model. The inclusion of different variables provides a more comprehensive view of the determinants of green bond returns and adds to the existing body of knowledge. To the best of my knowledge, this is the first work to address this issue in this way.

4. Methodology

In the following section, the methodology applied to verify the hypotheses is outlined. Furthermore, it is explained why the different variables were considered in the models.

This work uses a two-step regression model approach to measure the impact of oil price fluctuations on green bond returns. In the first step, a simple linear regression is estimated. The regression equation is as followed:

$$GB_{i,t} = \beta_0 + \beta_1 * WTI_{i,t} + \varepsilon_{i,t}, \tag{1}$$

where $GB_{i,t}$ is the log returns of green bonds, $WTI_{i,t}$ the log returns of WTI crude oil, and ε the error term. This regression allows to test the direct relationship between oil price fluctuations and green bond returns.

In the second step, a multivariate regression model is applied. Additional relevant variables (Table 1) are added to account for potential endogenous influences and to gain a more comprehensive understanding of the determinants of green bond performance. This approach increases the accuracy of the model and performs a robust analysis to control for potential confounders and draw accurate conclusions.

The multivariate regression model is in the following form:

$$\begin{aligned} GB_{i,t} = \beta_0 + \beta_1 * WTI_{i,t} + \beta_2 * Stock_{i,t} + \beta_3 * MSCI_{i,t} + \beta_4 * GB\ vola_{i,t} \\ + \beta_5 * WTI\ vola_{i,t} + \beta_6 * Stock\ vola_{i,t} + \beta_7 \\ * MSCI\ vola_{i,t}, + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where $Stock_{i,t}$ represents the returns on the shares of the issuer companies. These can be an important measure of general market sentiment and investors' risk preferences. Furthermore, incorporating this variable into the model can reveal potential systematic risks that could affect both the stock market and green bonds. This allows for a more nuanced view of the impact of the stock market on green bond performance and helps explain deviations from expected performance. The variable $MSCI_{i,t}$ represents market developments on a global level and can provide insights into overarching economic and political developments. By including this variable in the model, the influence of international trends and events on the performance of green bonds can be investigated. This is particularly relevant as green bonds are often purchased by investors who are globally diversified and thus also react to global market developments.

In addition to the log returns of WTI, the companies, and the MSCI World index, the volatility of these variables as well as the volatility of the green bonds are also taken into account and are marked with $vola_{i,t}$. This decision is based on two main reasons. First, the inclusion of volatilities allows for a more nuanced view of risk aspects and their potential impact on green bond performance. In addition, volatilities can provide important information about the uncertainty and fluctuations of the markets, which can have an impact on investors' investment decisions. Second, bond volatilities are considered because green bonds have special characteristics and must meet certain criteria and standards. The volatility of green bonds may therefore differ from other investment instruments and thus have an independent impact on their performance. By taking bond volatility into account, a detailed insight into the specific risk factors that may influence the performance of green bonds is provided.

Table 1
Variable Definitions

Variable	**Definition**
Dependent	
GB	Log green bond returns
Independent	
WTI	Log WTI crude oil returns
Stock	Log returns on the shares of the issuer
MSCI	Log MSCI World index returns
Bond vola	Volatility of log green bond returns
WTI vola	Volatility of log WTI crude oil returns
Stock vola	Volatility of log returns on the shares of the issuer
MSCI vola	Volatility of log MSCI World index returns

5. Data

The subsequent section gives an overview of the data used, as well as the calculation methods of the variables considered in the model. In addition, a descriptive statistic of the data is presented.

All data included in this analysis was retrieved from Refinitiv Eikon and Refinitiv Eikon Datastream. The sample covers the period from 01.01.2021 to 31.12.2022, as the oil price fluctuated strongly during this period. The Refinitiv universe contains just 7888 labeled green bonds (Refinitiv, 20.07.2023), making the data very limited indeed. For the sample, only green bonds were considered which belong to the issuer type "corporate". This reduces the number to 2346, as the majority of green bonds are issued by financial institutions. In order to create a homogeneous group for comparison, the sample is limited to green bonds with fixed coupons, which reduces the influence of interest rate risks. Moreover, the sample only includes green bonds issued in 2020, and thus is affected by similar market conditions. Furthermore, to include stock returns in the model, only green bonds of publicly traded companies were considered. After applying the filtering and eliminating green bonds with missing values, a final sample of 58 bonds from different regions and industries was obtained. Table 2 below presents the descriptive statistics for the dataset. An overview, including information on the issuers, is presented in Appendix E.

Table 2
Descriptive Statistics

Variable	N	Mean	St. Dev.	Min	Max
Dependent					
GB	30,160	-0.001	0.021	-0.916	0.693
Independent					
WTI	30,160	0.001	0.026	-0.129	0.080
Stock	30,160	-0.001	0.024	-1.091	0.545
MSCI	30,160	-0.0001	0.010	-0.037	0.049
Bond vola	30,160	0.014	0.025	0.000	0.244
WTI vola	30,160	0.027	0.003	0.000	0.032
Stock vola	30,160	0.022	0.014	0.000	0.131
MSCI vola	30,160	0.012	0.001	0.000	0.014

The use of logarithmic returns allows for linear aggregation across different time periods and simplifies the interpretation and comparability of the percentage price changes between the different variables. The log returns of all variables were calculated as follows:

$$\log return_t = \log\left(\frac{return_t}{return_{t-1}}\right). \tag{3}$$

For the calculation of the green bond log returns, the daily closing prices of the green bonds were used, using the Market Price Data (MPD) datatype to obtain the best available price. The daily closing prices of the relevant stocks were used to determine the returns for the companies and the MSCI (Appendix F). However, as not all green bond and share prices are inherently quoted in US-dollar, all prices were first converted into US-dollar in order to eliminate possible influences of exchange rates (Appendix G). As variable for the oil price, the Oil-WTI Spot Cushing U$/BBL and its daily closing prices were used. The reason for using the WTI is that about 22% of the bonds in the sample are American and the share of American stocks in the MSCI World is about 70% (MSCI, 2023).

Additionally, the volatilities were calculated on the basis of the log returns and the common standard deviation formula was used:

$$\sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{(n-1)}}, \tag{4}$$

where x_i refers to the log returns, $\bar{x}$ to the sample mean average of the log returns, and n to the sample size.

6. Empirical Results

In this chapter, the empirical results of the estimated models are presented and interpreted. First, Model 1 and then Model 2 are analyzed. This is followed by a comparison of the two models.

6.1. Model 1 Results

As described in the methodologies chapter, a two-step regression is used in this work, to investigate the impact of WTI price fluctuations on green bond yields. First, Model 1 was estimated to measure the direct effect of oil price fluctuations on green bond returns. The estimation of Model 1 (Table 3) shows that the estimated coefficient for log WTI returns $WTI_{i,t}$ is significant at the 1% significance level. On average, an increase in WTI returns increases the yield on green bonds by 0.0147%. Model 1 thus proves that there is an impact of oil price fluctuations on the returns of green bonds, although the effect is weak. The findings support my first hypothesis and are directly in line with previous findings of Kanamura (2020), Dutta et al. (2021), Braga et al. (2021), Pham and Nguyen (2022), and Huang et al. (2022).

Table 3
Model 1 Results

	Dependent variable:
	GB Coefficients
WTI	0.0147^{***}
	(0.0046)
Constant	-0.0008^{***}
	(0.0001)
Observations	30,160
R^2	0.0003
Adjusted R^2	0.0003
Residual Std. Error	0.0206 (df = 30158)
F Statistic	10.2844^{***} (df = 1; 30158)
p-value	0.00134

Note: ***, **, and * significance at 1, 5, and 10% respectively. Standard error values are in parentheses.

The correlation matrix is shown in Table 4. Similar to Kanamura (2020) and Dutta et al. (2021), a weak positive correlation was found between WTI log yields and green bond log yields (correlation coefficient = 0.018). This correlation suggests that some relationship exists between the two variables. An increase in oil prices is associated with a slight increase in green bond yields. This could indicate that green bond investors expect higher returns during periods of rising oil prices. Accordingly, this result suggests that green bonds are benefiting from developments in the oil market. Thus, this does not support my hypothesis that green bonds can be used as a hedge against oil price fluctuations. Investors who want to hedge against oil price fluctuations should therefore consider alternative hedging strategies.

Table 4
Correlation Matrix Model 1

	GB	WTI
GB		0.0185
WTI	0.0185	

Note: Computed correlation used pearson-method with listwise-deletion.

However, it should be noted that the value of the R-squared is just 0.0003. This suggests that only a very small fraction of the variation in green bond yields can be explained by changes in oil yields and other factors play a more significant role in determining green bond returns. Nevertheless, overall, the model demonstrates a statistically significant impact of oil price fluctuations on green bond returns. With a score of 10.28 and a p-value of 0.0013, the F-statistic indicates that the model is highly significant at the 1% level.

6.2. Model 2 Results

In the second step of the two-step regression, the log returns of the issuer companies and the MSCI World index were taken into account as independent variables in addition to the log returns of the WTI. Furthermore, the volatilities of the respective variables were included. The results of the regression analysis are shown in Table 5.

According to the correlation matrix (Table 6), the correlation between the log WTI returns $WTI_{i,t}$ and the green bond returns is 0.0185, which means that there is a slightly positive correlation between the two variables. These findings are consistent with Kanamura (2020) and Dutta et al. (2021). However, unlike in Model 1, the coefficient of the WTI returns is not statistically significant, neither at the 1% level nor at the 10% significance level. This means that the model cannot demonstrate sufficient evidence that WTI oil price fluctuations have a significant impact on green bond returns. The value of the coefficient is 0.0024, indicating that a one percent change in the WTI oil price is associated with a 0.0024 percent change in the green bond return. In accordance with Kanamura (2020), Dutta et al. (2021), Braga et al. (2021), Pham and Nguyen (2022), and Huang et al. (2022), the result indicates a weak relationship between the two variables. Nevertheless, the result is inconsistent with my hypothesis that oil price fluctuations have a significant impact on green bond returns. It appears that other factors have a stronger impact on green bond performance and that the WTI oil price itself does not make a significant contribution. It is possible that additional factors, such as macroeconomic conditions or specific characteristics of green bonds, have a greater impact and mask the effect of the oil price.

Table 5
Model 2 Results

	Dependent variable:
	GB Coefficients
WTI	0.0024 (0.0045)
Stock	0.1460*** (0.0051)
MSCI	0.0772*** (0.0115)
GB vola	-0.0682*** (0.0062)
WTI vola	-0.1004** (0.0424)
Stock vola	0.0315*** (0.0112)
MSCI vola	-0.3094*** (0.1028)
Constant	0.0060*** (0.0012)
Observations	30,160
R^2	0.0402
Adjusted R^2	0.0400
Residual Std. Error	0.0202 (df = 30152)
F Statistic	180.4996*** (df = 7; 30152)
p-value	< 2.2e-16

Note: ***, **, and * significance at 1, 5, and 10% respectively. Standard error values are in parentheses.

The coefficient of the returns of the issuer companies' stocks $Stock_{i,t}$ in Model 2 is 0.146 and is highly significant at the 1% significance level, indicating that there is a statistically significant relationship between the log returns of green bonds and the log returns of stocks. Additionally, there is a positive correlation between the independent variable and the dependent variable, of 0.1809. The result implies that a positive change in the issuer's stock returns tends to be associated with a higher return on green bonds. This could be attributed to rising share prices of the issuer, which could be associated with increased financial stability or a positive business outlook. As a result, there may be more investor confidence in green bonds, which could improve these bonds' performance. However, it should be noted that this is not the only reason and that the performance of green bonds is also influenced by other factors.

Table 6
Correlation Matrix Model 2

	GB	WTI	Stock	MSCI	GB vola	WTI vola	Stock vola	MSCI vola
GB		0.0185	0.1809	0.0801	-0.0786	-0.0259	-0.0422	-0.0389
WTI	0.0185		0.0528	0.1542	-0.0067	0.0214	-0.0031	-0.0218
Stock	0.1809	0.0528		0.2322	-0.0479	-0.0232	-0.0345	-0.0354
MSCI	0.0801	0.1542	0.2323		-0.0031	-0.0078	-0.0028	-0.0618
GB vola	-0.0786	-0.0067	-0.0479	-0.0031		-0.0012	0.6528	0.0802
WTI vola	-0.0259	0.0214	-0.0232	-0.0078	-0.0012		0.0940	0.4538
Stock vola	-0.0422	-0.0031	-0.0345	-0.0028	0.6528	0.0940		0.1043
MSCI vola	-0.0389	-0.0218	-0.0354	-0.0618	0.0802	0.4538	0.1043	

Note: Computed correlation used pearson-method with listwise-deletion.

Next, I consider the coefficient on the log return of the MSCI World index $MSCI_{i,t}$ in Model 2. The estimated coefficient is 0.0772 and statistically significant at the 1% level. Hence, if the MSCI increases by 1%, green bond returns increase by 0.07% on average. In this case, a positive correlation between the two variables could be assumed a priori, as the performance of bonds tends to improve in times of rising stock prices and positive market sentiment, thus boosting investor confidence and stimulating demand for green investments. The model proves a positive correlation. It should be noted, however, that the relationship between green bonds, or bonds in general, and the MSCI is not necessarily positive. Due to the different dynamics and influencing factors, the returns of green bonds and the performance of the MSCI or the stock market may also differ in certain situations.

The bond volatility coefficient $GB\ vola_{i,t}$ measures the effect of the volatility of green bonds on their return. A negative and highly significant (at the 1% significance level) coefficient of -0.0682 shows that an increase in volatility is associated with a decrease in the return on green bonds. This finding is in line with Doğan et al. (2023) and implies that investors demand a higher risk premium for bonds that exhibit higher volatility to compensate for the associated higher risk. As a result, yields decline. In addition, higher volatility may indicate uncertainty or market instability, which in turn may affect the demand for green bonds and thus lead to lower yields. Further, the two variables show a negative correlation, meaning that there is an inverse relationship between the two variables.

Volatile oil prices signal instability and uncertainty in the market. These fluctuations can be triggered by various factors, such as changes in demand or geopolitical tensions. Increased volatility can lead to a decline in investments, as companies and investors have difficulty estimating future energy costs. In addition, falling demand for oil may indicate a decline in economic strength, which in turn may affect bond yields. The regression shows that there is a negative relationship between green bond yields and oil price volatility $WTI\ vola_{i,t}$. The coefficient of WTI volatility is -0.1004 and is statistically significant at the 5% level. An increase in volatility is therefore associated with a decrease in green bond yields, and vice versa. The regression also shows a negative correlation between the two variables. The result suggests that green bonds can be used as a hedging instrument against oil price fluctuations in times of increased volatility. When the oil price is volatile and rising, investors can benefit from an expected decline in green bond yields and reduce potential losses in their portfolios. Thus, hypothesis 2 is indirectly confirmed.

The volatilities of the issuer's shares $Stock\ vola_{i,t}$ have a significant impact (at the 1% level) on the returns of the green bonds. On average, the yields of the green bonds increase by 0.03% as a result of a 1% increase in the share price. Furthermore, the correlation between the volatility measure and the returns is -0.0422. This negative correlation indicates that green bond returns increase during periods of higher volatility of the underlying stocks. This result suggests that green bonds can be used as a hedging instrument against stock market volatility. It may not be the case due to the greenness of the bond but much more about the relationship between stocks and bonds. In addition, these results show that the volatility of the underlying company's stock is an important factor influencing the performance of green bonds. Therefore, investors may increasingly invest in green bonds to hedge their portfolios against stock market volatility.

The estimation of MSCI World volatility $MSCI\ vola_{i,t}$ also yields a statistically significant impact on green bond returns. With a value of -0.3094, the coefficient is significant at the 1% level. In other words, a 1% increase in the volatility of the index is associated on average with a -0.31% decrease in the returns of green bonds. The negative correlation of -0.0389 also indicates an inverse relationship between the two variables. The results thus show an influence of the volatility of the MSCI on the returns of the green bonds. Investors can therefore use green bonds to diversify their portfolios. Especially in times of high uncertainty and volatility in the markets, green bonds, therefore, offer a good hedging opportunity. The negative correlation between MSCI volatility and green bond returns confirms this assumption.

Overall, model 2 with an F-statistic of 180.5 and a p-value of < 2.2e-16 is significant at the 1% level. The adjusted R-squared value of 0.04 indicates that about 4% of the variation in green bond returns can be explained by the independent variables in the model. It suggests that other factors not included in the model have an impact on green bond returns. Contrary to the hypothesis, the model does not find a significant impact of oil price fluctuations on green bond returns. On the other hand, the volatility of the oil price has a significant negative impact on the returns of green bonds. This means that more volatile oil prices are associated with lower green bond yields. Increasing volatility in oil prices often indicates uncertainty and instability in the energy sector. Investors can therefore use green bonds as a hedging instrument against the volatility of the oil price.

However, the remaining variables considered demonstrate significant influences on green bond returns. Both the log returns of the issuer companies' shares and those of the MSCI World index show a positive impact on the performance of green bonds. It can therefore be concluded that positive market developments, both on the part of the companies and the overall economic situation, strengthen investors' confidence in green bonds and possibly lead to an improvement in their performance. Yet, this is not the case for the volatility of equity returns and the MSCI. While rising equity volatility has a (slightly) positive impact on green bond returns, the opposite is true of MSCI volatility. Consequently, green bonds can be used as a hedging instrument in two ways. On the one hand, they can be used as a hedge against issuer risk. The positive impact of increasing volatilities of the issuer's shares on the yield of green bonds may indicate that investors are willing to accept lower yields if they consider the issuer's default risk to be low.

In other words, if the issuer is considered to be financially stable and trustworthy, investors may be willing to include the green bonds in their portfolio despite the issuer's volatility because they expect a lower probability of default. On the other hand, by including green bonds in their portfolio, investors can hedge against the volatility of the global equity market. The negative relationship between the volatility of the MSCI and green bond yields may allow portfolios to be protected against losses in times of high uncertainty and volatility, or even to realize gains. However, it should be noted that the greenness of the bond is not necessarily decisive for this but rather the general relationship between stocks and bonds.

The negative impact of bond volatility on green bond returns suggests that investors demand a higher risk premium for bonds with higher volatility to compensate for the associated increased risk. Higher volatilities can have several causes. First, they may be due to uncertainty and instability in the underlying markets. Second, volatility may be due to specific characteristics of the green bond. For example, this could be due to the risk level of the underlying project or the business model of the issuer. Furthermore, it is important to note that higher volatility is not necessarily seen as negative by every investor, as it is potentially compensated with higher returns. Depending on the investor's risk preference, attractive investment opportunities may therefore arise.

6.3. Comparison Model 1 & Model 2

Comparing the two models, it is immediately apparent that Model 2 generally has a higher degree of adaptation to the data than Model 1. Compared to Model 1 (R-squared = 0.0003), Model 2, with an R-squared value of 0.04, is able to explain a significantly larger share of the variation in the returns on green bonds. Even though the adjusted R-squared is not particularly large, adding the additional independent variables has greatly increased the goodness of fit of the model.

An important difference in the results between the models is that in Model 1, oil yields have a significant impact on green bond yields, while in Model 2 no significant impact can be estimated. This contradictory result could be due to confounding factors. On the one hand, it may be that other independent variables in Model 2 have greater explanatory power and thus mask the influence of WTI yields. In particular, issuer returns and MSCI returns have a significant impact on green bond returns. They may reflect different aspects of market behavior and market sentiment, which may have a stronger impact on green bond yields than oil yields. On the other hand, taking into account the volatility of oil may be the reason for the nonsignificant result of oil returns. By directly accounting for volatility, the direct impact of WTI yields on green bond yields may become less significant. Either the volatility of WTI may already contain information about the possible impact of oil price fluctuations on green bond yields. Otherwise, WTI oil price volatility may also serve as a proxy for other factors related to oil price fluctuations, for example, fluctuations may be due to geopolitical events, supply and demand, political decisions, or other external influences. These factors may also affect green bond yields and thus have an indirect impact.

In summary, by including additional independent variables, Model 2 provides a more comprehensive explanation of the variation in green bond returns. This finding suggests that the interaction and interplay of these variables have a stronger impact on green bond returns than oil returns by themselves.

7. Robustness Check

In this section, several robustness tests are performed to verify the validity of the two models.

7.1. Homoscedasticity

To test whether there was a violation of the assumption of homoscedasticity in the two models, the Breusch-Pagan (BP) test was performed in each model. In Model 1, the test shows a BP value of 1.2079 (Table 7) with a degree of freedom of 1 and a p-value of 0.2718. Thus, the test result is not significant at the 5% level and no sufficient evidence for the presence of heteroskedasticity in the error terms can be found. Therefore, this indicates that the variance of the error terms is constant, and the assumption of homoscedasticity is satisfied.

Table 7
Breusch-Pagan Test Results

	BP-Value	**df**	**p-Value**
Model 1	1.2079	1	0.2718
Model 2	1349.1	7	< 2.e-16

In model two, the Breusch-Pagan test returned a value of 1349.1 (Table 7) with a degree of freedom of 7 and a very small p-value of < 2.2e-16. The p-value indicates that there is sufficient evidence for the presence of heteroscedasticity in the error terms. To account for this heteroskedasticity in the error terms in the model, I estimated Model 2 again using robust standard errors. The use of robust standard errors allows to incorporate heteroskedasticity and to adjust its effects on the coefficients, as well as on the statistical significance of the results. The results of the estimation are presented below in Table 8 and show that the coefficients remain mainly unchanged. However, the significance of the coefficient on stock volatility has changed so that this variable is no longer statistically significant. This change may indicate that the impact of issuer stock volatility on green bond returns is less robust when heteroskedasticity is accounted for in the data. It should be noted, however, that the use of robust standard errors makes the values of the coefficients less precise and may cause some coefficients to lose their significance. It is possible that other factors or confounding variables play a role and weaken the relationship between issuer stock volatility and green bond yields.

Table 8
Model 2 Results - Robust Standard Errors

	Dependent variable:
	GB Coefficients
WTI	0.0024
	(0.0048)
Stock	0.1460^{***}
	(0.0199)
MSCI	0.0772^{***}
	(0.0164)
GB vola	-0.0682^{**}
	(0.0301)
WTI vola	-0.1004^{**}
	(0.0480)
Stock vola	0.0315
	(0.0380)
MSCI vola	-0.3094^{***}
	(0.0852)
Constant	0.0060^{***}
	(0.0013)
Observations	30,160
R^2	0.0402
Adjusted R^2	0.0400
Residual Std. Error	0.0202 (df = 30152)
F Statistic	180.4996^{***} (df = 7; 30152)

Note: ***, **, and * significance at 1, 5, and 10% respectively. Standard error values are in parentheses.

7.2. Autocorrelation

Furthermore, I tested the two models for autocorrelation in the residuals to ensure that the residuals are independent, and the statistical inference is correct. For verification, I used the

Durbin-Watson test. It tests if there is a linear autocorrelation between the residuals. The results of the test for both models show that the Durbin-Watson value is above 2 (Table 9) in each case. Values between 2 and 4 indicate the absence of autocorrelation. The p-values for both models are 1, indicating that there is no statistically significant evidence of positive autocorrelation in the residuals. The Alternative Hypothesis of the test, indicating that the true autocorrelation is greater than 0, is not supported. Hence, the residuals in both models do not exhibit systematic autocorrelation.

Table 9
Durbin-Watson Test Results

	Value	**p-Value**
Model 1	2.1062	1
Model 2	2.1765	1

7.3. Multicollinearity

Multicollinearity, the high correlation between independent variables in a model, can be problematic in regressions because it becomes difficult to isolate the individual influence of each variable on the dependent variable. However, this problem can only occur in multivariate regression models. Since Model 1 consists of only one independent variable, this can be neglected here.

To check whether the problem of multicollinearity exists in Model 2, I applied the Variance Inflation Factor (VIF). The result shows that all VIF values are below 5 (Table 10), indicating the absence of significant multicollinearity. This means that the independent variables are not highly correlated with each other and do not provide redundant information.

Table 10
Variance Inflation Factor Test Results

WTI	**Stock**	**MSCI**	**Bond vola**	**WTI vola**	**Stock vola**	**MSCI vola**
1.0259	1.0605	1.0838	1.7630	1.2781	1.7705	1.2783

In summary, both Model 1 and Model 2 provide significant results and reveal different factors influencing green bond returns. The tests for heteroskedasticity and autocorrelation show no significant results, indicating that these problems are not present in the models. The test for multicollinearity shows that there is no redundant information between the independent variables.

8. Conclusion

This paper investigates the impact of oil price fluctuations on green bond returns. It examines the hypotheses that oil price fluctuations have a significant impact on green bond returns and that green bonds are an effective hedging instrument against oil price fluctuations. To test these hypotheses, a two-step linear regression model is estimated, which first measures only the direct effect of oil price fluctuations on green bond returns. In the second step, the model is extended by adding several independent variables, including the returns of WTI crude oil, the stocks of green bond issuers, and the MSCI World index, as well as their volatilities. The main results show that oil price fluctuations do not have a significant impact on green bond returns. Model 1 suggests that the oil price has a significant slightly positive impact on green bond yields. However, the addition of the other variables in Model 2 cannot confirm this, so the coefficient is no longer significant. But the inclusion of the volatility of WTI proves to have a significant negative effect on the returns of green bonds. Two possible reasons for this could be that, first, the addition of other significant variables has greater explanatory power and thus masks the influence of WTI yields. Second, by directly accounting for volatility, the direct impact of WTI yields on green bond yields may become less significant. Either the volatility of WTI may already contain information about the possible impact of oil price fluctuations on green bond yields. Otherwise, WTI oil price volatility may also serve as a proxy for other factors related to oil price fluctuations. Therefore, the hypotheses can only be proven indirectly, and green bonds can be used as a hedging instrument in times of volatile oil prices. However, it should be noted that the values of the R-squared of both models are very small.

Other interesting findings are that the returns on issuers' shares and the market conditions represented by the MSCI World index have a low positive significant impact on green bond returns. It can therefore be concluded that positive market developments, both on the part of the companies and the overall economic situation, strengthen investors' confidence in green bonds and possibly lead to an improvement in their performance. On the other hand, Model 2 shows a slightly positive influence of the volatilities of the issuer companies' shares and a slightly negative influence of the volatilities of the MSCI World index on the returns of green bonds. Therefore, green bonds can be used as a hedge against issuer risk on the one hand and as a hedge against the volatility of the global equity market on the other.

It is important to consider the limitations of this research. First, the analysis is based on data from a limited time period and limited sample size. This may affect the representativeness of the results. Second, not all relevant variables affecting green bond returns may be included in the model. Other factors, such as macroeconomic conditions and specific characteristics of green bonds, could also be key determinants.

The results of this study have important policy implications. Policymakers should create incentives to promote green financing mechanisms. By creating a favorable regulatory framework and providing financial incentives, more companies could be encouraged to issue green bonds. This would not only contribute to climate protection but would also allow investors to invest more in sustainable projects. Furthermore, market transparency and integrity should be strengthened. The introduction of industry-wide standards and guidelines for the issuance and reporting of green bonds would help investors better evaluate them and quantify their environmental impact. Regulatory measures could, among other things, combat greenwashing, thereby strengthening investor confidence in the green bond market.

Finally, this study raises questions that could be explored in future research. For example, a larger sample could be considered, allowing comparisons between green bonds from different regions or industries. In addition, regional differences and specific market conditions in different countries could also be considered. This would allow to check the generalizability of the results. Furthermore, other variables could be included in the model, such as the credit rating of the issuer, to gain a more comprehensive understanding of the determinants of green bond yields. Future research can also investigate the relationship between green bonds and other commodities to get a more inclusive picture of the relationship between green bonds and the different commodities.

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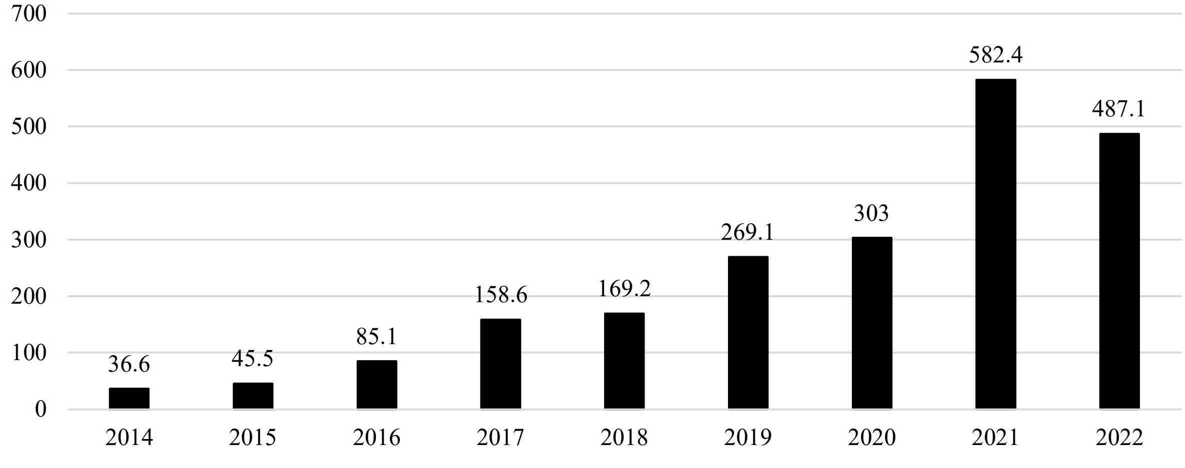
Appendix

Appendix A

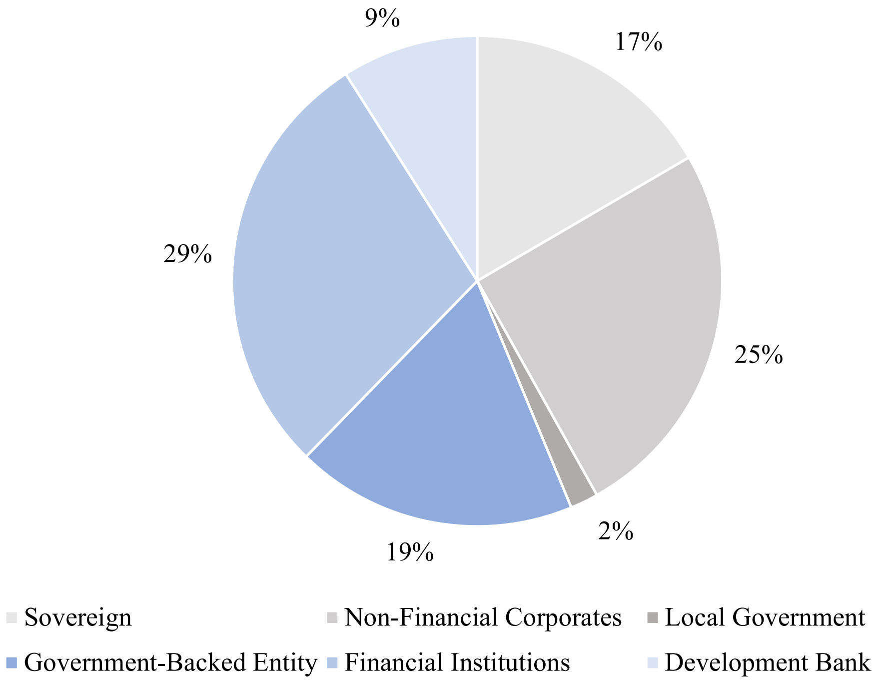
Green Bond Issuance Volume 2014-2022



Source: (CBI, 2023a)

Appendix B

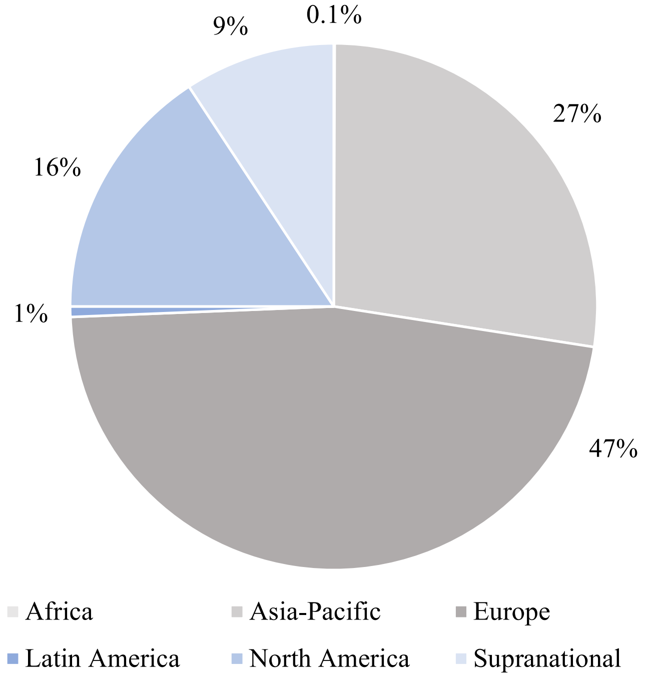
Green Bond Issuance per Type 2022



Source: CBI, 2023

Appendix C

Green Bond Issuance per Region 2022



Source: CBI, 2023

Appendix D

Crude Oil WTI FOB Cushing U$/BBL (Jan 1, 2021 – Dec 31, 2022)

Source: CBI, 2023

Appendix E

Green Bond and Issuer Information

Borrower	**Company RIC**	**Country**	**Bond RIC**	**Currency**	**Maturity Date**
AES Corp.	AES	US	00130HCD5=	United States Dollar	2026
Analog Devices Inc.	ADI.O	US	032654AS4=	United States Dollar	2025
Arkema SA	AKE.PA	FR	FR00140005T0=	Euro	2026
Arthaland Corp.	ALCO.PS	PH	PHALCOT0225=	Philippine Peso	2025
Asahi Group Holdings Ltd.	2502.T	JP	JP14012502=	Japanese Yen	2025
Asahi Kasei Corp.	3407.T	JP	JP00133407=	Japanese Yen	2025
Avangrid Inc.	AGR	US	05351WAC7=	United States Dollar	2025
BASF SE	BASFn.DE	DE	DE218231934=	Euro	2027
Coca-Cola Femsa SAB de CV	KOFUBL.MX	MX	191241AJ7=	United States Dollar	2032
E On SE	EONGn.DE	DE	DE215289958=	Euro	2025
EDP Energias de Portugal SA	EDP.LS	PT	PT215775925=	Euro	2027
Eneos Holdings Inc.	5020.T	JP	JP03015020=	Japanese Yen	2023
Engie SA	ENGIE.PA	FR	FR0013504677=	Euro	2028
ENN Energy Holdings Ltd.	2688.HK	CN	26876FAC6=	United States Dollar	2030
Equinix Inc.	EQIX.O	US	29444UBK1=	United States Dollar	2025
ERG SpA	ERG.MI	IT	IT222943485=	Euro	2027
EVN AG	EVNV.VI	AT	AT0000A2JSN2=	Euro	2035
Foran Energy Group Co. Ltd.	002911.SZ	CN	CN132000036=	Chinese Yuan Renminbi	2023

Getlink SE	GETP.PA	FR	FR224762364=	Euro	2025
Host Hotels and Resorts L.P.	HST.O	US	44107TAZ9=	United States Dollar	2030
Iren SpA	IREE.MI	IT	IT227502908=	Euro	2031
Johnson Controls International PLC	JCI	US	47837RAA8=	United States Dollar	2030
Kirin Holdings Co. Ltd.	2503.T	JP	JP00182503=	Japanese Yen	2025
Komatsu Ltd.	6301.T	JP	JP00146301=	Japanese Yen	2025
Landsea Green Management Ltd.	0106.HK	CN	CN209599201=	United States Dollar	2023
Manila Water Co. Inc.	MWC.PS	PH	PH220893936=	United States Dollar	2030
Mercedes Benz Group AG	MBGn.DE	DE	DE222943159=	Euro	2030
Mitsubishi Heavy Industries Ltd.	7011.T	JP	JP00367011=	Japanese Yen	2025
Mitsui Soko Holdings Co. Ltd.	9302.T	JP	JP00189302=	Japanese Yen	2030
Modern Land China Co. Ltd.	1107.HK	CN	BS220215270=	United States Dollar	2023
MTR Corp. Ltd.	0066.HK	CN	HK221366808=	United States Dollar	2030
National Grid Electricity Transmission PLC	NG.L	UK	GB210491503=	Euro	2025
Niagara Mohawk Power Corp.	NMK_pb	US	65364UAN6=	United States Dollar	2030
Nstar Electric Co.	NSARO.PK	US	67021CAP2=	United States Dollar	2030
Penta-Ocean Construction Co. Ltd.	1893.T	JP	JP00051893=	Japanese Yen	2025
Renova Inc.	9519.T	JP	JP00019519=	Japanese Yen	2025
Ryman Healthcare Ltd.	RYM.NZ	CK	NZRYM1226=	New Zealand Dollar	2026
Seiko Epson Corp.	6724.T	JP	JP00206724=	Japanese Yen	2023
Senko Group Holdings Co. Ltd.	9069.T	JP	JP00089069=	Japanese Yen	2025
Shaanxi Coal & Chemical Industry Group Co. Ltd.	601225.SS	CN	CN132000027=	Chinese Yuan Renminbi	2025
Snam SpA	SRG.MI	IT	IT226834001=	Euro	2028
Stora Enso OYJ	STERV.HE	AX	FI216333462=	Swedish Krona	2025
Telia Co. AB	TELIA.ST	SE	SE218760503=	Swedish Krona	2025
Terna Rete Elettrica Nazionale SpA	TRN.MI	IT	IT220902340=	Euro	2032
Tohoku Electric Power Co. Inc.	9506.T	JP	JP05179506=	Japanese Yen	2030
Tokyo Gas Co. Ltd.	9531.T	JP	JP00669531=	Japanese Yen	2030
Tokyu Fudosan Holdings Corp.	3289.T	JP	JP00223289=	Japanese Yen	2025
Union Electric Co.	UELMO.PK	US	906548CS9=	United States Dollar	2051
UPM-Kymmene OYJ	UPM.HE	AX	FI225796181=	Euro	2028
Verizon Communications Inc.	VZ	US	92343VFL3=	United States Dollar	2030
VF Corp.	VFC	US	US212397016=	Euro	2028
Vinci SA	SGEF.PA	FR	FR0014000PF1=	Euro	2028
Wuhan Sanzhen Industry Holding Co. Ltd.	600168.SS	CN	CN2080039=	Chinese Yuan Renminbi	2025
Xylem Inc.	XYL	US	98419MAM2=	United States Dollar	2028
Yuzhou Group Holdings Co. Ltd.	1628.HK	CN	KY221539931=	United States Dollar	2026
Zhenro Properties Group Ltd.	6158.HK	CN	VG222689821=	United States Dollar	2025
Daiwa House Industry Co. Ltd.	1925.T	JP	JP00221925=	Japanese Yen	2025
Cifi Holdings Group Co. Ltd.	0884.HK	CN	KY220531694=	United States Dollar	2025

Appendix F

West Texas Intermediate and MSCI World index

Variable	**RIC**
WTI	WTC-
MSCI World	.MSCIWO

Appendix G

Exchange Rates

Exchange Rate	**RIC**
Chinese Yuan	CNY=
Euro	EUR=
GBP	GBP=
Hong Kong Dollar	HKD=
Japanese Yen	JPY=
Mexican Peso	MXN=
New Zealand Dollar	NZD=
Philippine Peso	PHP=