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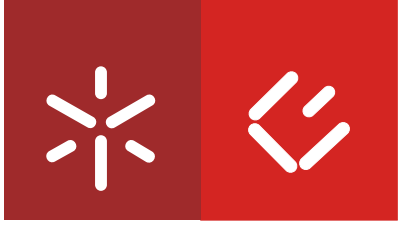

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Investing in environmentally friendly projects: the performance of green bonds

Master in Finance

Supervisor
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Acknowledgments

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Statement of integrity

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

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Resumo

Considerando o crescente crescimento da procura por investimentos ambientais, uma questão natural que surge tem a ver com o impacto financeiro destes tipos de investimentos. O desempenho do investimento em obrigações verdes (*green bonds*) é um tópico ainda por explorar. Neste contexto, este estudo avalia o desempenho de uma carteira de 42 obrigações verdes (*green bonds*) através de um modelo de avaliação baseado em rendibilidades para o período entre 2013 e 2018. O modelo de avaliação utilizado incorpora quatro fatores. Adicionalmente, consideram-se duas alternativas para o índice do mercado de obrigações: um índice de obrigações verdes e um índice geral de obrigações. Os resultados mostram que a carteira de obrigações verdes tem um desempenho não estatisticamente diferente do *benchmark*, pelo que os investidores não sofrem uma penalização financeira pelo facto de investirem neste tipo de obrigações.

Palavras-chave: avaliação do desempenho, carteiras de obrigações, investimentos socialmente responsáveis, obrigações verdes

Abstract

Considering the increasing growth in the demand for environmentally friendly investments, a natural question that arises refers to the financial impact of investing in green projects However, the topic of green bonds' investment performance is still largely unexplored. Therefore, this study evaluates the performance of a portfolio of 42 green bonds from 2013 to 2018, through a return-based performance evaluation model that incorporates four risk factors. Two benchmarks are used to proxy for the bond market: a green bond index and an overall bond index. The results show neutral performance of the portfolio of green bonds, indicating that investors are not penalized when investing in environmentally friendly projects.

Keywords: bond portfolios, green bonds, performance evaluation, socially responsible investing

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1. Introduction

"Climate change is not just an environmental challenge. It is a fundamental threat to economic development and the fight against poverty" stated Jim Yong Kim, President of The World Bank Group (Kim, 2013).

Nowadays, there is more than enough scientific evidence of the environmental crisis and its effects worldwide. We, as humans, are the main culprits of the climate change. Governments, companies and individuals have a major role in fighting the crisis, which may have severe financial implications. For instance, the current greenhouse gas emissions that public and private transportation unleash to the atmosphere are destroying the ozone layer and that will make the planet warmer (global warming), causing the sea level to rise. If the sea level rises, cities near the coast can be destroyed, implying major financial losses. This is one of many reasons we need to move to a more sustainable world, with the adoption of green solutions.

If a change does not come, we will likely face severe casualties in the future. In the past recent years, there has been an increasing awareness of these climate issues and there are several global initiatives that address this issue. For instance, every year there is a meeting of parties with the purpose of fighting the climate change, the Conference of Parties (COP). The best effort seen against the climate change was made during COP 21 in 2015, the Paris Agreement, where all parties committed to fight the global warming by establishing a limit global temperature rise of 1.5-2˚C compared to the pre-industrial level (Nicol, Cochran & Shishlov, 2017). Furthermore, the European Commission (EC) has already formed a Technical Expert Group (TEG) on sustainable finance to propose the development of a global classification system to easily identify sustainable investment activities and a unique label to identify green products. The EC is also showing clear signs of intention to promote sustainable investments by promoting the discussion of the topic among academics and practitioners.[1]

This change towards a sustainable world comes with a long-term public and collective commitment. As Paranque and Revelli (2019) claim, "green bonds cannot be managed as usual financial products in terms of portfolio management, but must be part of a social project embedded in collective governance (Paranque and Revelli, 2019, p.65)". The discussion of how green bonds fit into an investment ethic motivates Paranque and Revelli (2019) to use several ethico-economic frameworks such as the one defined by Aristotle, who qualified ethical economy around the notions of love (goodwill for

[1]: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en

humanity) and justice. The philosopher believed in the contribution of the economy to society's welfare through love and justice in order to obtain wealth (by using money to make money). He therefore idealized that economic relations must be built on a social and community-based approach that boosts the development of a real economy (Paranque and Revelli, 2019). In line with this, Polanyi (2001) argued that social relations are embedded in the economic system and that a market economy can only work in a market society. Elements of the industry, such as labor, land and money are comprehended in a market economy and as labor and land refer to us (human beings), it means the inclusion of society itself in the market economy.

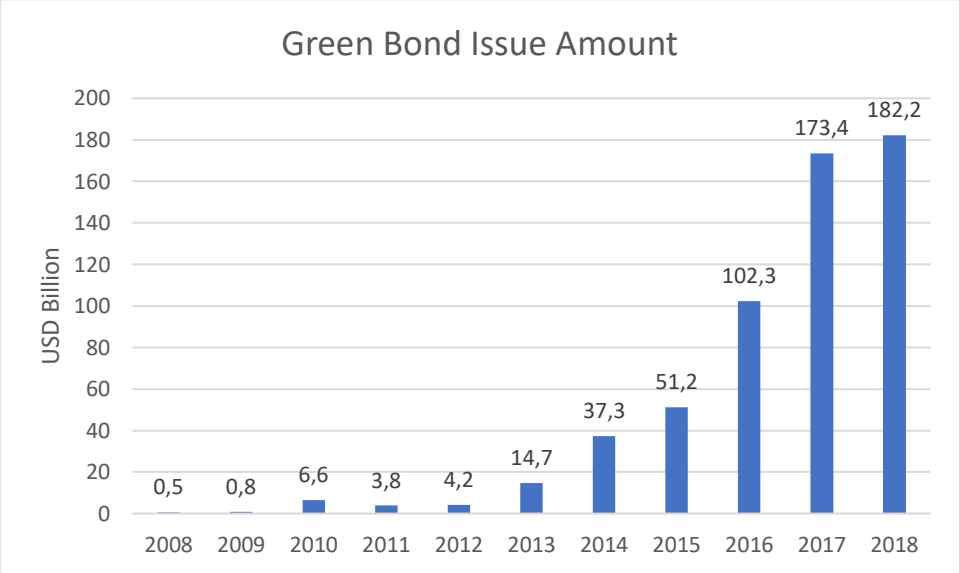
Willmott (2010) senses value with different meanings that may include "aesthetic value, ethical value" (Wilmott, 2010, p.518). For this scholar, the definition of value is perceived as articulations of ethico-political complexes. Ethico-political complexes define social relations as an ethical affair. The link between ethico-political and economy relates to social practices undertaken by the society itself. Accordingly, Parenque and Revelli (2019) contribute by proposing finance as an "ethico-political complex".

The fact that we should include social relations in finance induces a necessity for a change in the financial sector, mainly through a financial tool that allows public or private organizations/corporations or even individual investors to make their businesses more environmental friendly, by letting them put money in more sustainable projects. One way to do that is through the green bond market.

The term green bonds has come around in the latest years to describe a debt instrument that helps the issuer to raise funds with the purpose of funding green projects. Thus, it is aligned with the Green Bond Principles presented in 2014 by the International Capital Market Group (ICMA), which has four core components: use of proceeds; process for project evaluation and selection; management of proceeds; and reporting. (International Capital Market Group, 2018). One relevant detail of the Green Bond Principles is that they do not provide details on the specific criteria that a bond needs to meet in order to be labelled as "green". Although society has a defined notion on how to consider a bond "green", there is not yet available a universal system that recognizes the green features of a bond (Baker *et al.* 2018). These guidelines have been complemented with the Climate Bond Initiative (CBI) standards.

The first Green bond was launched in 2007 by the European Investment Bank (EIB). Until 2013, the green bond market remained relatively stable with very little deviations in the number of green bonds issued year-by-year. But in 2013, it became bigger than all the previous years together, with an issuance amount of $11Bn (EY, 2016). Since then and until today the market has been growing, breaking new records every year (Bloomberg Intelligence, 2019). Figure 1 presents the global issue amount of green bonds per year in billion dollars (USD) since 2008. As can be observed, there is an increase each year compared to the previous one. Green bonds started in 2008 with issues of $0,5Bn growing to $182,2Bn by the end of 2018.

Figure 1: Green Bond Issue Amount – Annual Amounts



USD = United States Dollar; Source: Bloomberg L.P.; Date: 2008 – 11/01/2019

There is a strong tendency for the green bond issuance amount to grow. Besides the necessity to change to a sustainable world, another reason that promotes green bonds is the fact that green bonds are good for the corporation's image.

Considering the recent growth of green bonds, the purpose of this dissertation is to evaluate the performance of this type of instruments. In particular, we will assume an investor's perspective and evaluate the financial performance of a portfolio of green bonds. By doing so, we aim to assess whether investors are penalized or benefited from investing in environmentally friendly projects. The financial performance of the green portfolio is evaluated through a multi-factor model that incorporates relevant risk factors. We expect this work to contribute to the literature since, to the best of our knowledge, studies on this topic are non-existent.

The remainder of the thesis is structured as follows: the following chapter discusses the existing literature on socially responsible investments, corporate social responsibility practices, bond fund performance and green bonds. Chapter 3 describes the methodology used in this study. Chapter 4 presents the data used to conduct the analysis. Chapter 5 provides the empirical analysis conducted. Chapter 6 presents the conclusions of the research, some of its limitations, and suggestions for future research on the topic.

2. Literature review

There is no definite consensus on the performance of socially and responsible investments (SRI). There are arguments that support a positive and negative impact of considering social criteria on portfolio performance. On one side, increased corporate social responsibility practices may imply additional costs that are not offset by the gains. Walley and Whitehead (1994) argue that the main challenge of reaching the socially responsible investor's goals will be to guarantee maximum environmental/social performance associated with minimum cost, since the greater the social performance is, the higher the costs will be. In line with this perspective, many studies find a negative impact between corporate and social financial performance. Wright and Ferris (1997), for instance, find a negative relation between corporate social responsibility and financial performance. Their work showed that the divestment seen in some businesses are driven by the lack of positive returns, which seems to be in agreement with agency theory, due to managers acting in their own interest. At the portfolio level, the underperformance argument is supported by portfolio theory (Markowitz, 1952), that implies that using social screens will penalize diversification by increasing the portfolio's exposure to risk which is not offset by an increase in returns, subsequently harming the portfolio performance (Rudd, 1981).

On the other side, Porter and Van der Linde (1995) argue that corporate social responsibility (CSR) practices can improve financial performance through lower costs, value creation and increased productivity and efficiency in the use of resources. Thus, when investing in companies with high levels of CSR, investors can benefit from their improved financial performance compared to their less socially responsible competitors. El Ghoul *et al.* (2011) find that high corporate social responsibility (CSR) investments increase firm value through lower firm's cost of equity capital.

Several empirical studies specifically investigate the relationship between corporate environmental and financial performance. King and Lenox (2001) and Montabon *et al.* (2007) find a positive relationship between corporate environmental practices and financial performance. In contrast, Wagner (2005) and Di Giuli and Kostovetsky (2014) find a negative effect of environmental on corporate financial performance. Although in the literature we can find evidence of both a positive and negative relationship, some review studies suggest a general tendency for a positive link between corporate environmental and financial performance (e.g., Orlitzky *et al.* 2003; Frooman *et al.* 2008; Dixon-Fowler *et al.* 2013).

At the portfolio level, Derwall *et al.* (2005) show that a stock portfolio of companies labelled as "most eco-efficient" significantly outperforms a less eco-efficient one. In terms of actively managed mutual

funds, studies on green equity funds, conducted by Climent and Soriano (2011), Muñoz *et al.* (2014), Ibikunle and Steffen (2015) and Silva and Cortez (2016), show over- and underperformance compared to conventional funds. For example, Ibikunle and Steffen (2015) show that green mutual funds significantly underperform conventional funds, although its performance is progressively improving to the point that no differences between both performances can be established.

In terms of bond portfolios, there are some studies that evaluate the impact of social screening in the financial performance of socially responsible bond funds (e.g., Derwall and Koedjik, 2009, Henke, 2016, Leite and Cortez, 2018) and porfolios (Polbennikov *et al.* 2016) but, to the best of our knowledge, there are no studies that evaluate the performance of portfolios of green bonds.

Other studies in the bond area investigate the effects of corporate social responsibility in the price of debt. For instance, Oikonomou *et al.* (2014) studies the impact of corporate social performance on the pricing of debt and on the credit quality and shows that higher corporate social performance leads to higher credit quality and reduces the cost of corporate debt. Menz (2010) finds evidence that the risk premium of bonds of socially responsible corporations is higher than for non-social responsible ones.

Some authors analyze the specific premium of green bonds. Hachenberg and Schiereck (2018) study the pricing differential (statistically influenced by industry category and ESG ratings) between green and conventional bonds and find that financial and corporate green bonds trade tighter than comparable non-green bonds and, in contrast, government-related bonds trade wider.

Zerbib (2019) compares green bonds with similar conventional bonds from the same issuer. He concludes that the riskier the bond is, the higher the green bond premium. The green premium is defined as the yield difference between a green bond and an equivalent conventional bond from the same issuer. However, the results are not clear on whether the premium is positive, negative or if it even exists at all. Although Ehlers and Packer (2017), Barclays (2015) and Zerbib (2019) find a negative yield on green bonds, Karpf and Mandel (2018), Piva (2017) and Schmitt (2017) find a positive premium. In addition, some authors also observe both a positive and a negative yield.

Ehlers and Packer (2017), and the Climate Bonds Initiative (2017) took the difference between the two yields on samples of 30, 21 and 14 bonds, respectively. The Climate Bonds Initiative (2017) did not find any significant differences on the primary market (market for new securities). However, Ehlers and Packer (2017) find a negative individual green bond average premium of 18 bps between 2014 and 2017 on 21 bonds (Eur- and USD-denominated bonds). Barclays (2015) focuses on the yield differential

on the secondary market (market for already existing securities) and points to a negative premium of 17 bps between March 2014 and August 2015.

Karpf and Mandel (2018) focus on U.S. municipal bonds with a green label. Using a sample of 1880 bonds, they highlight a positive average yield premium of 7.8 bps between 2010 and 2016. However, they observe that this premium became negative from 2015 onwards. Baker *et al.* (2018), when studying the U.S. corporate and municipal green bond market, find that green bonds are issued at a premium with lower yields and that green bonds ownership is more concentrated, which may be due to investors´ willingness to incur in lower returns in order to hold green bonds. They also conclude that the results obtained are stronger among bonds that are certified by external verifiers.

Schmitt (2017) extends the method used by Zerbib (2019) and uses up to twenty comparable bonds, instead of the previous two used by Zerbib (2019), to estimate the term structure of interest rates, taking into consideration the different coupons paid on the conventional bonds. This would allow smoothing through idiosyncratic yield variation and generating a price of a bond with the same characteristics and the same coupon as the green bond. The author finds that green bonds trade at a slight premium (-3.2bps). The boom in issuances, in 2016, indicates a larger negative premium up to -20bps at its maximum, perhaps due to the excess demand. After the supply of green bonds increased, the premium reached 0bps by the end of 2016 and turned positive in 2017.

In this research, we will adopt a green investor's perspective by simulating the investment in a portfolio of green bonds and analyzing its financial performance. To the best of our knowledge, this issue has not yet been explored in the literature.

3. Methodology

The methodology applied in this research involves measuring the performance of a portfolio of green bonds through return-based models. I decided to adopt a multi-index factor model because there is evidence that single-index models do not capture all the sources of systematic bond risk. Multi-index models explore the performance of green bonds better than a single-index model by capturing additional sources of systematic risk.

The multifactor model developed by Blake *et al.* (1993) to evaluate bond fund performance can be written as:

$$R_{p,t} = a_p + \sum_{J=1}^{K} \beta_{pJ} I_{jt} + \varepsilon_{p,t}, \quad (1)$$

Where R_{pt} is the excess return of fund *p* in month *t*, $r_{m,t}$ is the excess return of the bond market index over period *t* and $I_{j,t}$ is the excess return of the *j*th index over period *t*.

Our specification of the model is inspired in Elton *et al.* (1995), Derwall and Koedjik (2009) and Henke (2016), and includes five risk factors: a bond market factor, a default factor, an option factor, an equity factor and a term spread factor. The *Default* variable intends to capture default risk compensation in portfolio returns (Derwall and Koedjik, 2009). The *Option* variable includes a mortgage index to capture option features in specific bonds (Blake *et al.*, 1993). The *Equity* factor can be considered a measure of expectations about general economic conditions (Elton *et al.*, 1995) and it is also useful in case there is convertible debt. The *Term spread* factor is associated to the slope of the term structure and reflects the market's expectations with respect to changes of interest rates over time (Henke, 2016).

Thus, the model can be expressed as follows:

$$R_{pt} = \alpha_p + \beta_{0p} Bond_t + \beta_{1p}\, Default_t + \beta_{2p}\, Option_t + \beta_{3p} Equity_t + \beta_{4p} Term_t + \varepsilon_{it}, \quad (2)$$

Where R_{pt} is the excess return of portfolio *p* in month *t*, , $Bond_t$ is the excess return of the bond index, $Default_t$, is the return spread between an index of BBB-rated and an index of AAA-rated bonds, $Option_t$ is the return difference between a mortgage-backed security index and the risk free rate, $Equity_t$ measures the excess returns of a stock market index and the risk-free rate and the $Term_t$ corresponds

to the return differences between long- and short-term investment-grade government-bond indices. Alpha (α_p) represents portfolio performance relative to the multi-factor benchmark.

4. Data

This chapter presents the data regarding the green bonds. I started by identifying 113 green bonds from the Climate Bonds Initiative (CBI, 2018) website issued between October (2014) and September (2018), and 75 green bonds listed on the London Stock Exchange (LSE)[2].

The green bonds dataset from the CBI shows a maturity interval between 2 years and 47 years. The corresponding size amount, converted in USD, varies from 5.2 million issued by Big60million (United Kingdom) and 2.17 billion issued by New York Metropolitan Transport Authority (New York State, USA). Most of them act on the Solar, Wind, Low Carbon Buildings and Low Carbon Transport sectors. On the other side, most of the LSE green bonds are traded in Swedish krona (SEK), Euros (EUR) and British Pound Sterling (GBP), between September (2012) and November (2018).

From the initial 188 green bonds, the final sample includes only those for which I could find return data in Datastream - 30 and 12 green bonds from the CBI and LSE, respectively. Monthly returns were computed in a discrete way from the total return series collected from Datastream from 31/12/2012 to 31/10/2018. An equally weighted portfolio of green bonds is formed. The summary statistics of the equally weighted portfolio of green bonds are presented in table 1.

Table 1 - **Descriptive statistics of the excess returns of the portfolio of green bonds**

This table reports descriptive statistics of the equally weighted portfolio's excess returns. The portfolio includes 42 bonds from 31/12/2012 to 31/10/2018.

Average	-0,001268
Median	0,002541
Maximum	0,083723
Minimum	-0,050187
Std. Dev.	0,023285
Skewness	0,629489
Kurtosis	4,66024
Jarque-Bera	11,75802
P-value	0,002798

[2] : https://www.londonstockexchange.com/exchange/prices-and-markets/debt-securities/green-bonds-search.html

Returns on the indexes used to compute the bond, default, option, equity and term spread factors were collected from Datastream and FRED database in United States dollars (USD). To proxy for the bond factor returns, I used the return on the S&P Green bond index (from the S&P Dow Jones Indices website) above the one-month constant maturity risk-free rate (from the Federal Reserve database). Alternatively, I also use an overall bond market index as the benchmark, thereby using as the bond factor the returns on the FTSE WorldBIG index (collected from Datastream) minus the one-month constant maturity risk-free rate. The default factor is computed as the spread between the FTSE WorldBIG BBB index and FTSE WorldBIG AAA index. The option factor corresponds to the return difference between the FTSE WorldBIG MBS (mortgage-backed securities) index and the FTSE World Government Bond index (collected from Datastream). The equity factor is the return difference between the FTSE All World index (collected from Datastream) and the one-month constant maturity risk-free rate. Finally, the term spread variable is the return difference between the WD FTSE WGBI WORLD 10+Y index (long-term investment grade government-bond index) and the WD FTSE WGBI WORD 1-3Y (short-term investment-grade government-bond), collected from Datastream.

I include these five factors with the intention of capturing the full spectrum of the green bond portfolio risk exposures. My primary set of benchmark indexes is mainly provided by FTSE. I use the returns on the FTSE World Broad Investment-Grade Bond Index (WorldBIG) as well as the returns on some of its subsets. WorldBIG is a multi-asset, multi-currency benchmark that includes government, government-sponsored/supranational, collateralized, and corporate debt issues that have a minimum maturity of at least one year.

Tables 2 and 3 present the correlations between all the five factors. Especially noteworthy is the strong negative correlation between the option and the bond factors.

Table 2 - **Correlation between the factors (using the green bond index as the bond factor)**

This table reports the correlations between the monthly returns of the factors: bond, default, option, equity and term spread factors. The Bond Factor is the return difference between the S&P Green Bond Index and the one-month constant maturity risk-free rate

	BOND FACTOR GREEN	DEFAULT FACTOR	EQUITY FACTOR	OPTION FACTOR	TERM SPREAD
BOND FACTOR GREEN	1	0,196744	0,545492	-0,788647	0,431361
DEFAULT FACTOR	0,196744	1	0,383703	-0,106297	0,035750
EQUITY FACTOR	0,545492	0,383703	1	-0,253506	-0,007303
OPTION FACTOR	-0,788647	-0,106297	-0,253506	1	-0,506824
TERM SPREAD	0,43136	0,035750	-0,007303	-0,506824	1

Table 3 - **Correlation between the factors (using the overall bond index as the bond factor)**

This table reports the correlations between the monthly returns of the factors: the bond, default, option, equity and term spread factors), The Bond Factor is the return difference between the FTSE WorldBIG index and the one-month constant maturity risk-free rate

	BOND FACTOR OVERALL	DEFAULT FACTOR	EQUITY FACTOR	OPTION FACTOR	TERM SPREAD
BOND FACTOR OVERALL	1	0,131293	0,328102	-0,864364	0,717497
DEFAULT FACTOR	0,131293	1	0,383703	-0,106297	0,035750
EQUITY FACTOR	0,328102	0,383703	1	-0,253506	-0,007303
OPTION FACTOR	-0,864364	-0,106297	-0,253506	1	-0,506824
TERM SPREAD	0,717497	0,035750	-0,007303	-0,506824	1

Table 4 - **Jarque-Bera test results**

This table reports on Panel A the Jarque-Bera test results for the 5-factor regression model and on Panel B the Jarque-Bera test results for the 4-factor regression model. Two different indexes were used as a proxy for the Bond factor (Green bond index and Overall bond index) for the purpose of comparison

Panel A: 5-factor regression model		
	Green bond index*	Overall bond index*
Jarque-Bera	23,70686	39,3585
P-value	0,000007	0
Panel B: 4-factor regression model		
	Green bond index*	Overall bond index*
Jarque-Bera	24,53678	55,94539
P-value	0,000005	0

I used Jarque-Bera normality tests (table 4) to see if my residuals are normally distributed. As Panel A and B show p-values less than 5%, I will only apply the White (1980) test for Heteroskedasticity. Heteroskedasticity and serial correlation tests will be used, further, with the purpose of identifying the necessary corrections in my model regarding the standard errors.

5. Empirical Results

To evaluate the performance of green bonds I started by regressing the five-factor model presented in equation (2). This model is estimated in two alternative ways: (1) using a Green bond index as the bond factor and (2) using an overall bond index as the bond factor. Table 5 presents the estimation outputs for the five-factor regression model when using the Green bond index (Panel A) and the overall bond index (Panel B) as the bond factor.

Table 5 - **Estimation output for the 5-factor model**

This table presents estimates of performance for an equally weighted portfolio of green bonds from 31/12/2012 to 31/10/2018 using the five-factor model (equation (2)). Bond corresponds to the monthly excess returns of the Green Bond Index and the overall bond Index. Excess returns were computed using the Federal Reserve one-month constant maturity as the risk-free rate. Default is computed as the difference in returns between FTSE WorldBIG BBB index and FTSE WorldBIG AAA index. Option corresponds to the difference in return between the FTSE WorldBIG MBS and the FTSE World Government Bond index. Equity corresponds to the monthly excess returns of the FTSE All World index and the Federal Reserve one-month constant maturity risk-free rate. Adjusted R2 is the adjusted coefficient of determination. Panel A shows the estimates of performance. Panel B shows the results of the White (1980) Heteroskedasticity and Breusch-Godfrey serial correlation tests. P-values based on Huber-White (HC1) correction method are reported in parentheses. The asterisks are used to represent the statistically significant coefficients at the 1% (***), 5% (**) and 10% (*)

	Alpha	Bond	Default	Equity	Option	Term Spread	Adj. R^2
Panel A: Performance of Green Bonds							
Using a Green Bond Index							
Green Bonds	-5,13E-05	1,535509	-0,209857	0,080365	0,009348	-0,217106	0,83
	(0,9702)	(2,52E-07)***	(0,392762)	(0,142749)	(0,966979)	(0,001159)***	
Using a Overall Bond Index							
Green Bonds	-0,001367	2,072545	-0,170112	0,195699	0,155544	-0,6830405	0,77
	(0,422736)	(5,76E-06)***	(0,55637)	(0,000743)***	(0,625014)	(1,55E-11)***	
Panel B: White's Heteroskedasticity and Breusch-Godfrey Serial Correlation tests							
Using a Green Bond Index							
White Heteroskedasticity Test:			Prob. Chi-Square(20)		0,0008		
Breusch-Godfrey Serial Correlation Test:			Prob. Chi-Square(5)		0,9647		
Using a Overall Bond Index							
White Heteroskedasticity Test:			Prob. Chi-Square(20)		0,0053		
Breusch-Godfrey Serial Correlation Test:			Prob. Chi-Square(5)		0,5347		

The results of table 5 show that the alphas are not statistically significant whatever bond index is used, meaning that the performance of the green bond portfolio is neutral. In the model analysis, by performing a White's Heteroskedasticity test I reject the null hypotheses of homoskedasticity and by testing the model for the Breusch-Godfrey Serial Correlation I cannot reject the null hypotheses of no serial correlation. For that reason, the Huber-White correction method was applied on both regressions. However, some concerns can arise relative to these results, namely regarding the correlation between the variables (presented in Tables 2 and 3). To check whether there might be multicollinearity issues, I analyzed the Variance Inflation Factors (VIF), presented in Tables 6 and 7. A rule of thumb about the multicollinearity problem and the VIF test is that VIF should not exceed values of 10 or even values of 4 (O'Brien, 2007). As the centered VIF values for the Option factor and the Bond factor are higher than 10, multicollinearity can be a problem and for that reason I decided to exclude the Option factor from my model (Tables 6 and 7).

Table 6 - ***Variance Inflation Factors to test for multicollinearity (Green index as Bond factor)***

This table presents the Variance Inflation Factors test to check for multicollinearity between the factors (bond, default, equity, option and term). The Bond Factor is the return difference between the S&P Green Bond Index and the one-month constant maturity risk-free rate

Variable	Centered VIF
C	NA
BOND_FACTOR__G_	22,64117
DEFAULT_FACTOR	2,696155
EQUITY_FACTOR	2,306275
OPTION_FACTOR	24,03595
TERM_SPREAD	2,600019

Table 7 - **Variance Inflation Factors to test for multicollinearity (Overall index as Bond factor)**

This table presents the Variance Inflation Factors test to check for multicollinearity between the factors (bond, default, equity, option and term). The Bond Factor is the return difference between the FTSE WorldBIG index and the one-month constant maturity risk-free rate

Variable	Centered VIF
C	NA
BOND_FACTOR__G_	17,986738
DEFAULT_FACTOR	2,209787
EQUITY_FACTOR	2,414616
OPTION_FACTOR	14,44103
TERM_SPREAD	2,750612

Table 8 presents the regression estimation outputs of the four-factor model (without the option factor) and the results of White's (1980) Heteroskedasticity test and Breusch-Godfrey (1978) Serial Correlation tests. Panel A shows the regression model coefficients, adjusted R^2 and the correspondent p-values in parentheses. In Panel B, since my two regression models do not show a normal distribution, I use White's Heteroskedasticity test and the Breusch-Godfrey Serial Correlation LM test.

Table 8 - **Estimation output for the 4-factor model**

This table presents estimates of performance for an equally weighted portfolio of green bonds from 31/12/2012 to 31/10/2018 using the four-factor model (withdrawal of the option factor from equation (2)). Bond corresponds to the monthly excess returns of the Green Bond Index and the overall bond Index. Excess returns were computed using the Federal Reserve one-month constant maturity as the risk-free rate. Default is computed as the difference in returns between FTSE WorldBIG BBB index and FTSE WorldBIG AAA index. Equity corresponds to the monthly excess returns of the FTSE All World index and the Federal Reserve one-month constant maturity risk-free rate. Adjusted R2 is the adjusted coefficient of determination. Panel A shows the estimates of performance. Panel B shows the results of the White (1980) Heteroskedasticity and Breusch-Godfrey serial correlation tests. P-values based on Huber-White (HC1) for the Green bond index and ordinary standard errors for the Overall bond index correction method are reported in parentheses. The asterisks are used to represent the statistically significant coefficients at the 1% (***), 5% (**) and 10% (*)

	Alpha	Bond	Default	Equity	Term Spread	Adj. R^2
Panel A: Performance of Green Bonds						
Using a Green Bond Index						
Green Bonds	-4,69E-05	1,528419	-0,210178	0,081171	-0,218154	0,84
	(0,973059)	(1,05E-17)***	(0,396702)	(0,148969)	(7,67E-05)***	
Using a Overall Bond Index						
Green Bonds	-0,001255	1,895595	-0,180981	0,204157	-0,652304	0,77
	(0,402695)	(5,39E-15)***	(0,414299)	(0,000618)***	(6,30E-07)***	
Panel B: White's Heteroskedasticity and Breusch-Godfrey Serial Correlation tests						
Using a Green Bond Index						
White Heteroskedasticity Test:			Prob. Chi-Square(14)		0.0033	
Breusch-Godfrey Serial Correlation Test:			Prob. Chi-Square(5)		0.9664	
Using a Overall Bond Index						
White Heteroskedasticity Test:			Prob. Chi-Square(14)		0.1090	
Breusch-Godfrey Serial Correlation Test:			Prob. Chi-Square(5)		0.6243	

As can be observed in Panel A, the adjusted R^2s of the models are 84% and 77%, respectively, which indicates that both four-factor models do a pretty good job in explaining the returns of the equally weighted portfolio of green bonds. Both alphas from the models estimated are negative but not statistically significant, indicating a neutral performance of the portfolio. Regarding the coefficients estimated, in the first model (using a green bond index as the Bond factor), the Bond and Term Spread factors are

statistically significant at the 1% level. In the second model (using the overall bond index as the Bond factor) the Bond, Equity and Term Spread factors are statistically significant at the 1% level. Thus, both models show a positive exposure of the green bond portfolio to the Bond factor and a negative exposure to the Term Spread factor. The second model also shows a positive exposure to the Equity factor. The fact that the Default factor is not statistically significant in both models suggests that companies/organizations that issue green bonds are more propitious to comply with the commitments made when the debt was issued (high credit rating, AAA-BBB). Also, the difference found on the significance of the equity factor can indicate the overall bond index on the Bond factor portrays a more complete picture of the bond market and thus there might be differences in terms of the convertible debt held compared to the green bond index.

Panel B shows the results of the White Heteroskedasticity and the Breusch-Godfrey Serial Correlation tests. In the first model specification (green bond index), by performing White's Heteroskedasticity test I reject the null hypotheses of homoskedasticity and by testing the model for the Breusch-Godfrey Serial Correlation I cannot reject the null hypotheses of no serial correlation. For that reason, the Huber-White correction method was applied. On the second model (using the overall bond index) the null hypotheses were not rejected in both tests, so we conclude that the residuals are not correlated and are homoscedastic, and for that reason no correction was needed.

6. Conclusions

The performance of Green bonds is still largely unexplored in terms of empirical research. This dissertation aims to provide evidence on this issue by analyzing the performance of a portfolio of green bonds and assessing whether it is advantageous or not to invest in this type of financial instruments. Using a sample of 42 green bonds, I form an equally weighted portfolio from January 2013 to October 2018. The performance of this portfolio is evaluated through a multi-factor model that includes factors that have been recognized to be useful in evaluating bond portfolio performance. For comparison purposes, we use two alternative bond market indexes as the bond factor: a green bond index and an overall bond index.

The results show that the portfolio of green bonds is not statistically significant whatever bond index is used. I thus conclude that the performance of the green portfolio is neutral. This means that investors willing to bet on the green bond market may do so without sacrificing financial performance and still integrate their concerns regarding the environment, their image with respect to the financial world or to fulfill company/corporation obligations.

Although the overall bond index is more diversified because it represents a broad measure of the global fixed income market and the green bond index only has bonds whose proceeds are used to finance environmentally friendly projects, the major difference between the models is the fact that the Equity factor only is statistically significant when using the Overall bond index. This implies that, as the bond factor proxied by the green bond index focuses more on green bonds and less on the overall bond market, it might not capture the expectations of general market conditions in the same way.

Regarding the main limitations of my work, I found difficulties in finding conventional bonds from the same issuer and with approximately the same amount issued and so it was not possible to compare the performance of the green portfolio with a portfolio of conventional bonds. Furthermore, the fact that green bonds are a recent financial instrument implied a short period of analysis (31/12/2012-31/10/2018). This limitation did not allow to apply conditional models, which require a high number of observations due to the number of coefficients to be estimated. Also, my final sample only has 42 green bonds from an initial sample of 188 green bonds (30 from the CBI website and 12 from the LSE) since I couldn´t retrieve information on more bonds from Datastream.

Future research and studies on the performance of green bonds should include a larger data sample with a larger time period of analysis in order enable the application of conditional models, that capture to the economic conditions of the market. Another issue is the development of a universal way

to proper label a bond as “green”. This would simplify the identification of green bonds, because there is still a lot of debate regarding the labelling of green bonds. Apart from using a green bond portfolio, it would be interesting to also use a conventional bond portfolio, with the same characteristics of the green bond portfolio, in order to compare the performance of both types of bonds.

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