MASTER OF SCIENCE IN
FINANCE

MASTER´S FINAL WORK
DISSERTATION

GREEN BONDS

ANTÓNIO DA MATA MARTINS

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SUPERVISION:
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ABSTRACT

Financial markets, in their role of capital allocation, appear as a fundamental tool for the transition to a low-carbon intensity economy. Green bonds, whose proceeds finance climate-friendly projects, have emerged as a prevalent tool for issuers to align their sustainability mandates to their financing solutions. By adopting a CEM matching approach, we study the pricing difference between green and brown bonds in the Euro Corporates Market and conclude on the existence of a green bond premium – greenium - of -9.77 basis points. The greenium displays a positive link with the market's maturity, thus highlighting the case of green bonds as a viable solution to Transition Finance.

KEYWORDS: Social Responsible Investing, Transition Finance, Green bonds, Yield Spread, Initial Price Target, Coarsened Exact Matching

JEL Codes: C10, C15, G11, G12, G23, G24

Resumo

Os mercados financeiros, através do seu papel na alocação de capital, surgem com uma ferramenta fundamental na transição para uma economia global com baixa intensidade de carbono. As obrigações verdes, obrigações cujo financiamento é canalizado para projetos com impactos positivos no ambiente, têm emergido como um mecanismo de importância acrescida para os emitentes alinharem os seus objetivos de sustentabilidade com as soluções de financiamento. Através da aplicação da abordagem CEM, é estudada a diferenciação de preço entre obrigações verdes e castanhas no Mercado de Corporates Euro, onde se conclui a existência de um prémio verde – greenium – de -9.77 pontos base. O greenium apresenta uma relação positiva entre o desenvolvimento do mercado, destacando assim o argumento das obrigações verdes como uma solução viável para Transição Financeira.

Palavras Chave: Investimento Socialmente Responsável, Transição Financeira, Obrigações verdes, Spread da Yield, Alvo de Preço Inicial, Coarsened Exact Matching

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1. INTRODUCTION

Financial markets and corporations have been adapting to meet the global objectives defined by the Paris Agreement, namely, keep the global temperature rise below 2ªC and pursue efforts to limit the increase to a further 1.5ºC. The response included a "redirection of financial flows towards low-emission investments" (IPCC, 2021). Indeed, financial markets emerge as a prime vehicle to support the transition to a net-zero economy in their role of improvement of capital allocation (Wurgler et al., 2000). In this regard, debt markets have seen for the past couple of years the rise in the issue of green bonds.

Green bonds are bonds whose proceeds will be exclusively applied to finance or re-finance, in part or full, new and/or existing green projects (ICMA, 2021). A green bond is in every aspect identical to a conventional vanilla bond, except for the use of proceeds. Green bonds limit the investment of the proceeds derived from the debt emission to only green projects. For example, in March of 2022, EDP issued a EUR 1.25B green bond, whose proceeds were destined to finance or refinance, in whole or in part, EDP's Eligible Green Asset Portfolio (EDP, 2022).

The green bond market has been growing since its inception in 2013, totaling $508,8 billion issued in 2021 (CIB, 2021). This instrument seems to be more developed in the European market, typically with more matured issuers and players, representing 52,06% of the amount issued over the last year. In emerging countries, particularly in the Asia region, there has been a recent boom in green bond activity (Azhgaliyeva et al., 2020; Tu, et al., 2020; Banga, 2019). Corporates continue to be the most active issuer, with a total amount printed of $140,6 billion in 2021, outgrowing the green bond market (year-on-year growth of 56%) (CIB, 2021).

As the green bond market matures, so does the consensus regarding definitions, guidelines, and green taxonomy. Characteristic of emerging markets, such as this one, private governance rules the market, in the form of investment standards and certification schemes, providing a faster implementation in comparison to public governance (Park, 2018). The two green bond standards generally accepted by the market and usually used as a reference for issuers are the Green Bond Principles (GBP) published by the International Capital Market Association (ICMA) and the Climate Bond Initiative (CBI). The two provide voluntary guidelines for best practices in financial instruments that incorporate forward-looking, externally verified, sustainability objectives and outcomes. [1]The surge of these standards plays a fundamental role in the development of the green bond market, by taking an active role towards market transparency and diminishing the greenwashing dilemma[2], while providing post-issuance reporting, sparing information on the issuer's sustainability to the stakeholders (Yeow and Ng, 2021). Moreover, third-party agents offer issuers certification and consultation services, attributing the green label to securities, subject to the verification of specific conditions. These agents act as a credit rating agency, providing investors assurance regarding the worthiness of the green label. Additionally, Moody's and Standard & Poor's ratings agencies have also developed criteria and indexes for this market. The introduction of a green bond index in exchange-traded funds (ETFs) is a further indicator of the maturation of the market.

It may seem puzzling that companies would opt for a less flexible financing option such as green bonds, via the use of proceeds embedded in these instruments, in comparison to conventional bonds. Alternatively, firms would be better off issuing plain vanilla bonds and channeling the proceeds to sustainable projects, rather than limiting their investment options through green bonds.

In this study, we evaluate if there is a price advantage to the issuers to print green bonds over conventional bonds, or brown bonds from this point forward. More specifically, we evaluate if there are financial benefits to the issuance of green bonds, in the form of lower yield spreads and better bond auction metrics. A consistently lower yield of green bonds implies a green pricing premium- greenium. The greenium, in the issuer's perspective, acts as a Pigouvian subsidy priced by the market, rewarding the positive externalities provided by these instruments (i.e. promotion of environmentally friendly investments), aligning its economic cost to the social benefit provided, transmitting the willingness of bond investors to sacrifice some of their return in exchange of contributing to the sustainability mandates carried out by the issuer and the investor itself (Maltais and Nykvist, 2020). If green bonds indeed carry out a pricing advantage, as is market consensus, this would cement green bonds as the optimal option for issuers who wish to align their financing strategy with their climate sustainability mandates and

[1] These standards are often used as a reference for companies' financial frameworks in which relates to sustainability-linked financing. As an example, NOS sustainability framework is closely to ICMA's Green Bond Principles (NOS, 2021).

[2] The green the practice of making unsubstantiated or misleading claims about a firm's environmental impact (Berrone et al., 2015).

consequently further consolidate these instruments as a powerful financial tool to mitigate climate change.

This study contributes to the literature focused on the pricing differentiation between green and brown bonds (eg. Karpf and Mandel, 2017; Baker, 2018; Zerbib (2019), particularly in the Corporates Bond Market (Gianfrate and Peri., 2019; Nanayakkara and Colombage, 2019; Flammer, 2021), through three-fold improvements. Firstly, we resource to the final Yield Spread as the dependent variable to evaluate pricing difference, instead of the final yield figure, which dominates the literature around the topic, thus accounting for the implicit pricing rationale of bonds. The second improvement relates to pre-specification of the matching methods employed to pair green and brown bonds, through the use of Coarsened Exact Matching, achieving lower imbalance across the dataset. Finally, this study contributes to the increase of the scope of literature around green bond markets, on one hand introducing new variables related to the key metrics on bond auctions, namely the Initial Price Target and Oversubscription, and on another hand by increasing the time frame of the analysis, allowing to capture the Green Bonds Corporate Market at more developed stage of its maturity.

We conclude about the existence of greenium in the Euro Green Corporates Market of around 9 basis points in line with Zerbib (2019), Baker (2018), Gianfrate and Peri (2019), and Nanayakkara and Colombage (2019). The greenium seems internalized in more mature markets, as the greenium is more significant for Investment Grade issues and instruments issued by Eurozone and American corporates. Moreover, in line with Gianfrate and Peri (2019), we conclude that greenium is the most significant in the Utilities sector.

The remainder of this paper is organized in the following way: the next section presents the literature review. Thereafter, the sample and the methods are described. Section 5 presents the results, followed by a discussion of the findings and the main conclusions in Section 6.

2. Literature Review

Previous literature has defined several reasons for the surge in the popularity of green bonds and the consequent growth of the green bond market. These reasons can be broadly divided into financial and non-financial factors. Non-financial incentives seem to dominate the literature on green bonds.

In an in-depth interview with twenty-two agents in the Swedish green bond market, Maltais and Nykvist (2020) gather evidence that green bonds allow both investors and issuers to contribute to sustainability mandates they already have and respond to their stakeholder's sustainability interests. This goes hand in hand with the growth of sustainable financial products, which take into account environmental, social and governance (ESG) considerations, in response to the surge of Social Responsible Investing (SRI).

According to signaling theory, by issuing green bonds, firms provide the market with a credible signal of their commitment to the environment (Flammer, 2021). Nevertheless, like with other markets, investors face information asymmetry, as they often lack information regarding the firm's commitment to the environment (Lyon and Maxwell, 2011; Lyon and Montgomery, 2015). This negative externality aggravates the difficulty in distinguishing between firms committed to their sustainability mandates and the lemons, leading to increased transaction costs from the part of the investor (Arkelof et al., 1970).

The financial aspects that lead to the issuance of green bonds seem to be much less material, as green bonds are generally seen as an equivalent product to green bonds by the market. Ugolini (2019) and Pham (2016) conclude on the spillover effect verified from the conventional bonds (i.e. brown bonds) and currency markets, with the latter observing large volatility clustering on the labeled segment of the green bond market. These results seem to corroborate the theory of equality between green and brown bonds. For issuers, there is no added risk in the investment of green bon

Moreover, a relevant part of the literature on green bonds focuses on the correlation to other financial instruments. Broadstock and Cheng (2019) and Tolliver et al. (2020) find evidence of the correlation between green bond price benchmarks and macroeconomic factors, such as the changes in financial markets returns and volatility, economic policy uncertainty, daily economic activity, oil prices and news' sentiment towards green bonds.

In terms of the existence of greenium, the results are mixed. MacAskill, Roca, Liu, Stewart and Sahin (2020) conduct a systematic literature review on this subject and conclude on the existence of greenium in the primary and secondary market amongst the majority of the studies analyzed between 2007 and 2019.

In the US Municipal Bond Market, in contrast to what the rest of the literature on this subject suggests, Karpf and Mandel (2017) argue that investors value green bonds less favorably, in the form of a positive yield spread between brown and green bonds – a brownion – around eight basis points. On the other hand, Baker (2018) finds a green premium ranging from minus five to minus seven basis points among issuances between 2010 and 2016. Larcker and Watts (2020) revisit both studies and suggest empirical inconsistencies skewing the results found, resulting from the lack of data treatment regarding tax differences and callability of bonds, which are not accounted for during the data cleaning and bond matching process. When controlling for such variables, Larcker and Watts (2020) find no pricing difference between green and identical brown bonds.

In the Corporates market, Zerbib (2018) (2019) finds evidence of a green premium of 2 basis points, which appears to be greater for lower-rated investment-grade and financial (i.e issued by entities from the financial sector) bonds. Gianfrate and Peri (2019) show evidence of an even greater green premium, ranging between -14.8 and -19.4 basis points, which seems to be more prevalent in the Corporates bond market. Nanayakkara and Colombage (2019) take a different approach by studying the difference in spreads instead of yields between green and brown bonds. Specifically, the impact of the green label of bonds in the Option Adjusted Spread (OAS)34, through a panel regression analysis, in which the OAS is the independent variable and the green label serves as an explanatory variable, controlling for the currency, market risk, treasury rate, macroeconomic variables, and firm and bond specific effects. Green bonds are found to be traded at tighter credit spreads (i.e OAS) of around -62.7 basis points, resulting in the existence of a theoretical green premium of around 63 basis points. Finally, Flammer et al. (2021) does not find strength in the cost of capital argument for the growth of green bonds, showing evidence of no significant pricing difference between green and grown bonds, from 2013 to 2018 in the Corporates bond market.

3 Option-Adjusted Spread (OAS) is a methodology using option-pricing techniques to value the embedded option's risk component of a bond´s total spread. Embedded options are call, put, or sink features of bonds. This represents the incremental return due to credit risk (Bloomberg, 2021)

3. DATA AND VARIABLES

3.1. Data and Sample

We gather information on all the bonds issued in the Euro Corporates Market between January 1, 2018, and December 31, 2021, from Bloomberg's Fixed Income Dataset. Bloomberg's database compiles information regarding each security, namely the issue date of the security, the amount, its tenor, and coupon rate. Using the same database, we also retrieve information regarding the issuing company, specifically its name, industry, country, and credit rating from the three main rating agencies: Moody's, Standard & Poor's and Fitch. Importantly, this database allows us to distinguish between green and conventional bonds. Green bonds are identified as bonds for which the field Green Bond Indicator is 'Yes'.

Then, using the insights from a well-known Portuguese Investment Bank's Debt & Capital Markets (DCM) team, we retrieved information regarding the placement of the bonds, namely the final yield spread, the total book amount of the issue, the initial price target for the bond auction and the underlying oversubscription metric.

We merge the information from the two databases and perform some data-cleaning processes. First, we exclude from the sample all other forms of sustainable bonds, limiting the dataset to pure green and conventional bonds[4]. Second, to avoid the comparison between two bonds priced on a different basis, bonds with put and call options during their maturity are excluded from the sample since they tap into the growing hybrid market[5], which is ruled by different pricing characteristics. Finally, bonds with no rating attributed by either one of the three main rating agencies are also dropped from the dataset. Additionally, for each issuer, we collect information on the industry (general business activities) from Bloomberg's Industry Classification Systems (BICS). To ensure comparability between bonds, we use the macro sectors' classification. Since our study only evaluates bonds issued by corporates, we exclude the Government industry.

[4] There are two types of sustainable bonds. Use of proceeds instruments, encompass Green, Social and Sustainable bonds according to the typology of the use of the financing proceeds; and Sustainability-linkedbonds which do not restrict the use of proceeds but include a coupon adjustment or premium payment if the issuer fails to meet a given ESG Key Performance Target (KPI). (ICMA, 2021)

[5] Hybrid instruments are debt securities assumed to hold equity-content up to 50%, meaning that only a portion of the debt facility is represented in the issuer's Balance Sheet. Because of this, hybrids are issued at a premium over otherwise plain-vanilla bonds and are attributed lower credit ratings. Hybrid Instruments must follow very strict rules in order to deserve this recognition by the rating agencies.

VARIABLE	*Industry Sector*
S1	*Basic Materials*
S2	*Communications*
S3	*Consumer, Cyclical*
S4	*Consumer, Non-Cyclical*
S5	*Energy*
S6	*Financial*
S7	*Industrial*
S8	*Technology*
S9	*Utilities*

Table 1 - BICS Industry Sector Classification

In the end, our dataset is composed of 1,485 corporate bonds, split between 1,385 conventional bonds and 100 green bonds.

3.2. Variables

Our main dependent variable is the final yield spread. Bond yields quotation is based upon two factors: the cost of borrowing for the proposed maturity of the security, which is represented by a given reference rate used to quote securities and prices systemic risk, and therefore is universal for all securities, and an arbitrary yield spread, which prices counter-party risk and is evaluated in relation to the issuer's credit risk. Therefore, we can describe the final yield of a bond in the Euro market as:

$$\text{Final Yield} = \text{Mid-Swap (for the maturity of the bond)} + \text{Yield Spread} \qquad (1)$$

In contrast with previous studies, our measure of greenium is able to minimize any possible skewness related to non-issuer-related shocks, as it analyses the issuer-related portion of the final yield of the bond. Let us consider, for example, a conventional bond that has a higher yield than an otherwise equal green bond. As it happens, we come to find that the so-called brown bond was priced at a tighter yield spread than the green bond, but the last one benefited from a decrease of the mid-swap at the time of issuance, which more than compensated for a higher yield spread. In this case, without knowing the implicit pricing mechanics behind the issue, one would wrongly argue in favor of the existence of greenium. We avoid these situations by resourcing to the final yield spread instead of the yield figure.

The main independent variables are the issuer's credit rating, the nominal amount of the securities, the tenor, and the coupon rate. The credit rating of an issuer relates to the perceived creditworthiness of the company and is defined by credit rating agencies. In this study, we take into account Moody's, Standard & Poor's and Fitch's credit scores on issuers. To overcome the dilemma of having a sample of bonds graded by different rating agencies, creating incomparability between them, we transform the issuer's credit rating from a qualitative to a quantitative scale. This standardization allows for comparison between bond securities. Following Afonso et al. (2011), we group ratings into 21 categories, attributing the value 1 for observations below C, while AAA observations receive the value 21. For securities rated by more than one rating agency, the mean value of the scaled-down ratings was used. This methodology is described in Table 2.

Following previous literature (Karpf and Mandel., 2017; Baker, 2018; Zerbib, 2019; Flammer, 2021), we also control for the nominal amount of each bond issuance. We expect a negative relationship between the nominal amount of each issue and the level of the yield spread, through the mitigation of secondary market liquidity risk. Larger issues have a larger investor base, assuring bondholders liquidity in case they intend to sell of the securities in the secondary market.

Moreover, secondary market investors are often current bondholders wishing to increase their exposure to the issuer and accumulate interest capitalization. The market considers issues below EUR 500 million to hold more liquidity risk, hence the vast majority of the issues total EUR 500 million, which is oftencalled the Euro benchmark.

Another key factor to the pricing rationale of any fixed-income instrument is its tenor, i.e. the number of years until the maturity of the instrument.

		Ordinal Scale	Moody's	S&P	Fitch
Investment Grade	Highest quality	21	Aaa	AAA	AAA
	High quality	20	Aa1	AA+	AA+
		19	Aa2	AA	AA
		18	Aa3	AA-	AA-
	Strong payment capacity	17	A1	A+	A+
		16	A2	A	A
		15	A3	A-	A-
	Adequate payment capacity	14	Baa1	BBB+	BBB+
		13	Baa2	BBB	BBB
		12	Baa3	BBB-	BBB-
High Yield	Likely to fulfill obligations, ongoing uncertainty	11	Ba1	BB+	BB+
		10	Ba2	BBB	BBB
		9	Ba3	BB-	BB-
	High credit risk	8	B1	B+	B+
		7	B2	B	B
		6	B3	B-	B-
	Very High Credit Risk	5	Caa1	CCC+	CCC+
		4	Caa2	CCC	CCC
		3	Caa3	CCC-	CCC-
	Near default with the possibility of recovery	2	Ca	CC	CC
		1	C	C	C
	Default	0		SD/D	DDD/DD/D

Table 2 - Qualitative Credit Ratings Linear Transformation to Ordinal Scale

Notes: This table illustrates the methodology behind the attribution of an ordinal scale credit rating to each issue. We group ratings into 21 categories, attributing the value 1 for observations below C, while AAA observations receive the value 21. For securitiesrated by more than one rating agency, the mean value of the scaled-down ratings wasused.

4. Methodology

To evaluate whether there is a pricing difference between green and conventional bonds, we match the observations. Matching is the most common approach to measure the impact of a given bond characteristic in a key target variable (e.g. final yield of the bond). Matching allows us to pair in groups observations that are the most similar to each other. More specifically, this methodology matches a pair of securities with the same properties except for the one property whose effects we are interested in (Zerbib, 2018). The underlying notion is that ceteris paribus, any differences in the dependent variable (e.g. final yield of a bond) must relate to the different values for the key target variable.

Matching procedures aim to reduce the imbalance in the empirical distribution of the covariates when estimating the causal effect of treatment versus control (Stuart et al., 2010). It follows that by lowering the imbalance of the data through matching there is a reduction of the degree of model dependence as well as reduced statistical bias than would have been possible without matching (Ho et al., 2007; Iacus, King and Porro, 2011b).

Earlier incursions into the topic of bond pricing differentiation (Conrad and Frankena, 1969; Elderington, 1974; Lindvall, 1977; Weinstein,1978; Cai, et al., 2007) focused on the pricing of new bond issues, which historically converge down to secondary market levels after issuance in the so-called seasoning process. The general idea was that, after matching the newly issued and outstanding bonds and computing the difference in yields, ceteris paribus, such difference could only be attributed to the moment of issuance of the securities.

Matching two identical bonds proves to be quite challenging, aggravated by the lack of bond activity disclosure, which was even more evident at the time and ultimately influenced the methodologies used and thus, overall results. Lindvall et al. (1977) falls back on the use of two yield series, comparing a new Aa public utility issues with seasoned Aa public utility securities with the same coupon. Conrad et al. (1969) and Elderington et al. (1974) resorted to matching primary issuances with secondary market bond indexes, matching according to broad measures of maturity and credit rating. Additionally, Weinstein (1978) follows the secondary market's activity of the selected bonds post-issuance as means to compute returns in the period between the issuance and a recorded trade of the bond in the secondary market.

Fast forward to the contemporaneous studies on the existence of greenium, which benefit from improved technology and bond market activity, and we observe different approaches. Larcker and Watts (2020), Baker (2018), and Karpf and Mandel (2017) employ within-issuer matching methodology to directly compare green and comparable conventional municipal bonds. This is possible due to the liquid municipal bonds market, which benefits from a high degree of publicly available information, through platforms such as Mergent and the Electronic Municipal Market Access (EMMA) and convenient issuance architecture.[6]

This assessment is not feasible for Corporate bonds, since there are no green and brown bond issuances from the same issuer within a relevant timeframe that allows for comparison between the two, up until this point. For example, Tang and Zhang (2020) study the corporates market through issuer matching, comparing issuers of identical size, market-to-book, and stock liquidity, which had issued green and conventional bonds in a space of one year, but ignores fundamental bond characteristics, such as maturity and credit rating, in the process. Flammer (2021) resorts to Mahalanobis matching to choose the closest brown bond to each green bond, measured by Mahalanobis distance, with the number of days between the issuance of the two securities, the issue amount, the maturity, and coupon as arguments and Gianfrate and Peri (2019) use Propensity Score Matching (PSM) techniques to match observations with comparable propensity scores. Diverging from other matching approaches, Zerbib (2018) (2019) creates a synthetic brown bond, resulting from the linear interpolation of two maturity-similar brown bonds that closely match the relevant green bond.

In this study, we will match green and conventional (brown) bonds using Coarsened Exact Matching (CEM) (Iacus et al., 2011a). CEM temporarily coarsens each variable into substantially meaningful groups, exact match on the coarsened data, and then only retains the original values of the matched data. This allows us to match each variable of the treated group (i.e. green bonds) X_i to an otherwise identical brown bond $\hat{X}_j$ (i.e. $X_i \simeq \hat{X}_j$).

[6] Municipal bonds are issued in multiple tranches which are often identical between them. It is not unusual to observe the issue of a green labelled bond among such tranches, facilitating the exercise of finding a within issuer perfect pairing

We match the bonds on credit rating, nominal amount, and tenor and impose an exact match on the industry sector of the securities issuer. We match on the sector because the green bond issues depend on the sector where the issuer operates. For instance, firms that operate in the Utilities sector have a higher probability of issuing green bonds since they already have sustainability mandates in place.

After the matching is complete and we have achieved identical pairs of green and brown bonds, we apply statistical estimators to the data. Since the matching is not exact, a parametric model is applied to control for the differences in the covariates across the treated and control groups.

To estimate the impact of greenium on the final yield spread, we run the following linear regression:

$$spread_i = \alpha_i + \beta\, green_i + Z_i'\theta + \varepsilon_i \qquad (2)$$

where α_i are security-fixed effects capturing unobserved heterogeneity across securities and ε_i is an error term satisfying the usual assumptions.

Our dependent variable is $spread_i$ and represents the final yield spread on bonds, and our coefficient of interest is β. If the coefficient is negative, it suggests the existence of greenium, thus substantiating the cost of capital argument for the issuance of green bonds.

The main independent variable is $green_i$, a dummy variable equalling one if the bond is green and zero otherwise (i.e. conventional bonds). We also include a vector of other determinants Z_i' . This vector includes $Rating_i$, a continuous variable indicating the standardized credit rating[11] of the issuer; ln $(amount)_i$, the logarithmic transformation of the nominal amount of the issue; $Coupon_i$ is the continuous variable indicating the fixed coupon rate of the security; and $Tenor_i$ is the continuous variable indicating the number of years until maturity.

We expect a negative relationship between the nominal amount and the yield spread, through the mitigation of secondary market liquidity risk. The same relationship is expected between the dependent variable and the credit rating of the issuer, due to the risk-return trade-off. On the other hand, the coupon rate and tenor of the securities should display a positive relationship with the yield spread, through the increase of the counterparty's credit risk.

In the next step, we compare the final yield results with other matching methods, through the computation of the sample Average Treatment effect on the Treated (ATT) of $green_i$ on the yield spread ($yield\ spread_i$) across the matched samples. More specifically we compute:

$$ATT = \frac{1}{n_T}\sum_{i \in T} TE_i \quad \text{, where } n_T = \sum_{i=1}^{n} T_i \text{ and } T = \{1 \le i \le n : T_i = 1\} \quad (3)$$

Let T_i, for each unit i, be an indicator variable with covariates X_i and value $T_i = 1$, if the bond i is green and receives the treatment (and so is a member of the "treated" group) and $T_i = 0$, if not (and is therefore a member of the "control" group). We define our outcome variable $spread_i$ as the yield spread, where $spread_i(1)$ is the outcome for observation i if the unit is a green bond and $spread_i(0)$ if not. The treatment effect for each unit i is simply $TE_i = spread_i(1) - spread_i(0)$, which is unobserved since there are no bonds that are both green and brown at the same time.

Additionally, following Gianfrate and Peri (2019), other matching procedures based on propensity score techniques are performed. Namely, Nearest Neighbor matching with 3,5, and 8 matches, restricting the matching brown bonds for a single green bond, that is the closest in propensity score, to the indicated number of units from the untreated group (3,5 and 8); Kernel matching, which uses the weighted averages of all brown bonds in the control group to construct the counterfactual outcome, attributing more weight to control units closer to the treated unit; Radius matching, which helps to solve the possible drawback of the previous methods related to the undesired matching quality, as they force the matching between treated and control units, ignoring how close propensity scores are (Kaliendo and Lopeinig, 2008). Radius matching restricts possible matches to a pre-defined range ("r"), allowing for propensity scores between treated and control units, thus defining the tolerable distance within which bonds are matched. We will define the radius to be 0.001 and increase the restriction to r = 0.0005. It follows that the lower the radius allowed, the more restrictive is the matching, leading toward fewer matched bond groups in exchange for more robust results. We complement the previous matching methods with Mahalanobis matching used in Flammer (2021), which also falls under the approximate matching methods, but uses the Mahalanobis distance, instead of the propensity score to determine the closest control unit to each treated unit. The variables considered in all matching methods are the same as used in CEM, namely credit rating, amount, tenor, and sector of activity.

5. RESULTS

5.1. Greenium

We start our empirical analysis by assessing the standalone (unconditional) and conditional link between the final yield and green bonds in the unmatched sample. The results reported in Column (1) of Table 3 show that green bonds are negatively related to the yield spread, with green bonds trading almost 19 basis points lower than conventional bonds.

	(1)	(2)
VARIABLES	Model 1	Model 2
Green	-18.876***	-10.933***
	(4.582)	(3.326)
Lnamount		8.946***
		(2.683)
Tenor		-1.199***
		(0.269)
Rating		-8.613***
		(0.668)
Coupon		63.205***
		(2.050)
Constant	102.858***	107.794***
	(1.771)	(19.214)
Observations	1,485	1,485
R-squared	0.005	0.667

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3 - Results of Regression (2) on the unmatched dataset

Next, we estimate the initial specification augmented with a set of control variables in Column (2). In this specification, the green bond yield spreaddecreases to -11 basis points.

Nevertheless, these previous results do not consider the differences in the characteristics of the green and conventional bonds that compose the dataset, and therefore the estimators are likely biased. To illustrate this point, we compute the mean differences across the matching variables between green and brown bonds. As reported in Table 4, we conclude mean differences between green and brown bonds in rating, amount and most of the industry sectors are statistically different. Moreover, following Iacus, King and Porro (2008) we compute the f_1 statistic[15], which equals approximately 0.897, and find evidence of a large imbalance in the dataset.

To address this situation, we employ the CEM methodology, controlling in our dataset to reduce the model imbalance. A new sample of identic 359 bonds, split between 79 green bonds and 280 brown bonds, is created. We represent the set of bonds graphically in Figure 1.

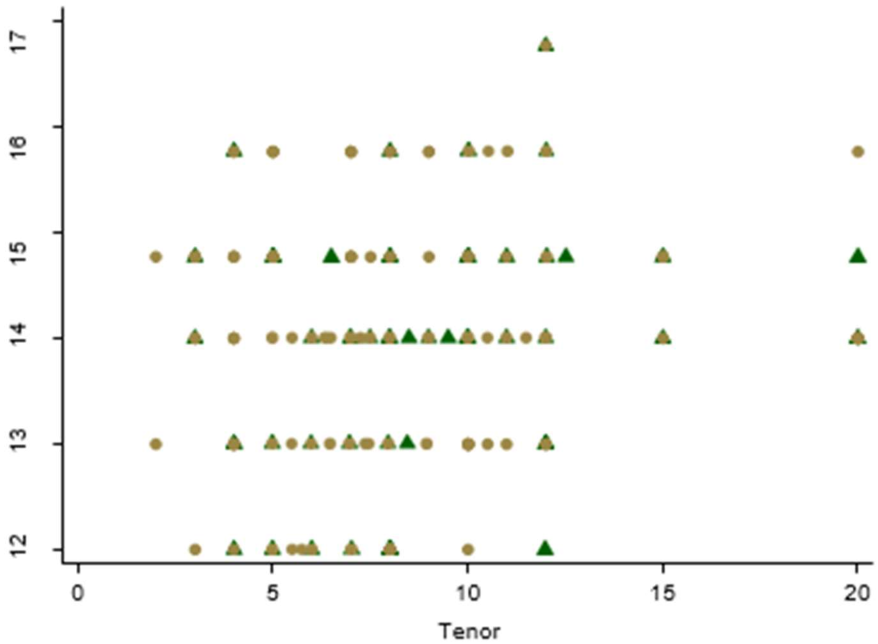

Figure 1- CEM matched sample

Notes: This figure illustrates the set of the 359 CEM-matched bonds, with green bonds in green and brown bonds in brown. Bonds are broken down by the Credit Rating in the y-axis and Tenor in the x-axis.

During the matching process, 1126 bonds were pruned away from the dataset, due to the inexistence of a comparable security, leading to a decrease in model imbalance ($f_1(f^m, g^m) = 0.493 < f_1(f, g) = 0.897$). We carry out robustness tests across all independent variables for the unmatched and matched samples to evaluate whether mean differences between the matching variables are statistically significant.

As reported in Table 4, the null hypothesis of equality in mean differences between the independent variables cannot be rejected for the CEM matched data, signaling that, in coherence with the diminishing of the $f1$ statistic, imbalance across the matched sample has been greatly reduced.

	Green Bonds			*Conventional Bonds*			
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
	Obs.	*Mean*	*Std. Dev.*	*Obs.*	*Mean*	*Std. Dev.*	*Difference between (2) and (5)*
rating	*100*	*13.96*	*1.279*	*1385*	*14.387*	*1.837*	*0.427***
amount	*100*	*603.25*	*226.709*	*1385*	*687.986*	*269.9*	*84.736****
tenor	*100*	*8.86*	*3.553*	*1385*	*8.865*	*4.657*	*0.005*
s1	*100*	*0.03*	*0.171*	*1385*	*0.0448*	*0.207*	*0.148*
s2	*100*	*0.03*	*0.171*	*1385*	*0.9*	*0.287*	*0.06***
s3	*100*	*0.02*	*0.141*	*1385*	*0.129*	*0.009*	*0.109****
s4	*100*	*0.05*	*0.219*	*1385*	*0.251*	*0.434*	*0.201****
s5	*100*	*0.04*	*0.197*	*1385*	*0.05*	*0.218*	*0.01*
s6	*100*	*0.45*	*0.5*	*1385*	*0.173*	*0.378*	*-0.277****
s7	*100*	*0.05*	*0.219*	*1385*	*0.137*	*0.344*	*0.087***
s8	*100*	*0.01*	*0.1*	*1385*	*0.036*	*0.187*	*0.026*
s9	*100*	*0.32*	*0.469*	*1385*	*0.09*	*0.286*	*-0.23****

rating	*79*	*13.962*	*1.214*	*280*	*14.014*	*1.148*	*0.052*
amount	*79*	*547.152*	*140.226*	*280*	*542.464*	*124.527*	*-4.688*
tenor	*79*	*8.81*	*3.524*	*280*	*8.79*	*3.219*	*-0.02*
s1	*79*	*0.025*	*0.158*	*280*	*0.039*	*0.195*	*0.014*
s2	*79*	*0*	*0*	*280*	*0*	*0*	*0*
s3	*79*	*0.025*	*0.158*	*280*	*0.036*	*0.186*	*0.01*
s4	*79*	*0.063*	*0.245*	*280*	*0.1*	*0.301*	*0.037*
s5	*79*	*0.013*	*0.113*	*280*	*0.011*	*0.103*	*-0.002*
s6	*79*	*0.532*	*0.499*	*280*	*0.536*	*0.5*	*0.004*
s7	*79*	*0.051*	*0.221*	*280*	*0.57*	*0.232*	*0.007*
s8	*79*	*0.13*	*0.113*	*280*	*0.004*	*0.06*	*-0.009*
s9	*79*	*0.278*	*0.422*	*280*	*0.218*	*0.414*	*-0.061*

Standard errors in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Table 4 - Results of the robustness tests on the mean differences across matching variables on the unmatched (above) and CEM matched (below) samples

We run Regression (2) on the CEM-matched sample, on both the simple and the expanded forms, and conclude on the existence of a green bond premium of -9.77 basis points over otherwise identical conventional bonds, as reported in Column (4) of Table 5. Moreover, the control variables for the determinants of the yield spread are in line with the previous literature, correcting for the unexpected negative relationship with the nominalamount of the issue verified in the analysis of the unmatched dataset.

We expand the analysis to include other matching methodologies used in the literature. Similarly to Gianfrate and Peri (2019), we apply the nearest neighbors matching (NN), Kernel matching, and Radius matching with different levels of the radius ("r"), as well as Mahalanobis distance matching, used in Flammer (2021), to compute the Average Treatment Effect on the Treated (ATT) and compare them to our results.

Variables	(1) Regression (1) Non-Matched	(2) Regression (1) Non-Matched	(3) Regression (1) Matched	(4) Regression (1) Matched
green	-18.876***	-10.933***	-22.209***	-9.770***
	(4.582)	(3.326)	(6.190)	(3.357)
lnamount		8.946***		-11.294
		(2.683)		(7.796)
tenor		-1.199***		-2.599***
		(0.269)		(0.575)
rating		-8.613***		-12.871***
		(0.668)		(1.564)
coupon		63.205***		58.481***
		(2.050)		(3.869)
Constant	102.858***	107.794***	108.275***	314.717***
	(1.771)	(19.214)	(3.594)	(50.990)
Observations	1,485	1,485	359	359
R-squared	0.005	0.667	0.025	0.687

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 - Results of Regression (2) on both the unmatched and CEM-matched dataset

As reported in Table 5, we reach the same overall conclusion, as the estimates of (ATT) indicate that the green label on bonds has a negative absolute impact on the yield spread of bonds. Moreover, our findings preserve the robustness of the previous analysis, irrespective of the matching method used. Estimated greenium figures range from -13.878 to -7.820 basis points, using Mahalanobis Distance Matching and 5-Nearest Neighbors matching, respectively.

Matching:	*Nearest Neighbors*			*Radius*	*Radius*	*Kernel*	*Mahalanobis*
	(NN=3)	*(NN=5)*	*(NN=8)*	*(r=0.001)*	*(r=0.005)*		
ATT	*-8.064*	*-7.820*	*-8.876*	*-9.820*	*-11.336*	*-13.464*	*-13.878*
Std. Err.	*(5.673)*	*(5.219)*	*(4.970)*	*(4.961)*	*(6.961)*	*(4.639)*	*(7.396)*
# treated	*100*	*100*	*100*	*98*	*98*	*100*	*100*
#untreated	*1385*	*1385*	*1385*	*1033*	*719*	*1383*	*1385*

Standard errors in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Table 6 - Average Treatment Effect on the Treated according to the different matching methods

a. Analysis of the Robustness of Results

In this section of the study, we perform robustness results across different industries, geographies, and risk segments and verify if the greenium is still consistent across different market structures.

We start by examining the impact of issuer geography on the pricing rationale of green bonds. We would expect the green bond pricing rationale to be accepted by market participants where the green bond market runs deeper, which would translate into a significant yield premium over conventional bonds.

The Euro Corporates bond market is dominated by Eurozone issuers that align their sustainability mandates to their financing needs, issuing debt facilities in domestic currency. Between 2018 and 2021, across our sample, 68 green bonds were printed in the Euro market, allocating a total of EUR 42.1Bn to finance green projects (Table 7).

On the other hand, issuers seek to diversify their financing sources across different currencies to reduce currency risk exposure, as the importance of foreign currency issuers tapping into the Green Bond Euro Market has been growing over the past couple of years. An example of this, is the growing number of American issuers, the so-called reverse-Yankees, to tap into this market, which raised a total of EUR 6.55Bn in green funding across 10 operations. By executing operations in a foreign market, issuers benefit from a larger investment base and possible arbitrage opportunities against their domestic currency.

Country	*No. Green Bonds*	*Accumulated Nominal Amount (€ Mn)*
Belgium	*3*	*1,600*
Czech Republic	*1*	*500*
Denmark	*1*	*500*
Finland	*5*	*1,800*
France	*8*	*6,100*
Germany	*13*	*8,400*
Hong Kong	*1*	*500*
Ireland	*3*	*1,500*
Italy	*6*	*3,700*
Japan	*3*	*2,000*
Luxembourg	*10*	*5,550*
Netherlands	*16*	*10,500*
Poland	*1*	*500*
Portugal	*2*	*1,550*
Spain	*5*	*2,900*
Sweden	*1*	*500*
UK	*11*	*5,875*
US	*10*	*6,350*
Total	*100*	*6,325*

Table 7 - Green Bonds by Issuer's Country

We divide green bonds by the geography of the issuer and form 4 groups accordingly. We then run Regression (2) on the CEM-matched sample to isolate geography-specific green factors affecting the yield spread and report the results in Table 8.

As expected, we find a statistically significant green premium in geographies where the Euro Corporates bond market is deeper. For issuers in the Eurozone, we conclude about the existence of a statistically significant green premium of -12.587 basis points over conventional bonds, which decreases to -9.072 basis points (statistically significant at a 90% confidence level) when we consider American issuers. The same inference cannot be made for European issuers outside the Eurozone and issuers from the Asia-

Pacific region.

VARIABLES	(1) Regression (1) Matched Euro-Area	(2) Regression (1) Matched Europe outside Eurozone	(3) Regression (1) Matched Asia-Pacific	(4) Regression (1) Matched USA
green	-12.578***	-7.465	4.026	-9.702*
	(4.680)	(7.366)	(19.705)	(5.334)
lnamount	-13.396	-12.947	-10.930	-7.262
	(11.454)	(15.112)	(36.747)	(19.324)
tenor	-3.013***	-2.530*	-3.519	-0.354
	(0.850)	(1.274)	(3.095)	(0.772)
rating	-14.430***	-11.897***	-10.338	-12.176***
	(2.555)	(2.791)	(7.713)	(3.028)
coupon	61.366***	58.485***	52.698**	46.196***
	(5.059)	(10.612)	(21.073)	(5.026)
Constant	349.853***	311.988***	286.488	275.796**
	(75.648)	(94.082)	(276.372)	(124.469)
Observations	215	65	21	57
R-squared	0.694	0.715	0.516	0.774

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8 - Results of Regression (2) on the CEM-matched dataset, broken down bygeography

We proceed to make the same analysis regarding the issuer's industry sectors, where the relationship between market maturity and the existence and dimension of the greenium over conventional bonds still holds. We estimate the impact of the green label when controlling rating, nominal amount, tenor, and coupon across the different industry sectors.

As reported in Table 9, only the Utilities sector registered a significant green premium of -16.775 basis points. In the other sectors, where green bond activity is scarcer, we fail to observe the same behavior, as a statistically significant impact of green on the final yield spread is not verified.

For the Utilities sector, in the context of energy transition, green bonds have grown to be a fundamental source of funding to companies, since these instruments provide an outlet to invest in renewable energy projects through the use of proceeds obligation embedded in them. As highlighted in Table 10, the Utilities sector alone was responsible for the issuance of 32 green bonds, which raised a total of EUR 22.5Bn to finance the energy transition.

VARIABLES	(1) Regression (1) Matched Basic Materials	(2) Regression (1) Matched Consumer Cyclical	(3) Regression (1) Matched Consumer Non-Cyclical	(4) Regression (1) Matched Energy	(5) Regression (1) Matched Financial	(6) Regression (1) Matched Industrial	(7) Regression (1) Matched Utilities
green	-20.948	6.997	-24.638	41.182	-5.391	-7.154	-16.775***
	(34.760)	(15.770)	(14.783)	(0.000)	(3.897)	(14.364)	(4.519)
lnamount	-232.205	-1.252	-28.932		0.922	137.665	4.461
	(165.700)	(42.117)	(34.630)		(10.478)	(106.179)	(16.423)
tenor	-5.087	14.110	-0.148	14.545	-3.057***	-3.988	-0.092
	(17.087)	(7.267)	(1.184)	(0.000)	(0.947)	(4.373)	(1.032)
rating	-10.415	-11.393			-12.754***	-11.116*	-5.144
	(13.426)	(16.492)			(1.794)	(5.306)	(4.637)
coupon	55.922	48.766**	42.801***	138.909	64.809***	56.447**	29.203***
	(34.613)	(15.450)	(8.887)	(0.000)	(5.613)	(19.399)	(7.630)
Constant	1,690.638	40.824	241.621	-127.545	236.727***	-634.846	98.515
	(1,056.305)	(477.248)	(221.916)	(0.000)	(67.835)	(692.246)	(130.056)
Observations	13	12	33	4	192	20	83
R-squared	0.611	0.817	0.598	1.000	0.711	0.803	0.358

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9 - Results of Regression (2) on the CEM-matched dataset, broken down by industry sector

	Credit Rating	6	9	10	11	12	13	14	15	16	17	18	19	20	Total
Basic Materials	*Avg. yield spread (%)*		*267,5*			*153.7*	*114.5*	*123*	*94.5*	*52.3*					*107.2*
	Avg. tenor (years)		*4*			*6.1*	*8.3*	*9.2*	*9.7*	*9.8*					*8.6*
	Number of BBs		*2*			*9*	*12*	*15*	*6*	*18*					*62*
	Avg. yield spread (%)							*60*		*51.5*					*54.3*
	Avg. tenor (years)							*10*		*9.5*					*9.7*
	Number of GBs							*1*		*2*					*3*
Communications	*Avg. yield spread (%)*		*387*			*154.9*	*140*	*83.89*	*77.05*	*78.3*	*35*	*65.5*			*113.2*
	Avg. tenor (years)		*5.3*			*9.1*	*9.1*	*11,5*	*9.2*	*9.5*	*6.5*	*9.5*			*9.8*
	Number of BBs		*1*			*18*	*42*	*37*	*20*	*3*	*2*	*2*			*62*
	Avg. yield spread (%)									*44*					*44*
	Avg. tenor (years)									*8.7*					*8.7*
	Number of GBs									*3*					*3*
Consumer, Cyclical	*Avg. yield spread (%)*	*98*	*130*	*85*	*192.1*	*157*	*123*	*84*	*108.2*	*55.6*	*47.9*				*103.8*
	Avg. tenor (years)	*10*	*6*	*5*	*6.7*	*5.7*	*9.1*	*11.5*	*9.2*	*9.5*	*6.5*				*7*
	Number of BBs	*1*	*2*	*1*	*14*	*15*	*27*	*10*	*57*	*27*	*24*				*178*
	Avg. yield spread (%)								*70*	*80*					*75*
	Avg. tenor (years)								*12*	*12*					*12*
	Number of GBs								*1*	*1*					*2*
Consumer, Non-Cyclical	*Avg. yield spread (%)*			*230*	*195*	*94.5*	*118.7*	*102.9*	*104.7*	*65.1*	*61.6*	*41*		*7*	*94.5*
	Avg. tenor (years)			*7*	*8.3*	*7*	*7.5*	*9*	*11.3*	*10*	*13.2*	*10.3*		*2*	*9.4*
	Number of BBs			*1*	*3*	*42*	*60*	*94*	*35*	*35*	*36*	*41*		*1*	*348*
	Avg. yield spread (%)							*65.6*							*65.6*
	Avg. tenor (years)							*9.9*							*9.9*
	Number of GBs							*5*							*5*
Energy	*Avg. yield spread (%)*			*279.5*		*163.3*	*137*	*62*	*118.3*	*107.2*	*97.9*	*100.6*	*100.8*		*123.4*
	Avg. tenor (years)			*7*		*6.6*	*7.3*	*5*	*8.8*	*10.5*	*12.4*	*9.7*	*10.2*		*9.4*
	Number of BBs			*4*		*4*	*9*	*1*	*13*	*17*	*8*	*7*	*6*		*69*
	Avg. yield spread (%)					*79.3*	*125*								*90.75*
	Avg. tenor (years)					*8.7*	*7*								*8.3*
	Number of GBs					*3*	*1*								*4*
Financial	*Avg. yield spread (%)*			*270.8*		*167.9*	*142.8*	*121.6*	*94.5*	*77*	*47.6*	*59*	*26.6*		*121.6*
	Avg. tenor (years)			*7*		*6.5*	*7.5*	*9.5*	*9.2*	*11*	*7.8*	*15.7*	*8*		*8.8*
	Number of BBs			*1*		*25*	*69*	*82*	*25*	*24*	*5*	*3*	*5*		*239*
	Avg. yield spread (%)					*147.9*	*120.9*	*98.3*	*73.8*	*85*					*111.4*
	Avg. tenor (years)					*6.3*	*7.2*	*9.6*	*9.3*	*8.5*					*8*

	Number of GBs					*11*	*13*	*9*	*8*	*4*					*45*
Industrial	*Avg. yield spread (%)*		*57.5*		*240*	*131.2*	*98.7*	*104.3*	*98.6*	*84.6*	*49.5*		*51.9*		*90.3*
	Avg. tenor (years)		*8*		*5.3*	*7.4*	*7.4*	*7.5*	*9.5*	*8.4*	*9.8*		*14.9*		*9*
	Number of BBs		*2*		*3*	*13*	*26*	*33*	*47*	*19*	*33*		*14*		*190*
	Avg. yield spread (%)					*72.5*	*60*	*70*	*40*						*63*
	Avg. tenor (years)					*10*	*7*	*10*	*5*						*8.4*
	Number of GBs					*2*	*1*	*1*	*1*						*5*
Technology	*Avg. yield spread (%)*			*142.5*		*125.5*		*68.6*	*49.3*						*97.7*
	Avg. tenor (years)			*8.3*		*7.5*		*10*	*8*						*8.1*
	Number of BBs			*2*		*27*		*9*	*12*						*50*
	Avg. yield spread (%)									*45*					*45*
	Avg. tenor (years)									*10*					*10*
	Number of GBs									*1*					*1*
Utilities	*Avg. yield spread (%)*				*171.7*	*156*	*89.7*	*84.1*	*62.2*	*68.1*	*85.9*	*45,3*			*86.3*
	Avg. tenor (years)				*8.3*	*7.4*	*8.3*	*9.6*	*9.3*	*14*	*8.5*	*11.3*			*9.4*
	Number of BBs				*3*	*5*	*30*	*56*	*13*	*8*	*6*	*3*			*124*
	Avg. yield spread (%)						*69.6*	*63.3*	*52.4*	*43*	*35*				*59*
	Avg. tenor (years)						*8.3*	*9.4*	*10.6*	*12*	*12*				*9.8*
	Number of GBs						*5*	*14*	*11*	*1*	*1*				*32*
Total	*Avg. yield spread (%)*	*98*	*185.3*	*221*	*196.1*	*147.2*	*124*	*102.6*	*97.4*	*69.8*	*58*	*50.6*	*58.6*	*7*	*102.9*
	Avg. tenor (years)	*10*	*5.9*	*7.1*	*7*	*7*	*7.7*	*9.3*	*9.2*	*9.5*	*10.4*	*10.5*	*12.4*	*2*	*2*
	Number of BBs	*1*	*7*	*9*	*23*	*131*	*302*	*328*	*225*	*163*	*114*	*56*	*25*	*1*	*1385*
	Avg. yield spread (%)					*125.6*	*105.3*	*74.3*	*60.8*	*61.9*	*35*				*84*
	Avg. tenor (years)					*7.3*	*7.5*	*9.6*	*9.9*	*9.4*	*12*				*8.86*
	Number of GBs					*16*	*20*	*30*	*21*	*12*	*1*				*100*

Table 10 - Description of the sample of 1485 bonds, by average yield and maturity, broken down by industry sector and credit rating

Another important distinction between bonds, which leads to the creation of different market segments, is the credit risk categorization of the instruments. Corporate bonds are broadly divided into two categories: Investment Grade (IG), which offer lower coupon rates in exchange for less counterparty risk, and High Yield (HY) bonds that offer higher returns in exchange for lower default risk. Credit rating agencies attribute this classification based on their assessment of the issuer's creditworthiness.

For the purpose of this study, we will take into account Moody's, Standard&Poor's and Fitch ratings, and respecting each rating agency's methodology on this topic, we classify bonds with a credit rating lower than 12 as High Yield and bonds with a rating equal to or higher than 12 as Investment Grade. IG issuers dominate the green bond market, printing 1298 bonds across our dataset, compared to the 187 bonds issued by HY corporates.

VARIABLES	(1) Regression (1) Matched All bonds	(2) Regression (1) Matched IG bonds	(3) Regression (1) Matched HY bonds
green	-9.770***	-10.533***	-1.493
	(3.357)	(3.546)	(7.450)
lnamount	-11.294	-7.416	-16.367
	(7.796)	(8.195)	(22.175)
tenor	-2.599***	-2.372***	-0.476
	(0.575)	(0.595)	(3.039)
rating	-12.871***	-12.726***	
	(1.564)	(1.913)	
coupon	58.481***	54.329***	86.147***
	(3.869)	(4.238)	(9.177)
Constant	314.717***	290.368***	138.483
	(50.990)	(58.622)	(136.050)
Observations	359	318	41
R-squared	0.687	0.628	0.823

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11 - Results of Regression (2) on the CEM-matched dataset, broken down by risk segmentation

As reported in table 11, the greenium effect persists for Investment Grade securities but does not seem to verify for speculative instruments, as we observe a statistically greenium of -10.533 basis points against conventional bonds in the Investment Grade segment, whereas in the High Yield market the same conclusion cannot be made.

Analysing the results achieved of the impact of issuer industry, country, and credit risk profile on greenium, it seems that as markets mature, the green bond premium integrates the pricing rationales of these securities.

5.2.Green Bonds: Stylized Facts

In this section of the study, we reflect on the differences between green and brown bonds regarding the auction process of bond issuances in the primary market. Resourcing to the insights of a well know Portuguese Bank DCM's team insights we analyse the impact of green bonds in the book-building process, namely in the Initial Price Target (IPT), which allows us to infer the change in IPT during the placement of the securities and the total book value.

The IPT (ipt_i), measured in basis points, is the figure announced before the public auction process that signals the market on which levels the operation will take place. The IPT refers to the yield spread in relation to the reference rate, as detailed before. The IPT of an issue is fixed by the Agency Banks that build the operation together with the issuer, which, acting on their client's best interest and considering comparable emissions and market appetite for the issuer, define a price for which bids will be generally satisfactory. The target IPT is often higher than the price effectively targeted by the issuer to avoid unmeasured price aggressiveness that leaves a portion of the investors out of the market.

An important metric used by the industry to measure the success of an operation is the actual change in the IPT ($dipt_i$), during the auction process. In other words, the measure of how much did the yield spread tighten during pricing. The change in IPT is obtained by subtracting the IPT by the final yield spread. Large contractions of the yield spread, i.e. big revisions of the IPT, signal strong demand from investors, as a large number of bids drove the book value above the nominal amount of the bond, allowing issuers to choose the lower yield levels[7] for the allocation of the securities.

[7] The allocation of the securities is discretionary by the issuer and does not have to always consist of choosing the lowest yields, although this is the most common. Reasons for which issuers, together with the Agency Banks, may decide to allocate securities to investors out of the competitive pricing range are often

Finally, the book amount ($amount_i$) refers to the accumulated amount of investor's offers during the bond placement and is used as a proxy by the market to gauge investor demand. Although there is no direct relationship between the success of a bond and the total book value of the operation, since it may be filled with uncompetitive offers that failed to drive down the IPT, high IPT revisions are often associated with large investor demand, in the form of high total book values. Relative demand by investors is measured by the oversubscription ratio ($oversubscription_i$) which considers the total book value of the issue by its nominal amount. Even more so than the total book value of the issue, this figure is often

Since our sample does not have IPT and book figures for all observations, we choose to drop these units. We then run robustness tests of the CEM-matched sample and report the results in Table 12.

	Green Bonds			*Conventional Bonds*			
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
	Obs.	*Mean*	*Std. Dev.*	*Obs.*	*Mean*	*Std. Dev.*	*Difference between (2) and (5)*
ipt	*77*	*113.864*	*45.803*	*194*	*132.459*	*61.431*	*-18.595***
dipt	*77*	*-27.614*	*7.618*	*194*	*-25.268*	*10.340*	*-2.346**
book	*77*	*1.830*	*0.969*	*194*	*1.958*	*0.128*	*-0.489*
oversubscription	*77*	*3.361*	*2.319*	*194*	*3.654*	*2.559*	*-0.348*

*** p<0.01, ** p<0.05, * p<0.1

Table 12 - Results of the robustness tests on the mean differences across key metrics of bond auctions on the matched dataset

Contrary to expectation, green bonds are subject to less investor demand both in absolute and relative terms, as the average total book across the 77 green bonds was EUR1,830 million, whereas otherwise comparable conventional bonds attract on average EUR 1,958 million per bond offering, while the average oversubscription ratio was 0.348x lower compared to that verified in otherwise equal conventional bond offerings.

related to a desired investor profile. For example, an American issuer printing bonds denominated in Euros may prioritize Eurozone investors in order to conquer investor base overseas, or an Utilities company may prioritize SRI investors in the placement of their green bond to deepen their sustainable profile investor base

One possible explanation for this behavior is the price-aggressiveness of green bond issuers, which on average set IPTs almost 19 basis points lower than comparable brown bonds, although this difference is only significant at a 90% confidence level. This leads to lower absolute spread compression over the course of pricing, as conventional bond offerings tighten on average 2.346 basis points more than their green counterpart. Since green bonds are priced at a native yield premium by the issuer through lower IPTs, a significant portion of the conventional bonds' investor base is ruled out even before the auction begins, leaving only SRI investors willing to trade a portion of their returns in exchange of contributing to the investors and their own sustainability mandates.

6. Conclusion

This Thesis investigates corporate green bonds, a relatively new instrument in sustainable finance, and its financial viability as a solution for companies wishing to align their sustainability mandates and financing needs.

Our results confirm the cost of capital argument for green bonds, as we verify the existence of a greenium of around -9.7 basis points. We find a positive relationship between the maturity of the markets and the greenium priced-in in the transacted securities, as i) IG-rated bonds, ii) bonds issued by Eurozone and American issuers, and iii) bonds issued by corporates in the Utilities sector, all register significantly higher green bond premiums.

Green bonds are priced at a native greenium through the bond auction process, as these instruments do not verify statistically significant better key metrics than otherwise comparable brown bonds. In fact, green bonds are subject to less demand from investors, roughly less EUR 128 million on average per issue, since they offer larger returns for investors in the form of higher IPTS, leading to a higher spread tightening, around 2.3 basis points higher, during the pricing of the issue.

This study calls for future research. First, due to the limited number of green bonds issued over the last couple of years, future investigations may benefit from the rising number of green bonds issued to gauge the evolution of greenium. Secondly, although this study focuses on green bonds, there are other types of sustainability-related financial instruments gaining traction amongst issuers. It would be of value to conclude on the existence of greenium for these securities and understand their possible role on the road to a low-carbon emissions economy.

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