EMPRAD ENCONTRO DOS PROGRAMAS DE PÓS-GRADUAÇÃO PROFISSIONAIS EM ADMINISTRAÇÃO

GREEN BONDS E O DESENVOLVIMENTO SUSTENTÁVEL

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Resumo

Este estudo analisa algumas características dos Green Bonds como um novo instrumento para financiar a transição para o desenvolvimento sustentável, e avalia sua performance em relação a outros bonds comparáveis antes e durante a crise econômica causada pela pandemia do COVID-19 O rendimento dos Green Bonds e outros bonds são comparados para avaliar a importância que a sociedade atribui ao tema das mudanças climáticas e degradação ambiental, e para avaliar se os Green Bonds podem ser uma classe de ativos defensivos durante crises de mercado Os resultados deste estudo são consistentes com os de vários outros estudos que usaram diferentes metodologias e que indicam que a maioria dos Green Bonds obtém um prêmio de preço, embora tal prêmio seja pequeno Este estudo é o primeiro que mostra que o prêmio cai com o tempo e que os Green Bonds são sensíveis à crise causada pela pandemia do COVID-19 Os resultados deste estudo contribuem com a área de finanças sustentáveis O autor sugere que a provisão de relatórios periódicos, certificados e padronizados sobre a performance ambiental das atividades financiadas pelos Green Bonds poderia diferenciá-los no mercado secundário, atrair novos investidores e tornar os Green Bonds uma classe de ativos menos volátil.

Palavras-chave: Green Bonds, Mudanças Climáticas, Desenvolvimento Sustentável, Covid-19

Abstract

This study analyses some interesting features of green bonds as a new instrument to finance the transition to sustainable development and assesses their performance before and during the COVID-19 economic crisis in relation to comparable bonds. The yields of green bonds and other bonds are compared to evaluate the importance that society places on climate change and environmental degradation, and to assess whether green bonds can be a defensive asset class during periods of market turmoil. The results of this study are consistent with the findings of several other studies that have used different methodologies and indicated that most Green Bonds obtain a price premium, although the premium is small. This study is the first to show that the premium decreases over time and that green bonds are sensitive to the turmoil caused by the COVID-19 pandemic. The result of this study contributes to the field of sustainable finance. The author suggests that the provision of periodic, certified and standardized reporting of the environmental performance of the activities financed by Green Bonds could differentiate them in the secondary bond market, attract new investors and ultimately turn Green Bonds into a less volatile and more defensive asset class.

Keywords: Climate Change; Green Bonds, Sustainable Development; COVID-19

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Keywords: Greenhouse Gases; Climate Change; Green Bonds, Sustainable Development; COVID-19

1. Introduction

In economics, an externality is a cost or benefit that affects a party that has not chosen to incur such a cost or benefit, respectively (Buchanan and Stubblebine, 1962). The emission of greenhouse gases (GHGs) is an example of an externality since it causes climate change (Millennium Ecosystem Assessment, 2005).

According to the OECD (2017), US$6.7 trillion in infrastructure investment would be necessary to attain the global warming limit of 2° Celsius. The present study seeks to understand the role of green bonds as a new market mechanism to finance the transition to sustainable economies and whether they can be a defensive asset class during periods of economic crisis.

For the present study, the yields to maturity (YTM) of green bonds and other bonds are considered proxies for an assessment of society's interest in environmental issues and its willingness to sacrifice returns in favor of the environment and for evaluating the performance of green bonds during volatile periods such as during the COVID-19 crisis.

Green bonds are the object of this study due to the growing adoption of this type of financial instrument for projects and programs related to climate change and sustainable development, as reflected in the growing number of academic publications in the fields of economics and finance in the last five years, as presented in Table 1.

Table 1. Growing number of academic articles related to green bonds.

RESEARCH THEME	2017	2018	2019	2020	2021	Growth 17-20	TOTAL
GREEN BONDS	10	13	36	46	6	460%	111
ESG	49	60	148	178	28	363%	463
GREEN FINANCE	51	66	108	109	13	214%	347
SUSTAINABLE FINANCE	148	154	249	254	19	172%	824
TOTAL	258	293	541	587	66	228%	1745

Source: the author

To search for academic publications related to the above themes, the Web of Science database of articles was assessed in March 2021 with the following filters:

- Years: the last five years.
- Research Fields: ENVIRONMENTAL STUDIES; ENVIRONMENTAL SCIENCE, PUBLIC ADM; BUSINESS FINANCE; ECONOMICS; INTL. RELATIONS; LAW; MANAGEMENT; POLITICAL SCIENCE; SOCIOLOGY; SOCIAL ISSUES; DEVELOPMENT STUDIES; SOCIOLOGY; PUBLIC ADM.

Other authors, such as Park D. et al. (2020), have also recognized the growing importance of green bonds, highlighting the growing interest and research in sustainable growth and corporate environmental responsibility and increasing investments in environmental, social, and governance (ESG) factors. The author also states that issuances and trading volumes of green bonds are increasing.

According to the International Capital Market Association (ICMA, 2018), green bonds are any type of debt security whose funds will be used exclusively to finance or refinance part or all new or existing projects with eligible environmental purposes.

According to Climate Bonds Standard (CBS) V 3.0 (2019), several debt instruments can be certified as green, and the most popular instruments are green bonds.

Table 9, displayed further down in this document, presents ten other studies that have estimated the premium (if any) of green bonds. The present study contributes to the growing but still early-stage literature in the area by adopting a different methodology for estimating the green bonds premium (greenium) in the secondary market based on a comparison with other bonds traded by the same issuer. This methodology has been adopted by the Climate Bonds Initiative in a series of reports called Green Bond Pricing in the Primary Market (CBI, 2021) issued since 2017. This series estimates the premium of green bonds in primary markets.

According to the CBI (2021), the advantage of adopting this methodology is that since green bonds rank pari-passu (on equal footing) with bonds of the same payment rank and issuer, there is no reason why a bond being green should impact its price. There is no credit enhancement to explain pricing differences; and the issuers of green bonds often incur costs such as second-party opinions and certification, although these costs are typically negligible. Green bonds and vanilla equivalents are subject to the same market dynamics such as supply, rate expectations, geopolitical issues, and fallouts from global pandemics.

This study takes advantage of the careful selection process of green bonds to establish the sample and applies the same methodology to analyze the green bond premium during the crisis

caused by the COVID-19 pandemic. The results of this analysis are the first to show how green bonds perform during challenging times in the global economy and financial markets.

Based on the results obtained, the present study also aims to suggest measures to various stakeholders to maintain the differentiation of green bonds throughout their lifetime, motivating investors to hold them for longer, attracting new investors, and ultimately turning green bonds into a defensive asset class.

The remainder of the paper consists of seven sections. Section Two provides important information from the literature review and presents the research motivations for the present study. Section Three describes the methodology adopted for the analysis of the performance of green bonds in secondary markets through a comparison of their YTMs with those of other similar bonds by the same issuer. This section also explains how the green bonds sample was established. Section Four presents the results of the performance of green bonds in the secondary market and during the COVID-19 pandemic crisis. Section Five discusses the results obtained in the present study and compares them with the results of other studies that adopted different methodologies, connecting the results with the literature. In Section Six, the author presents the conclusions of the present study and makes recommendations to various stakeholders involved with green bonds, aiming to reduce information asymmetries, reduce price distortions and further develop the market.

2. Literature Review

Fama and French (2007) demonstrated that when a group of investors appreciates a certain type of asset, equilibrium prices change, and the traditional Capital Asset Pricing Model (CAPM) fails to explain the returns of such assets. Applying this to green bonds, some investors may appreciate the nonpecuniary characteristics of green bonds while others may be indifferent to them.

A possible explanation for the green bonds yield premium could be the appreciation of some investors for the environmental attributes of green bonds, increasing their disposition to pay relatively higher prices.

In addition, traders who are indifferent to the environmental attributes would sell green bonds with lower yields and buy another bond with a similar modified duration on the curve by the same issuer, profiting from the YTM difference between the two, a sort of arbitration.

In line with Fama and French (2007), indifferent traders would restore the price balance according to the CAPM as they have no appreciation for the nonpecuniary characteristics of green bonds, causing yields to return to the yield curve of the green bonds' issuer.

The issuance of green bonds can also improve the market's perception of the issuer since the allocation of resources for and management of environmental projects improves the governance and integration of different teams within the organization (Karpf and Mandel, 2018; Zerbib, 2019; Hachenberg and Shiereck, 2018). However, given the possible economic, market and reputational benefits of issuing green bonds and the immature monitoring and reporting systems, one must be careful with the risks of green washing, as described by Bachelet et al. (2019).

Ehlers and Packer (2017) estimated the premium of green bonds and concluded that green bonds at issuance have been priced at a premium on average relative to conventional bonds while their performance in the secondary market has been like that of other bonds if currency

risks are hedged. The author also concludes that green bonds are exposed to environmentally related financial risks to a relatively high degree.

Baker et al. (2018) studied the premium of US municipal green bonds and found that they are issued at a premium compared to otherwise similar ordinary bonds. The author also found that pricing and ownership effects are the strongest for bonds that are externally certified as green.

Karpf and Mandel (2018) investigated the differences between the yield term structures of green and conventional bonds in the US municipal bond market. His research showed that although returns on conventional bonds are on average higher than those for green bonds, the differences can largely be explained by the fundamental properties of the bonds. Historically, green bonds have been penalized on the municipal market and traded at lower prices and higher yields than expected by their credit profiles. In recent years, however, the credit quality of municipal green bonds has increased, and the premium turned to positive.

Hachenberg and Shiereck (2018) have also investigated the performance of green bonds through the matching of daily i-spreads of green-labeled and similar non-green-labeled bonds. The author has found that rating classes AA–BBB of green bonds and the full sample trade marginally tighter for the respective period compared to nongreen bonds of the same issuers. Furthermore, financial and corporate green bonds trade tighter than their comparable nongreen bonds, and government-related bonds trade marginally wider. Issue size, maturity and currency do not have significant influences on differences in pricing but industry and ESG rating do, as concluded this study.

Bachelet et al. (2019) examined the characteristics of a sample of green bonds matched with their closest brown bond neighbors and found that green bonds have higher yields and a lower variance and are more liquid. Green bonds from institutional issuers have higher liquidity with respect to their brown bond correspondents and negative premia before correcting for their lower volatility. Green bonds from private issuers have much less favorable characteristics in terms of liquidity and volatility but have positive premia with respect to their brown correspondents unless the private issuer commits to certify the “greenness” of the bond.

Zerbib (2019) adopted green bonds as an instrument to identify the effect of nonpecuniary motives, specifically pro-environmental preferences, on bond market prices. Through a matching method, followed by a two-step regression procedure, an estimation of the yield differential between a green bond and a counterfactual conventional bond from July 2013 to December 2017 was performed. The results suggest a small negative premium: the yield of a green bond is lower than that of a conventional bond. The author shows that this negative premium is more pronounced for financial and low-rated bonds. The results emphasize the low impact of investors’ pro-environmental preferences on bond prices.

Gianfrate and Peri (2019) adopted the propensity score matching approach as the method to study 121 European green bonds issued between 2013 and 2017. The results of this method indicated that green bonds are more financially convenient than nongreen bonds. The advantage is larger for corporate issuers, and it persists in the secondary market.

Hyun et al. (2019) investigated the impact of external verification and CBI certification on the YTM of green bonds and identified premiums of 6 BPs and 15 BPs, respectively.

Lacker and Watts (2020) assessed the possibility of green premiums in municipal bonds. Comparing green securities to nearly identical securities issued for nongreen purposes by the same issuers on the same day, this assessment indicated economically identical pricing for green

and nongreen issues. The author concludes that when risk and payoffs are held constant and are known to investors ex ante, investors view green and nongreen securities by the same issuer as almost exact substitutes, and the greenium is essentially zero.

Nanayakkara and Colombage (2020) examined the impact and degree of compliance with Green Bond Principles (GBPs) on investor demand for Green Bonds (GBs) in G20 countries by employing a cross-sectional regression to analyze data over the 2007–2016 period. After controlling for common bond-specific and macroeconomic variables, the analysis identified a significant positive impact of higher compliance with principles on investor demand, as measured by the bid-ask spread and yield spread. The study also shows that the green bonds issued by government institutions can minimize the adverse effects of low compliance with GBPs and that investor demand for fixed coupons is higher than that for float-coupon green bonds.

While the studies above have investigated different variables that could impact the performance of green bonds, they have produced mixed results regarding the green premium. The present study aims to answer the research question on the performance of green bonds in the secondary market through the adoption of another methodology (CBI, 2021) to investigate whether there is a green premium and consequently whether society is, at present, willing to accept lower returns for nonpecuniary reasons.

The second research question that the present study seeks to answer is how green bonds have performed during the COVID-19 pandemic, the first large-scale economic and financial crise since green bond issuances reached some critical mass and importance in investment portfolios. The same methodology has been adopted for this analysis (CBI, 2021).

Research by Broadstock and Cheng (2019) reveal correlations between the performance of green bonds, other bonds and variables at the macrolevel or macroeconomic level. Such research has provided evidence that the connection between the performance of green bonds and other bonds is sensitive to factors such as changes in financial market returns, volatility, economic policy uncertainty, oil prices and news-based investor sentiment. The article highlights the role that macroeconomic conditions can play either reinforcing or destabilizing progress towards the healthy development of the green bond market.

Park et al. (2020) investigated the volatility dynamics and spillovers between equities and green bonds. The conclusion is that green bonds present asymmetric volatility since they are sensitive to positive shocks but less sensitive to negative shocks.

The article by Huynh et al. (2020) included the role of green bonds in a portfolio diversification strategy. In doing so, the article analyzes the transmission of volatility to various assets including green bonds during economic turbulence. The study identified that volatility transmission among selected assets during periods of economic crisis is higher in the short term, but it decreases in the long run; and recommends a buy-and-hold strategy including green bonds.

Hammoudeh et al. (2020) investigated the relationship between green bonds and financial and environmental variables. The study reveals a significant causality running from the US 10-yr Treasury bond index to green bonds starting at the end of 2016 until the end of the sample period. Another finding was that the link between CO2 emission allowance prices and green bonds was significant from the beginning of the sample period to the end of 2015. Furthermore, the causality running from the clean energy index to green bonds was limited to 2019. However, there is no significant causality running from green bonds to all considered assets, indicating no predictive power for this asset in its proper domain.

In a different and innovative research front, Phan and Huynh (2020) investigated how investor attention influences the green bonds market. The research has found a time-varying feedback effect between green bond performance and investor attention, which has several implications. Investors with interests in green bonds can rely on market attention as a useful tool to predict green bond performance.

The present study builds on the findings of the literature presented above to assess and evaluate the performance of green bonds during the COVID-19 pandemic.

The third motivation of the present study is to provide recommendations to several stakeholders interested in increasing the viability and attractiveness of green bonds and developing the market.

3. Methodology and Calculations

3.1. Quantitative analysis

In the comparison between the yields of green bonds and other bonds, a statistical regression technique was used to obtain the second-order polynomial curves of the yields of several bonds and green bonds of the same issuer versus the modified duration of each bond.

For the same issuer, only green bonds and other bonds with the same rating, payment priority (seniority), same currency (EUR or USD) and same redemption options are compared. The ratings of the bonds are expected to reflect the existence of guarantees and collateral involved.

For the comparative analysis of the YTMs, the methodology adopted since 2017 by the IFC and the Climate Bonds Initiative[1] to prepare the report series Green Bond Pricing in the Primary Market (CBI, 2021) was adapted by the author. The CBI (2021) adopts this methodology to assess the performance of green bonds in the primary market while the current author is adapting and applying the methodology to evaluate green bonds in the secondary market.

The impact of the liquidity of green bonds on the YTM has not been evaluated as a separate variable in this study due to other already published academic research, such as that by Wulandari et al. (2018), concluding that the liquidity differences between green bonds and other bonds are negligible. Nevertheless, the selection of the sample considered the most liquid portion of the green bonds market by using filters such as minimum issue size and currencies.

The final analysis applied the same methodology to assess the performance evaluation of the same green bonds sample during the COVID-19 crisis, limited to the period of Feb. 2020 until Feb. 2021, which includes the price bottom of the USD corporate bonds markets in March 2020.

Comparing green bonds' performance with the performance of other similar bonds seems to be a superior approach than comparing the performance of existing green bond indexes or green bond ETFs with their regular counterparts. This is due to different methodologies that are used to establish the composition of indexes or ETFs (Liaw, 2020). Examples include different currencies, hedged/unhedged, and different proportions of green bonds or other bonds (e.g., evenly or proportional) within the index or portfolio.

[1] Available from www.climatebonds.net

3.1.1. Quantitative Analysis Steps

The stages of the Green Bond Pricing in the Primary Market (CBI, 2021) series of publications were adapted so that the methodology could assess the performance of green bonds in the secondary market. Steps 2, 13, 14 and 15 and 16 below were added to the present study.

1. Identification, through the Climate Bonds Initiative website (2018) of the green bonds issued, of the bonds classified as green by the issuer and that adhere to the green bonds' principles.

2. Confirmation of the green classification in Bloomberg terminals (menu "Description"> "Additional Information").

3. Selection of green bonds issued in USD or EUR to seek liquidity.

4. Selection of green bonds in EUR and USD with an issue above USD 300 million, also seeking liquidity.

5. Selection of green bonds in EUR and USD that have a third party or audit report.

6. Elimination of green bonds that are not less than three years to maturity, avoiding reduced liquidity close to the maturity date.

7. Identification of the issuers of each green bond selected up to step 6 above.

8. Identification of the other bonds issued in the same currency by green bond issuers who have more than three years until maturity and minimum issuance value of USD 300 million.

9. Compilation of the green bonds and other bonds of each issuer previously selected and identification of the bonds with the same rating and payment priority (seniority) of the green bonds issued by each issuer.

10. Selection of green bonds issuers that have at least four other comparable bonds (cf. item 9) in the first data collection in May 2018 (although the number of comparable bonds decreases due to the passage of time between collections monthly) so that it is possible to regress the data to a minimally accurate polynomial curve.

11. Compilation of the YTMs and modified durations of the bonds selected in the previous step.

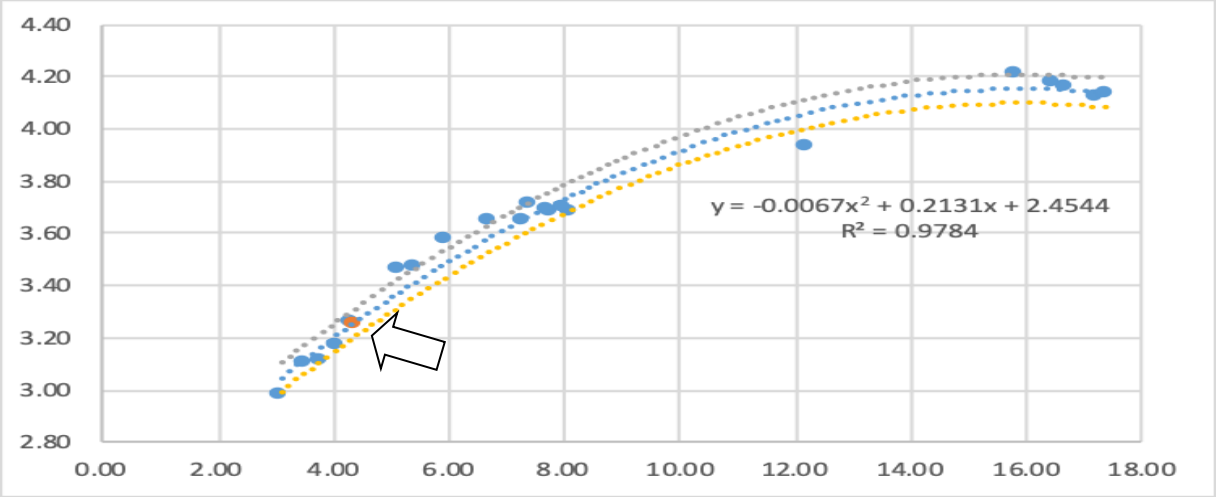
12. For each issuer, perform a statistical regression of the YTM versus modified durations to obtain the respective polynomial curves formed only by the other bonds (excluding green bonds) as per step 4 above.

13. Calculation of the difference between the real YTM value of each bond and the theoretical value obtained from the polynomial regression curve. Calculation of the standard deviation of the differences.

14. Assessment of where the green bonds' YTMs position themselves in relation to their issuer's yield curve.

15. Classification of the YTM of each green bond as (a) below the curve, (b) on the curve, or (c) above the yield curve of its issuer.

Figure 2. Example of the polynomial yield curve (YTM x Modified Duration) of green bonds: Apple 2023 (highlighted by the arrow in the figure), and classification (b) in this example = 'within the curve'.



Source: the author (2021) based on data obtained from Bloomberg

16. Comparison of the results of the above classification for each green bond at various points in time, including during the COVID-19 crisis (limited to Feb. 20 to Feb. 21).

The variations in ratings of each green bond were also considered in the analysis because the specialists in ratings agencies may have their own perspective and can have opinions that differ from the risk/return perception and other nonmonetary interests on the part of other fixed income market players.

In some cases, the rating change anticipates changes in investors' risk/return perception in relation to the assets evaluated by the agencies. In other cases, rating changes occur because of the change in investors' perception, expressed through the variation of prices and yields.

3.4. Green Bonds' Performance during COVID-19

The same set of green bonds selected for the previous analysis has been used to assess their performance during the COVID-19 crisis, encompassing the one-year period between Feb. 19, 2020, the high of the bond markets prior to the crisis; and Feb. 19, 2021, when bond markets recovered and reached higher price levels compared to one year before. The performance of green bonds was also assessed on March 20, 2020, the price bottom of the USD corporate bonds market during the crisis. For the overall performance of the USD corporate bonds market, the LUACTRUU index (Bloomberg Barclays US Corporate Total Return Value Unhedged) was used.

The performance of the USD corporate bonds market during the COVID-19 pandemic was initially used to define the period of analysis for the performance of green bonds during the crisis due to the correlation between green bonds and corporate bonds, as identified by Reboredo et al. (2020).

3.5. Variables and Data Collection

The Climate Bonds Initiative compiles all green bonds issued since 2009 and labeled as such by the issuer on its market page.

Table 3. *Green bonds* issued in USD and EUR by 2018

	Euro	**Dollar**	**Total EUR + USD**
Total amount in US$ * million (face value)	144,327	157,5	301,827
Quantity of Bonds	212	1,702	1,914
Average value in US$ * million upon issuance	663	93	378
Amount over US$ 300 million (face value) - minimum value for analysis	156	154	310
Amount above US$ 300 million and with second opinion report	123	116	239
Steps above and possibility to compare with other 4 bonds, same issuer, maturity over 3 years	45	13	58

Source: the author, based on data from the *Climate Bonds Initiative* (2018).

3.4.1. Variables

The following variables were collected and analyzed for each green bond and its comparisons:

• YTM

• Modified duration.

4. Results

The data show that green bonds have a small price premium and the premium remained stable from March 2018 until March 2019. At the end of this period, only 25.8% of green bonds had a green premium, with an average value of -2 basis points (BPs). Such a premium has been estimated through the difference between the actual YTM of green bonds and the corresponding theoretical value estimated by the polynomial regression curve of each issuer. Data related to the month of August 2018 have not been obtained due to limitations in accessing Bloomberg Terminal.

Table 4. Evolution of the green premium between March 2018 and March 2019

Number of Green B.	May 2018	Jun. 2018	Jul. 2018	Sep. 2018	Oct. 2018	Nov. 2018	Dec. 2018	Jan. 2019	Feb. 2019	Mar. 2019
with discount	8	9	8	7	6	5	7	10	8	7
%	14%	16%	14%	12%	10%	9%	12%	17%	14%	12%
Green Premium	10	13	15	14	14	14	16	15	14	15
%	17%	22%	26%	24%	24%	24%	28%	26%	24%	26%
Within its curve	40	36	35	37	38	39	35	33	36	36
%	69%	62%	60%	64%	66%	67%	60%	57%	62%	62%
Total	58	58	58	58	58	58	58	58	58	58

Source: the author (2021) based on data obtained from Bloomberg

The following tables present the performance of green bonds during the COVID-19 pandemic, limited to the period between Feb. 2020 and Feb. 2021, which includes the worst moment of the bond market sell off in March 2020.

Table 5 – Green bond premium during COVID-19

	Feb. 19, 2020	Mar. 20, 2020	Feb. 19, 2021
Average Premium in BP	0.0	**-0.07**	0.0
Standard Deviation	-0.10	-0.24	-0.16
Mean	0.01	0.0	0.01

Source: the author (2021) based on data obtained from Bloomberg

Table 6 – Green bonds' performance changes during COVID-19

NO CHANGES	34	60,7%
DETERIORATES AND RECOVERS	7	12,5%
INCREASES AND DETERIORATES	1	1,8%
RANDOM MOVEMENTS	5	8,9%
INCREASES AT THE END	2	3,6%
DETERIORATES AT THE END	3	5,4%
EXCLUDED - DATA PROBLEMS	4	7,1%
Total	**56**	

Source: the author, based on data obtained from Bloomberg

Table 7. Green bonds' performance changes during COVID-19 per green bond premium status

Changes in Green Premium	with GREEN PREMIUM	NORMAL	ABOVE YTM CURVE
NO CHANGES	40,0%	67,6%	71,4%
DETERIORATES AND RECOVERS	40,0%	2,9%	0,0%
INCREASES AND DETERIORATES	0%	2,9%	0,0%
RANDOM MOVEMENTS	7%	11,8%	0,0%
INCREASES AT THE END	0%	2,9%	14,3%
DETERIORATES AT THE END	7%	5,9%	0,0%
EXCLUDED - DATA PROBLEMS	7%	5,9%	14,3%

Source: the author (2021), based on data obtained from Bloomberg

Table 8. Green bonds' performance changes during COVID-19 per type of issuer

Changes in Green Premium	Gov. Agency	Corporate	Sovereign
NO CHANGES	70,0%	51,2%	66,7%
DETERIORATES AND RECOVERS	10,0%	16,3%	0,0%
INCREASES AND DETERIORAGES	0,0%	4,7%	0,0%
RANDOM MOVEMENTS	20,0%	18,6%	0,0%
INCREASES AT THE END	0,0%	2,3%	0,0%
DETERIORATES AT THE END	0,0%	0,0%	33,3%
EXCLUDED - DATA PROBLEMS	0,0%	7,0%	0,0%

Source: the author, based on data obtained from Bloomberg

5. Discussion

The review of academic articles that prior to 03/2021 have quantitatively assessed the green premium of green bonds resulted in ten articles whose results are in Table 9, including the results of the present research.

The present study is the only one that has analyzed the evolution of the green premium in the secondary market including a period of significant economic stress caused by the COVID-19 pandemic.

Table 9. Articles estimating the green premium of Green Bonds

	Ehlers et al., 2017	Karpf et al., 2018	Baker et al., 2018	Hachenberg et al., 2018	Zerbib, 2019	Bachelet et al., 2019	Gianfrate et al., 2019	Hyun et al. 2019	Nanayakkara et al. 2019	Lacker et al. 2020	this aut 2019
GB aligned with GBP	yes	no	no	yes	yes	yes	n.a.	yes	n.a.	n.a	yes
Scope	EUR and USD	US Munic. and Bloomberg Green	US Munic./Corp. and	Global	Global	Global	EUR	Global	Global	US Municipal	EUR and
Primary or Secondary	Primary	Secondary	Primary	Secondary	Secondary	Secondary	Both	Secondary	Secondary	Primary	Second
Green Bonds in the Sample	21	1880	2083	63	110	89	121	60	82	640	59
Analysis period	2014-2017	2010-2016	2010-2016	Out. 2015 – mar. 2016	Jul. 2013 – dez. 2017	Jan. 2013 – dez. 2017	Jan. 2007 – dez. 2017	2010 - 2017	2016-2017	2013-2018	2014 – 2019
Method	Comparison	Decomposition Oaxaca-Blinder	Regression OLS	Matching + regression panel	Matching + regression	Matching	Propensity score matching	Matching + regression	Panel data regression	Matching	Compari using Y Polynor regressi
Liquidity control	no	no	Issuance Volume	Issuance Volume	yes	no	yes	yes	n.a.	yes	Issuan Volum
Maturity control	yes	yes	yes	yes	yes	yes	yes	n.a.	n.a.	yes	yes
Green Premium in Basis Points	-18	7.8	-7	-1	-2	2.06 to 5.90	-17 primary	- 6 with external review.	-63	0	- 2
							- 5 secondary	-15 with CBI Certification			
Publication	*Bank for International Settlement*	*Nature Climate Change*	*National Bureau of Economic Research*	*Journal of Asset Management*	*Journal of Banking and Finance*	*Sustainability*	*Journal of Cleaner Production*	*Accounting and Finance*	*Applied Economics*	*Journal of Accounting and Economics*	

Source: the author

Liaw (2020) reviewed some of the studies included in Table 9 and others and have found mixed results. Such author concludes that several reports showed no evidence of a green bond yield discount at issuance and of green bonds trading at a higher yield in the secondary market. Conversely, there is no guarantee that green bonds have a lower cost. The author stated that the conflicting results are likely explained by differences in sample selections, time periods, methodologies, ratings, currencies, and the properties of the respective issuing entity and its bond.

The data in Table 6, which is related to the performance of green bonds during the COVID-19 pandemic, reveal that the majority (60.7%) of green bonds maintained the same premium status as before COVID-19 in relation to the yield curve formed by the other comparable bonds of the same issuer. Table 7 shows that 40% of the green bonds that had a premium prior to the COVID-19 pandemic lost the premium in the worst moment of the USD corporate bond market selloff in March 2020. Nevertheless, the results presented in Table 7 show that the green premium of these bonds was recovered in Feb. 2021, showing that the loss of green premium was a temporary phenomenon during the pandemic. These results are consistent with the findings of Huynh et al. (2021) related to market volatility transmission being higher overall in the short term but lower in the long term during the economic crisis.

Regarding the types of issuers, as Table 8 shows, it is possible to identify that during the COVID-19 crisis the green bonds issued by corporations were more sensitive to the selloff in bonds, presenting more changes in premium status compared to the period prior to the pandemic.

The results of the present analysis provide nuances to the academic research on the risks of green bonds since the results indicate that green bonds would be harder to sell in times of panic (Atkins, 2015) or that investors are more likely to be long-term holders of green bonds until maturity (Schroders, 2015).

The performance of green bonds during the COVID-19 pandemic, especially those that lost their green premium and recovered it a year later, may be due to the asymmetric behavior of investors, as explained by Tversky and Kahneman (1992). The authors have identified an asymmetric reaction of investors to gains and losses, to events of high and low assigned probabilities, and with different scales of gains or losses.

Choice is a constructive and contingent process. When faced with a complex problem, people employ a variety of heuristic procedures to simplify the representation and the evaluation of prospects, as concluded in Tversky and Kahneman (1992). Furthermore, the evidence indicates that human choices are orderly, although not always rational, in the traditional sense of this word.

Future studies can also consider how human behavior, as explored by Tversky (1992) and Kahneman and Tversky (1979) has impact on the performance of green bonds. Studies by McGraw et al. (2010) and others reveal interesting features of the decision processes involving different probabilities and scales of financial outcomes and asymmetric attitudes related to gains, losses and the unknown. The literature on behavioral finance and behavioral economics may help the understanding of green bonds' performance in times of normality and crisis.

While the market does not incorporate environmental externalities into asset prices and adjust risks/returns, investors can still be encouraged to pay a green premium for green bonds as an asset class for nonpecuniary reasons (Fama and French, 2007).

According to Phan and Huynh (2020), there are feedback effects between green bonds and investor attention. Therefore, policies that keep investors informed about green bond environmental performance can be an incentive to invest in this market over the long run. Additionally, creating universal standards for green bonds certification will allow investors to differentiate green bonds from conventional investments, which can further draw attention and demand.

According to the Climate Bonds Initiative (2020), only 24% of green bonds have CCB (Certified Climate Bonds) certification. Others have non standardized external reviews, and others have no reviews at all. The fact that most green bonds still have no standardized certification results in information asymmetries and uncertainties related to risk assessments, resource allocation and the reliability of the initiatives financed by green bonds.

The Climate Bonds Standard V. 3.0 (2019) requires that post issuance reports contain information on the allocation of resources, the eligibility of projects and assets, and impact reporting. Regarding the latter, no validated methodologies are presented, which again may create uncertainties. A couple of decades ago,the Clean Development Mechanism under the Kyoto Protocol has addressed this issue by publishing validated methodologies with standardized procedures to estimate GHG emissions reductions, monitoring parameters and baselines.

Conversely, the EU Green Bond Standard (2020) requires that green bond issuers publish allocation reports until the full allocation of the bond proceeds and impact reports afterwards, but without setting validation methodologies or metrics for calculations and without requiring verification to be mandatory.

In terms of performance monitoring, reporting and verification (MRV) of environmental impacts, GHG emissions reduction markets (carbon markets), such as the EU ETS or Clean Development Mechanism, are more mature and sophisticated than the green bonds market. They could serve as a reference for MRV and impact reporting systems for green bonds.

Reliable impact reporting is important, and Mihálovits and Tapaszti (2018) address the issue of the default of the environmental obligations of green bond issuers. The authors state that there are, with few exceptions, no clauses that penalize the green bonds' environmental default. They propose to regulate environmental default through mechanisms such as the repurchase of green bonds by the issuer, the loss of tax benefits and the loss of the green bond seal or certification.

An alternative proposed by the present study would be the creation of environmental compensation clauses (or performance bonds) in case of environmental default through the purchase of carbon credits from other projects in an equivalent amount of what would be expected from the projects financed by a defaulting green bond.

Based on the results of the present study, the following section outlines recommendations to several stakeholders interested in increasing the viability and attractiveness of green bonds and developing the market.

5.1. Recommendations to Stakeholders for the Development of the Green Bonds Market

5.1.1. Green Bond Issuers

Karpf and Mandel (2018) evaluated the yields of American municipal green bonds and concluded that the further away the green bond maturity is, the greater the formation of the green premium, with the lower rated green bonds benefiting more after a maturity of longer than 23 yr. Investors perceive green bonds as aligned with sustainable development goals and less risky in the long run.

Therefore, one can recommend that while a standardized MRV system for impact reporting is not widely adopted, green bond issuers should seek to issue long-term bonds.

A transparent and standardized MRV system for impact reporting could contribute to the emergence and maintenance of the green premium for green bonds with shorter maturities. According to Karpf and Mandel (2018), green bonds with maturities between 10 and 23 yrs. would benefit the most.

According to Zerbib (2019), issuers with a low rating or in the financial sector would benefit the most from the expansion of the investor base of green bonds as they are the ones that obtained the highest premium.

The financial sector could take advantage of its higher premium and centralize the raising of resources through green bonds that would later be allocated to finance other sectors where the green premium is lower.

External audits would also be greatly beneficial to issuers by adding transparency and credibility to the reports. Studies by Bachelet et al. (2019) concluded that the green premium is higher for green bonds that have gone through the external verification process.

Hyun et al. (2019) identified a premium of 6 BPs and 15 BPs for green bonds with external verification and CBI certification, respectively.

Within the scope of the management structure of green bonds issuers, new performance indicators related to the creation of shared values could be developed and adopted, including environmental, social and governance goals (ESGs), in addition to the existing financial indicators.

To align decision making with ESG indicators, managers' variable remuneration could be linked to such indicators, which would indirectly contribute to the performance of projects financed by green bonds.

5.1.2. Governments and Central Banks

In addition to the tax benefits or fast-track issuance process of green bonds, governments could also do the following:

• Reduce the barriers to publishing post issue reports by sponsoring them.

• Offer the fastest depreciation of assets financed by green bonds.

• Give preference to the purchase of green bonds by the Treasury.

Monnin (2018) suggests the following measures for central banks:

• Expand the knowledge base on systemic risks related to climate.

• Raise capital requirements for loans to carbon-intensive sectors.

5.1.3. Multilateral Financial Institutions

Karpf and Mandel (2018) and Zerbib (2019) concluded that the credit risk quality of green bond issuers has a strong influence on the appearance of the green premium.

An important part of the financial resources needed to mitigate and adapt to climate change come from less developed countries and small projects, which generally have worse credit quality.

A solution proposed by Karpf and Mandel (2018) would be the distribution of risks (pooling) in a portfolio of projects, which could be financed through the issuance of green bonds by multilateral institutions.

Multilateral financial institutions such as the World Bank can play an important role as catalysts in the expansion and development of the green bond market, as well as in the definition and implementation of public policies.

Credit guarantees could be offered to noninvestment grade green bond issuers, and funds dedicated to the acquisition of green bonds could be created, in addition to a scheme that would sponsor the additional costs of external verification for smaller issuers.

Finally, the results of this research on the performance of green bonds during the COVID-19 pandemic, as shown in Table 8, revealed that green bonds issued by government agencies are the most resilient to selloffs in the bonds market and therefore will not disappoint investors who paid a premium upon issuance.

5.1.4. Standardization Organizations and Programs

The International Organization for Standardization (ISO) is developing an international standard for green bonds within the scope of ISO 14030. In the European Union, the European Standard for Green Bonds, which includes a European taxonomy, was developed. A third initiative by the Climate Bonds Standard also contributes to the standardization and reliability of green bonds.

For the reasons discussed above, it is important that standards be developed for post issuance impact reporting (monitoring, reporting, and verification) and that rules are created for environmental noncompliance. The emissions markets could be a benchmark for this.

5.1.5. NGOs

NGOs could motivate altruistic behavior or create social pressure (Brodback et al., 2018; Dellavigna et al., 2012), which can generate increased demand for green bonds (Hong and Kacperczyk, 2009; Riedl and Smeets, 2017).

NGOs could also play the role of gathering inputs from the stakeholders of projects financed by green bonds and monitoring their environmental performance while standardized protocols are not available.

5.1.6. Academia

Research institutions could also contribute to the development of methodologies for impact reporting, frameworks, proxies, and protocols for monitoring the environmental performance of green bonds.

Obviously, independent academic research on the performance of green bonds is also positive in the sense that it can provide investors with an impartial view and insights to mitigate the risks of green washing.

5.1.7 Regulatory agencies

Regulatory agencies can create regulatory frameworks that unlock the potential of the green bond market. For example, the European Commission has developed the EU Green Bonds Standard and a taxonomy for sustainable finance, in addition to green labels for financial products.

All the agents mentioned above would also be advised to promote the nonpecuniary attributes of green bonds in a broader and more intense way to reach investors who may appreciate and be loyal to this type of asset, making the demand and the premium increase (Fama and French, 2007) and remain stable.

5.1.8 Banks and other Financial Institutions

Other green bond-related assets could be developed to increase the products offered to institutions and especially individual investors who are environmentally sensitive but do not direct access to platforms to trade bonds. According to Liaw, K (2020), green bond mutual

funds and green bond ETFs are still small. Expanding the menu of green bond mutual funds and ETFs is fundamental to a wider investor base. Liquidity will then be enhanced.

6. Conclusions

The results found in the present study show that at the end of 2019, 25.7% of the Green Bonds sample had been traded with a small premium. The average premium was -2 basis points in YTM in relation to the theoretical yield indicated by the polynomial yield curve formed by other bonds of each issuer. The small premium found in this research is consistent with some other studies in the academic literature, which have used different methodologies. It confirms that the methodology used in the present study is suitable for this type of analysis and can be adopted for future studies.

In early 2020, before the outbreak of the COVID-19 crisis, the green premium of the green bond sample converged to zero (Table 5). This result is consistent with the results obtained by Lacker and Watts (2020) who also identified no premium in the period immediately before the outbreak of the COVID-19 crisis. Other three studies presented in Table 9 have assessed the green premium upon the issuance of green bonds prior to 2020, and all of them supported a green premium.

The present study indicates that even though there may be a green premium upon issuance, it tends to disappear over time with negotiations in the secondary market. Kanamura (2020) reached the same conclusion implying that green bond investment performance is superior to that of conventional bonds, but the superiority decays over time.

The small green premium encountered in the secondary market may discourage some investors who have no specific mandate to invest in green bonds from accepting relatively lower yields when green bonds are launched. It would be impracticable to justify them from a risk/return point of view.

Taken together, the results of the present study and those of the other articles included in Table 9 show that society, through its investments, is still in the early stages of recognizing the positive attributes of green bonds and accepting marginally lower returns (yields).

During the COVID-19 pandemic, a discount of 0,07 on average in the YTM of green bonds (Table 5) appeared during the selloff of corporate bonds in March 2020. This reveals that green bonds cannot yet be considered defensive assets in moments of panic in financial markets, even though they have presented some resilience by recovering prior YTMs one year later in Feb. 2021.

The provision of periodic, certified and standardized reporting of the environmental performance of the activities financed by green bonds could differentiate them in the secondary bond market, attract new investors and ultimately turn green bonds into a less volatile and more defensive asset class. Standardization of reports like those adopted in carbon emissions markets such as the Clean Development Mechanism of the Kyoto Protocol could avoid subjective interpretations and reduce information asymmetries.

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