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Facts and Fantasies about the Green Bond Premium

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Abstract

The purpose of this study is to determine if investors are rewarded with lower yields when they invest in Green Bonds in the secondary market. To make the assessment of whether this premium exists we consider green bonds belonging to an established green bond index, we make use of two methodologies: an intra-curve method at the security level and a matching method at the asset class level. We show that on average there is a statistically significant overall negative premium on green bonds compared to their associated regular bonds, and that the premium is more pronounced in certain fixed income sub-segments. We also run a panel regression with control variates to investigate the determinants of the premium. After neutralizing the liquidity factor in the search of the premium, we find an even lower premium.

Keywords: Green bond, risk premium, credit rating, liquidity, environmental, ESG.

JEL classification: C23, G12, Q56

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1 Introduction

Green Bonds (GB) are fixed income securities whose proceeds are earmarked exclusively for new and existing projects with environmental benefits focused on renewables, energy efficiency, water, clean transport, and climate change mitigation and adaptation. They are part of the broader universe of socially responsible investments, which include bonds and equities from issuers identified by environmental, social and governance (ESG) standards.

According to OECD (2016), a green bond is differentiated from a regular bond by commitment to use the funds raised to finance or refinance *green* projects, assets, or business activities. As it is an emerging financial instrument, there is not yet a commonly accepted definition of a green bond. Green bond investors face the issue of distinguishing a genuine commitment on the part of the issuer to use the proceeds in a *greenly* way from a simple *greenwashing*[1]. That said, green bond issuance, having started in June 2007 with a EUR 600 million *Climate Awareness Bond* issued by the European Investment Bank, has seen explosive growth in the recent years to more than USD 950 billion in outstanding issues as of September 2020[2], thanks to the progress made on standards and especially to the introduction of the Green Bond Principles (GBP) in 2014.

The GBP are the most widely accepted standards[3] and represent voluntary procedural guidelines developed by key market participants and put forward by the Zurich-based International Capital Market Association (ICMA). They consist of four core components that recommend disclosure and transparency and promote integrity in the development of the green bond market. These components are Use of proceeds, Management of proceeds, Process for project evaluation and selection and Reporting. They define the subjects of the projects financed by the proceeds and the management of these proceeds, which should be tracked in an appropriate manner through a transparent process. For instance, Green bond proceeds should be credited to a sub-account that is financially separate from other business accounts, so all transactions can be easily identified. The GBP also provide guidance on the provision of information by green bond issuers regarding the process for project evaluation and selection. Reporting, the fourth component of the GBP, specifies the ongoing information that the issuer should provide after the issuance of a green bond regarding the status and the use of the proceeds. Issuers of green bonds are also encouraged to obtain an external review such as a second opinion, a rating or a certification rating[4] (Ehlers and Packer, 2017) to provide an objective assessment of the project's compliance with the GBP, thereby reducing the asymmetry of information between borrowers and investors. For instance, certifications under the Climate Bond Standard (Almeida *et al.*, 2019) administered by the non-profit organization Climate Bonds Initiative (CBI), certify the full alignment with the GBP and the goals of the Paris Climate Agreement to limit global warming to under 2 degrees.

[1] Flammer *et al.* (2018) shows how green bonds may allow a firm to portray an environmentally responsible public image without actually doing so. In a similar way, Schmuck *et al.* (2018) noticed how misleading advertising about the environmental features of product affects how consumers perceive ads and brands.

[2] Environmental Finance, `https://www.bonddata.org/`.

[3] Along with the Climate Bond Standard of the Climate Bond Initiative (CBI). However, China and the European Union have taken an interest in developing their own standards as well. China, has drawn up its Green Bond Endorsed Project Catalogue, and the European Union is in the process of developing the EU Green Bond Standards(EU Technical Expert Group on Sustainable Finance, 2019)

[4] The external reviewers guarantee the sustainable use of proceeds at issuance, however only certification providers monitor practices post-issuance.

From the issuer's point of view, it seems clear that issuing a green bond is more expensive than a regular bond, given the costs of possible external review, regular reporting and holding separate accounts for the proceeds. Hachenberg and Schiereck (2018) report that the costs entailed are estimated at between 0.3 and 0.6 basis points for a USD 500 million issue. Even through CBI, a certification costs 0.1 bps[5]. From the investor's perspective, the question that arises is whether the green label influences the price that investors are willing to pay for a bond, that is, whether investors are willing to accept a lower yield spread for a green bond relative to a conventional bond with the same characteristics.

Throughout the paper, we will use the term *premium*, to refer to the excess yield on the bond due to its green characteristic[6]. At first sight, there is no fundamental rationale for the green label to influence the yield of a Green Bond. Green bonds rank pari-passu with bonds with the same rank and issuer. The Green Bonds holder does not own any additional right on the underlying projects and is subject to the same market dynamics. A green premium for the issuer is therefore somewhat of a market anomaly[7].

In this paper, we try to answer the question on the secondary market for bonds belonging to an established green bond index using two different methodologies: a top-down approach using the index and a bottom-up method focusing on the individual green bonds in the index. After a review of related literature in Section 2, Section 3 describes the data we use in the pricing analysis. Section 4 and 5 introduce the methodologies cited above while Section 6 discusses the results and offers some conclusions and implications.

2 Literature review

Academics have studied the prices of GBs from different angles and periods, either at issuance or in the secondary market, relying on a set of bonds or on special types of bonds (for instance EUR denominated or US municipals[8]). Regressions of the yields (or the yield spreads) or analysis of the yield curves are the main methods used and are often performed with the support of matching processes. The matching, i.e. pairing the green bond with its regular equivalent that has similar bond price determinants, allows the green label effect to be isolated as the differences in the pricing of the two bonds can stem only (presumably) from this different determinant. The findings show contrasting evidence and do not offer a definitive answer. Some studies report GBs trading at a negative premium (i.e. at lower yields) than regular bonds. Others document no significant difference in yields or even higher yields for GBs. Table 1 displays 18 recent studies. For each of them, we report the universe of green bonds, the type of market, the period of observations, the final number of green bonds after a potential data cleaning or matching, the method used and the findings. Mixed results are presumably attributable to differences in time periods, samples, and methodologies.

[5] https://www.climatebonds.net/certification/get-certified.

[6] In the case of a negative premium, this implies giving up yield.

[7] For ease of reading, we will use interchangeably the terms green bond premium and green premium.

[8] US Municipal bonds are issued in series at the same time by the same issuer, with the same official statement and use of proceeds covering each series of bonds, this aspect of the muni market give the unique opportunity to compare the green bonds with their direct vanilla equivalents.

Table 1: Overview of GB pricing in the literature

Study	Market	#GBs	Universe	Period	Method	Premium estimate
Bachelet *et al.* (2019)	Secondary	89	Global	2013 - 2017	OLS model	2.1 to 5.9 bps
Baker *et al.* (2018)	Secondary	2 083 19	US Municipals US Corporates	2010 - 2016 2014 - 2016	OLS model	-7.6 to -5.5 bps
Bour (2019)	Secondary	95	Global	2014 - 2018	Fixed effects model	-23.2 bps
Ehlers and Packer (2017)	Primary	21	EUR & USD	2014 - 2017	Yield comparaison	-18 bps
Fatica *et al.* (2019)	Primary	1 397	Global	2007 - 2018	OLS model	
Gianfrate and Peri (2019)	Primary Secondary	121 70 – 118	EUR	2013 - 2017 3 dates in 2017	Propensity score matching	-18 bps -11 to -5 bps
Hachenberg and Schiereck (2018)	Secondary	63	Global	August 2016	Panel data regression	Not significant
Hyun *et al.* (2020)	Secondary	60	Global	2010 - 2017	Fixed effects GLS model	Not significant
Kapraun and Scheins (2019)	Primary Secondary	1 513 769	Global	2009 - 2018	Fixed effects model	-18 bps +10 bps
Karpf and Mandel (2018)	Secondary	1 880	US Municipals	2010 - 2016	Oaxaca-Blinder decomposition	+7.8 bps
Larcker and Watts (2019)	Secondary	640	US Municipals	2013 - 2018	Matching & Yield comparaison	Not significant
Lau *et al.* (2020)	Secondary	267	Global	2013 - 2017	Two-way Fixed effects model	-1.2 bps
Nanayakkara and Colombage (2019)	Secondary	43	Global	2016 - 2017	Panel data with hybrid model	-62.7 bps
Ostlund (2015)	Secondary	28	Global	2011 - 2015	Yield comparaison	Not significant
Partridge and Medda (2018)	Primary Secondary	521	US Municipals	2013 - 2018	Yield curve analysis	-4 bps Small but below 0
Preclaw and Bakshi (2015)	Secondary	Index	Global	2014 - 2015	OLS model	-16.7 bps
Schmitt (2017)	Secondary	160	Global	2015 - 2017	Fixed effects model	-3.2 bps
Zerbib (2019)	Secondary	110	Global	2013 - 2017	Fixed effects model	-1.8 bps

Source: this information is retrieved from the discussed articles.

Only two of the above studies (Ehlers and Packer, 2017; Fatica *et al.*, 2019) are fully dedicated to the primary market. Mainly, due to the fact that primary market yields express a market price at time t, which can be influenced by the imbalance of demand and supply, most studies focus on the secondary markets that signal the stability of premia and also indicate windows of opportunity to issue new bonds. Kapraun and Scheins (2019) examine both primary and secondary market effects and find that green bonds listed on the London and Luxembourg secondary markets with a dedicated green bond segment are traded on average 7 bps lower[9]. This highlights that issuers benefit from the reduction of information asymmetry on the secondary market, which will undeniably influence primary market yields.

As can be noted, most cited studies find negative premia whose estimates are close[10] to zero. Lau *et al.* (2020) find that a relatively large premium tends to suffer from a sample being too small or biased, a yield comparison without a sound matching process or a lack of controls for bond features. For instance, as mentioned by Baker *et al.* (2018), the positive yield spread of 7.8 bps by Karpf and Mandel (2018) is a result of neglecting the effect of taxation in the US municipal securities market. According to Zerbib (2019), the low premia "*emphasize the low impact of investors' pro-environmental preferences on bond prices, which does not represent, at this stage, a disincentive for investors to support the expansion of the green bond market.*"

The studies, using matching procedures, control for bond risk factors such as default and curve risks but not all of them control for the liquidity risk. This risk arises because the green bonds market is smaller and less liquid than the conventional bond market. For instance, Zerbib (2019), Bour (2019) and Hyun *et al.* (2020) define the premium as the residual part of the difference in spreads after controlling for the difference in liquidity proxy.

Five studies point out the importance of external reviews in the pricing of green bonds. Kapraun and Scheins (2019) (resp. Fatica *et al.* (2019)) find investors are more likely to pay a premium (i.e. accept lower yields) for corporate (resp. non-financial) green bonds when they are certified as such by a third party. Kapraun and Scheins (2019) even mention the term of credibility in the green label. Fatica *et al.* (2019) show that among the financials, only institutions that have declared a clear commitment to environmental principles (i.e. those subscribing to the United Nations Environment Programme Financial Initiative) issued green bonds at a premium. Although Larcker and Watts (2019) do not document a significant overall premium, they find that green bonds carrying CBI Certifications exhibit lower premia. Baker *et al.* (2018) assess that the negative premium doubles or even triples for GBs that are externally certified and publicly registered with the CBI. Hyun *et al.* (2020) estimate that GBs enjoy 7 bps discount if they have an external reviewer and 9 bps if they obtain a CBI certification.

Along with credibility, reputation is relevant. Kapraun and Scheins (2019) find that premia are observed in both primary and secondary markets only when bonds are issued by governments or supranational entities, denominated in EUR or USD, or corporate bonds with very large issue sizes. These bonds and their issuers can be considered as more credible in terms of a better potential implementation or a greater impact of the financed green project. Fatica *et al.* (2019) show that green bonds issued by repeat issuers benefit from an additional negative premium compared to

[9] In the full sample, they report mixed results: a negative premium in the primary market and a positive premium in the secondary market.

[10] If we except Nanayakkara and Colombage (2019).

those issued by one-time issuers in the green market.

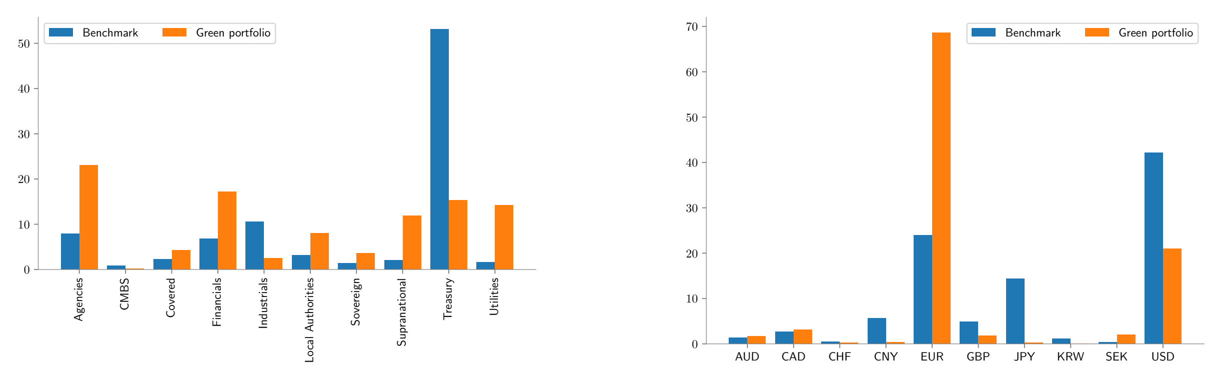
3 Data

We define as green bonds all bonds that are both self-labelled as green bonds or sustainability bonds by their issuer and are part of the Bloomberg Barclays MSCI Global Green Bond Index, hereafter denoted as the "Green Index". The independent screening conducted by MSCI guarantees that all bonds in the studied universe comply with the basic requirements of most ESG investors on the definition of green bonds such as

- the proceeds being *exclusively and formally applied to projects or activities that promote climate or other environmental sustainability purposes*[11];
- the bonds complying with the four dimensions set by the Green Bond Principles;
- at least 90% of the use of proceeds falling within at least one of seven eligible environmental categories defined by MSCI ESG Research (alternative energy, energy efficiency, pollution prevention and control, sustainable water, green building, climate adaption, and other)[12], with operational or research & development expenses excluded.

In addition to the robustness of the green screening, the mentioned index also ensures that we are focusing on Green Bonds of a minimum size and other characteristics that guarantee that they are tradable and as such quoted with consistent market prices. The bonds enter the index after issuance and not before month-end, which ensures that when included in our studied universe, the bonds have been trading for some time in the secondary market. All the post issuance effects on prices (like issuance premium/concession, allocation adjustments) have then been mostly removed.

Figure 1: Breakdowns per sector and currency



(a) Sectors (b) Currencies

The "Green Index" consists of 532 green bonds as of 25 September 2020. These green bonds are or have been in the Bloomberg Barclays Global Aggregate Bond Index[13] (hereafter referred to

[11] Bloomberg Barclays MSCI Global Green Bond Index factsheet.

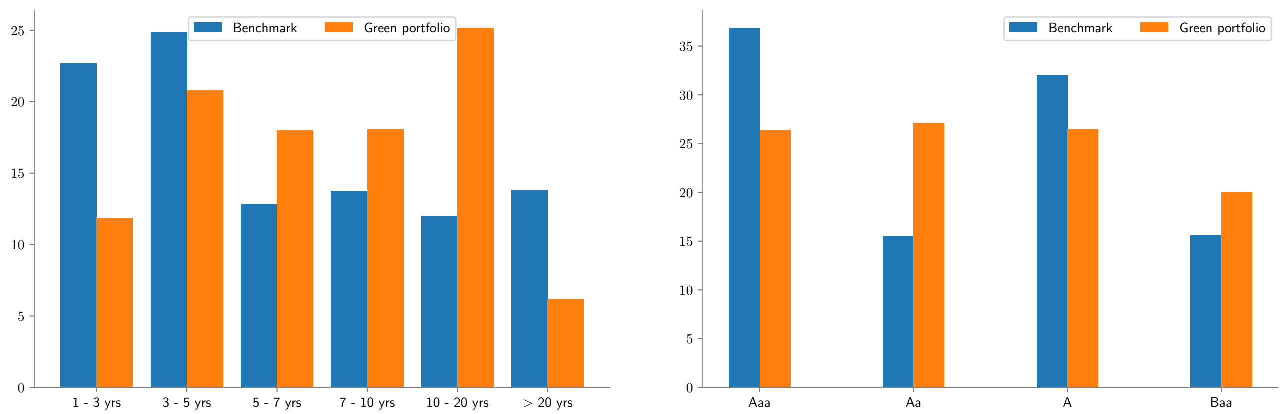
[12] ibid.

[13] The Bloomberg Barclays Global Aggregate Bond Index is a flagship measure of global investment grade debt from twenty-four local currency markets.

as the "benchmark") before falling below their minimum maturity requirement of one year[14]. In our study, we discard bonds with less than 1-year to maturity from the green index to form our rebased portfolio of green bonds (referred to as the "green portfolio").

Figure 1 illustrates the breakdowns per sector and currency of both the "benchmark" and "green portfolio" as of 25 September 2020. We note in Figure 1a that the "green portfolio" tends to have disproportionately more supranationals, agencies, financials, and utilities. We have reported in Figure 1b the weight of currencies with at least 0.50% presence in the "benchmark" or "green portfolio". We note that the "green portfolio" is mainly EUR-denominated (more than 65% compared to 20% in "benchmark"). Around 20% is USD-denominated (compared to 40% in the "benchmark") and the remainder is denominated in 11 other currencies.

Figure 2: Breakdowns per time to maturity and rating



(a) Time to maturity

(b) Credit rating

In Figure 2, we report the breakdowns per time to maturity and credit rating. We note that the green issuance is relatively higher between 5 years and 20 years compared to "benchmark" and especially on the 10-20 years bucket. The ratings are balanced between the first three categories. Compared to the "benchmark", the "green portfolio" is overweighted in Aa and Baa rated bonds.

4 First method: Top-down approach

We first consider a method which should be of particular interest to a macro focused investor who is concerned with the cost or benefit of green bonds in the context of a pure top down fixed income allocation. We have noted that there are significant compositional differences between conventional indices and green indices hence we cannot simply make "off-the-shelf" comparisons. We therefore adopt the same approach as Fender *et al.* (2019) to compare two matched indices. We dissect the portfolio of GBs into each currency c, sector s, quality q, and maturity m. We build then a synthetic conventional portfolio from the "benchmark" that matches the same dissection by applying the weights of the green index.

[14] The "Green Index" does not have a 1-year minimum time to maturity and will hold bonds until final maturity. The inclusion of green bonds to maturity is designed to accommodate this market practice by not forcing unwanted turnover.

Here, we define the *premium* as the excess weighted average OAS[15] on our universe of green bonds versus the "benchmark" which has been re-weighted to match the characteristics of currency, sector, quality and maturity. We make use of the Barclays Level 2 sector field where 12 categories are available[16]. For quality, we classify bonds according to their category of ratings AAA, AA, A and BBB. Regarding the maturity, bonds are split into 6 buckets[17].

The *premium* is the weighted excess spread. Indeed, we write

$$\begin{aligned} Premium &= OAS_G - OAS_B \\ &= \sum_{i=1}^{N} \omega_{G_i} OAS_{G_i} - \sum_{i=1}^{N} \omega_{G_i} OAS_{B_i} \\ &= \sum_{i=1}^{N} \omega_{G_i} \left(OAS_{G_i} - OAS_{B_i} \right) \end{aligned}$$

where N is the number of quadruplets Q_i of (Currency, Sector, Quality, Maturity), ω_{G_i} is the weight of Q_i in the "green portfolio", OAS_{G_i} (respectively OAS_{B_i}) is the spread over govies of the Q_i in the "green portfolio" (respectively the "benchmark").

4.1 Evolution of the green premia and returns

In what follows, we use the "global bond index" to refer to the synthetic index built from the "benchmark" where the weights are matched with those of the "green portfolio" according to the available quadruplets of (currency, sector, quality, maturity).

Table 2: OAS and Premium - Statistics

Metric	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
Green portfolio OAS	73.41	14.77	55.13	71.13	132.88	1.75	4.74	4.97	***
Global bond index OAS	78.07	15.57	58.10	75.96	143.36	1.97	5.92	5.01	***
Premium	-4.66	1.37	-10.47	-4.40	-2.54	-2.03	6.49	-3.40	***

Note: * $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$

In Table 2, we report different statistics of the OAS of the "global bond index" and "green portfolio" and the premium over the last 4 years[18]. Premium is negative, has a mean of -4.66 and has evolved between -10.47 and -2.54. The metrics of skewness and kurtosis indicate the presence of outliers to the left of the distribution.

Figure 3a displays the change in both OAS over the studied period. Both OAS widened in 2018 and 2020 and peaked during the recent turmoil. On the other hand, Figure 3b shows that the premium reached its minimum during the recent Covid-19 crisis before reverting to its mean.

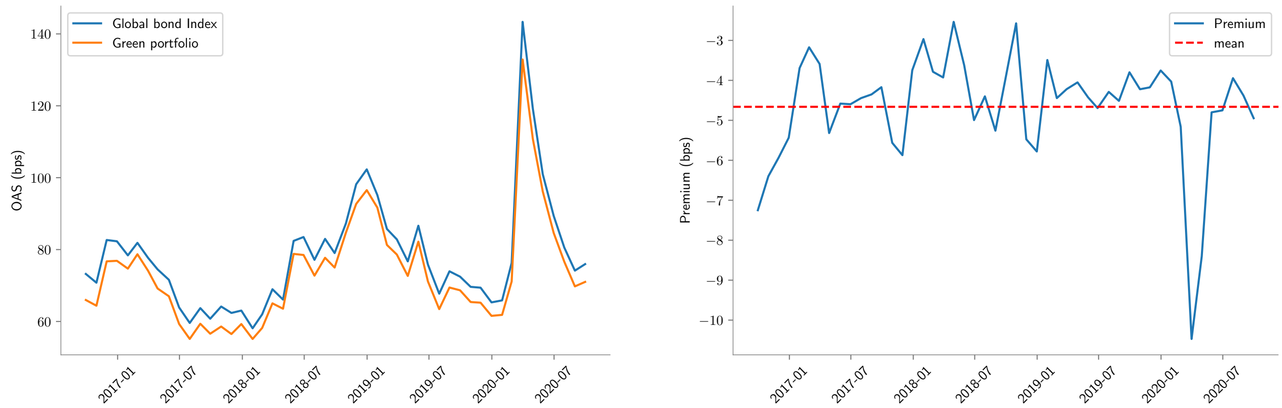
[15] OAS, the acronym for Option Adjusted Spread, is the constant spread above the treasury curve that compensates for credit and liquidity risks but excludes the premium for the option risk.

[16] They are Financials, Corporates, Sovereigns, Utilities, Local Authorities, Agencies, Government, ABS, CMBS, Supranationals, MBS and Covered.

[17] They are $1-3$ yrs, $3-5$ yrs, $5-7$ yrs, $7-10$ yrs, $10-20$ yrs and > 20yrs.

[18] From September 2016 to September 2020

Figure 3: OAS and Premium



(a) OAS

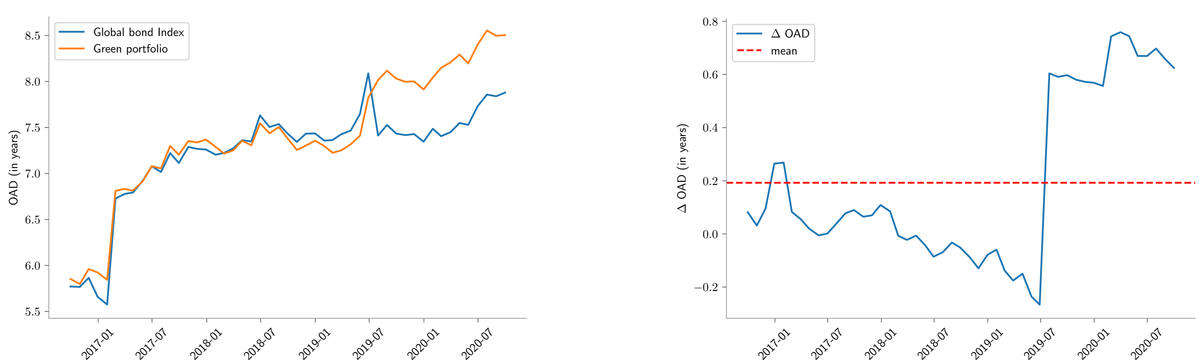
(b) Premium

Table 3: Durations - Statistics

Metric	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
Green portfolio OAD	7.41	0.70	5.80	7.35	8.56	-0.62	0.35	10.55	***
Global bond index OAD	7.21	0.57	5.57	7.36	8.09	-1.72	2.64	12.60	***
Δ OAD	0.19	0.32	-0.27	0.07	0.76	0.61	-1.21	0.60	

We make use of the OAD[19] to calculate the duration of the bonds in the "global bond index" and the "green portfolio" and we measure the duration of both portfolios as the weighted average OAD. Table 3 shows that on average the duration of the "green portfolio" is +0.19 years longer.

Figure 4: Global OAD and Δ OAD



(a) OAD

(b) Δ OAD

Table 4 reports the metrics of excess returns[20] of both portfolios. Although, lagging in term of returns, the "green portfolio" exhibits the same Sharpe ratio and thus a relative lower volatility.

[19]Option Adjusted Duration or effective duration refines the duration of bonds that contain call features by incorporating the probability of issuers exercising their call options.

[20]Excess return is the return in excess of the total return of a risk-matched basket of governments or interest rate

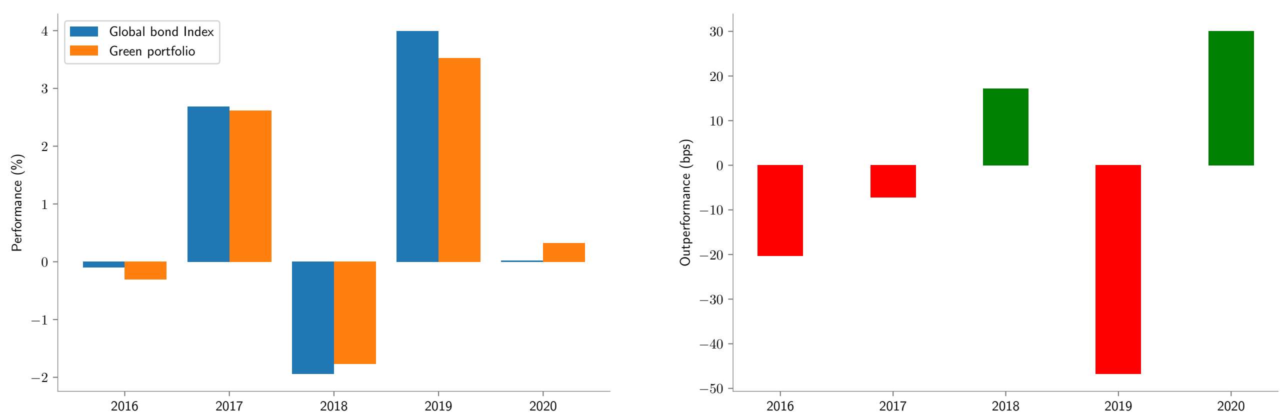
Negative skewness and high kurtosis indicate the presence of outliers on the leftmost side of the distributions of returns. We note that these metrics are relatively low for the "green portfolio".

Table 4: Excess returns - Statistics

Portfolio	Excess return (%)	Std dev.(%)	Sharpe	Skewness	Kurtosis
Green portfolio	1.08	2.59	0.42	-3.01	15.53
Global bond index	1.15	2.70	0.42	-3.13	16.39

Figure 5a shows the yearly excess returns of the "global bond index" and the "green portfolio" and Figure 5b reports the differences in yearly returns between these two portfolios. The "green portfolio" outperformed in 2018 and 2020, two years of elevated risk aversion and extreme uncertainty. While in 2020, the Covid-19 outbreak caused global economic disruption and the largest global recession since the Great Depression, investors saw a significant market sell-off in 2018 when concerns about the slowdown in the global economy, the ramping up of trade tensions between the US and China, and the unexpected tightening of the FED monetary policy caused major market jitters. The first crisis manifested most notably during the last thirteen weeks of 2018 whereas the second crisis manifested strongly between February and April 2020. We showed above the OAS spikes during these two periods.

Figure 5: Outperformances



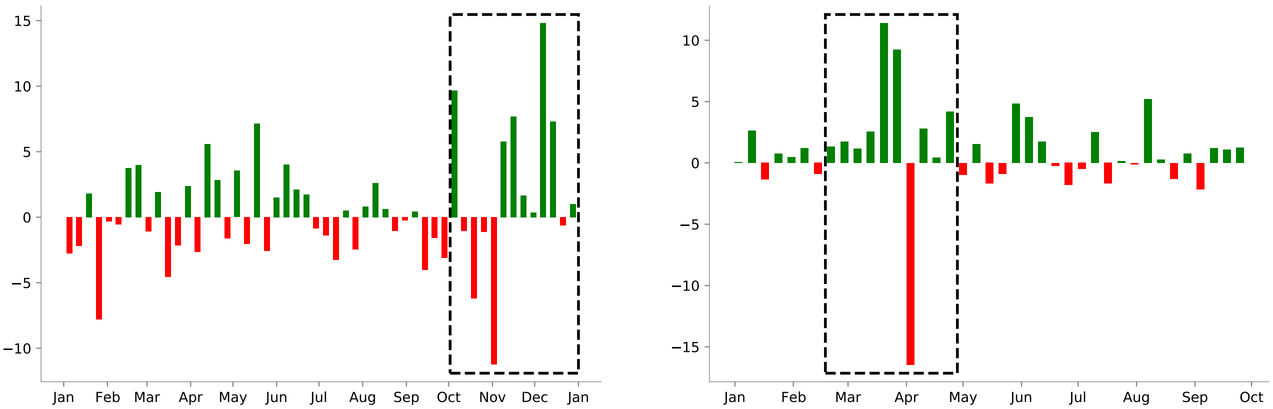
(a) Yearly returns

(b) Outperformance

We report in Figure 6 the weekly outperformances of the "green portfolio" and emphasize the crisis periods using dashed boxes. We note (Figure 6a) that in 8 weeks out of 13, the green portfolio has outperformed by 6 bps on average peaking at 14 bps in the midst of the 2018 crisis. On the other hand, Figure 6b shows that during the first six weeks of the Covid-19 crisis that began in mid-February, the green portfolio has outperformed 6 weeks out of 6 by 4.6 bps on average peaking again at the height of the crisis.

swaps, thus neutralizing the interest rate and yield curve risk and isolating the portion of performance attributed solely to credit and optionality risks.

Figure 6: Weekly Outperformances in bps



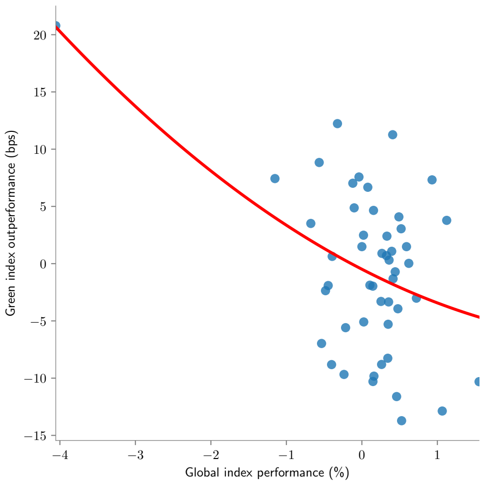
(a) 2018 returns

(b) 2020 returns

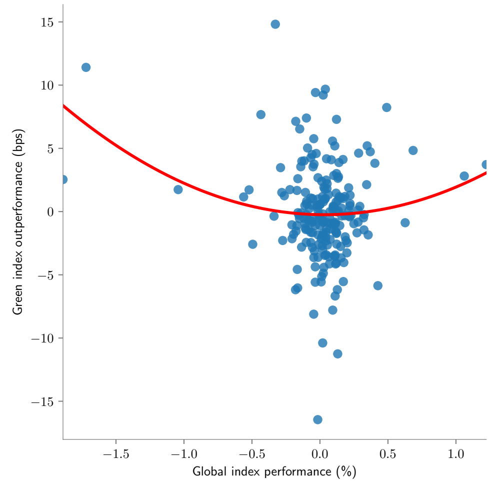
The findings on the behavior of the "green portfolio" during the 2018 and 2020 crises are strengthened by the payoff charts displayed in Figure 7. Here, the outperformance[21] of the "green portfolio" is plotted against the "global bond index" performance where one point corresponds to one month of data (Figure 7a) or one week of data (Figure 7b). To illustrate the payoff, a local regression line is added. The put profile of these payoffs, reinforces the belief that the green portfolio has a very interesting contrarian feature in market downturns. This result is consistent with the findings of Silva and Cortez (2016) and Nofsinger and Varma (2014). Silva and Cortez (2016), who evaluate the performance of green mutual funds invested globally, find that the green funds performed worse than the benchmark. However, their performance increased in crisis periods compared to non-crisis periods. Nofsinger and Varma (2014) report that the outperformance of socially responsible funds during periods of market crises compared to matched conventional mutual funds comes at the cost of underperforming during non-crisis periods. The nature of green bonds issuers and investors may be put forward to explain the resilience during crises. Issuers of green bonds have historically been large, such as development banks, with established governance structures and thus better armed to cope with crises. Secondly, green bond investors include a large share of buy-and-hold investors, such as pension funds and insurance companies (Cochu *et al.*, 2016), which are unlikely to move from green investments in a crisis.

[21] We show in Appendix A.5 that the outperformance is driven by the difference in spreads' variations and is negatively correlated to the variation of premium.

Figure 7: Payoffs



(a) Monthly returns



(b) Weekly returns

4.2 Breakdown of the Green premium

In what follows, we report the breakdown of green premia per sector, per currency, per credit rating and per time to maturity bucket. First, we define the broken-down premium as

$$Premium\left(c,s,q,m\right)=\frac{\sum\limits_{i\in Q_B}\omega_{G_i}\left(OAS_{G_i}-OAS_{B_i}\right)}{\sum\limits_{i\in Q_B}\omega_{G_i}}$$

where $Q_B = \{(currency_j, sector_j, quality_j, maturity_j) \in Q : currency_j = c \wedge sector_j = s \wedge quality_j = q \wedge maturity_j = m\}$[22]

4.2.1 Currency

Table 5: Breakdown per currency

Currency	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All currencies	-7.30	2.39	-13.16	-7.82	-3.41	-0.45	-0.28	-3.06	***
EUR	-7.30	2.39	-13.16	-7.82	-3.41	-0.45	-0.28	-3.06	***
USD	-0.98	5.26	-21.33	-0.93	10.82	-0.95	4.09	-0.19	
GBP	-9.28	9.94	-40.52	-6.49	2.55	-1.09	0.81	-0.93	
CAD	0.05	6.34	-12.00	0.00	13.41	0.16	-0.63	0.01	
AUD	-1.07	2.14	-5.99	-0.69	3.06	-0.43	-0.50	-0.50	

The Euro, which is the main currency of the "green portfolio", has a negative premium with

[22]Obviously, if one characteristic is omitted, its condition is omitted too.

an average of -7.30 and standard deviation of 2.39. Table 5 shows that this premium is only significant compared to the premia of other currencies including the US Dollar.

Figure 8: EUR and USD premia (in bps) – 2016 - 2020

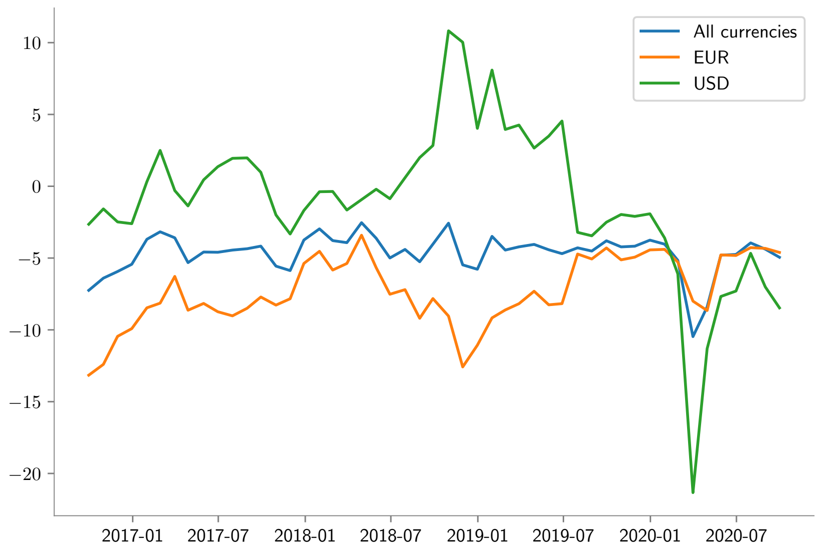


Figure 8 shows the trend of EUR and USD premia since September 2016. The EUR premium fluctuated in a negative range between -13 bps and -3 bps. The impact of the 2018 crisis is more striking than the impact of the recent crisis. The USD premium, which is twice as volatile as the EUR premium, had been oscillating around 0 bps until September 2018, it then rose to 10 bps during the 2018 crisis and has decreased since, slipping down to -21 bps during the recent crisis before bouncing back.

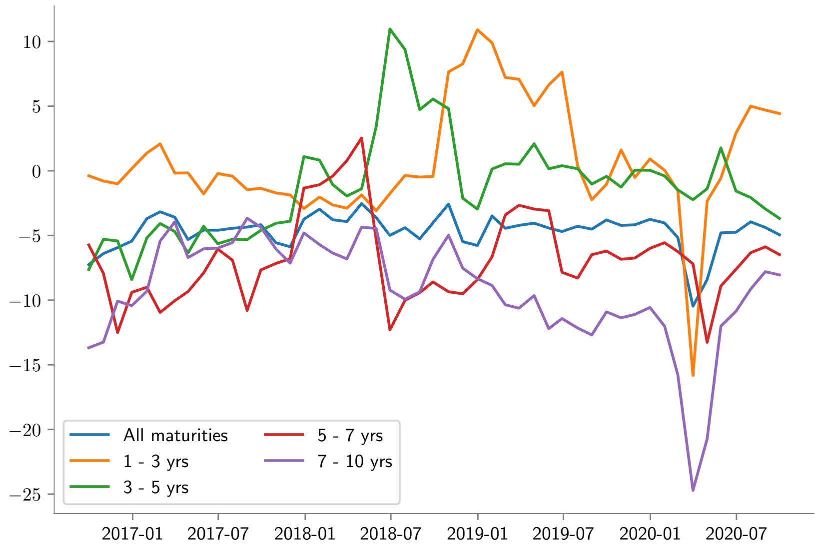
4.2.2 Time to maturity

If we look at the average monthly premium broken down per time to maturity displayed in Table 6, we see that it is only the maturities between 5 and 10 years that have a significant negative premium. We note also that when the time to maturity is below 10 years, the lower the maturity bucket, the higher the premium. Figure 9 confirms this last finding where we see that most of the time, premia of lower maturity buckets trend above those of higher maturity buckets.

Table 6: Breakdown per time to maturity

Maturity	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All maturities	-4.66	1.37	-10.47	-4.40	-2.54	-2.03	6.49	-3.40	***
1 - 3 yrs	0.82	4.45	-15.83	-0.38	10.90	-0.31	3.31	0.18	
3 - 5 yrs	-1.26	3.93	-8.41	-1.40	10.96	0.94	1.53	-0.32	
5 - 7 yrs	-6.84	3.32	-13.26	-6.91	2.53	0.72	0.77	-2.06	**
7 - 10 yrs	-9.25	4.08	-24.72	-9.22	-3.67	-1.49	3.88	-2.27	**
10 - 20 yrs	-5.45	7.78	-21.19	-3.42	18.27	0.44	0.92	-0.70	
Beyond 20 yrs	-5.41	6.28	-20.57	-5.40	16.63	0.91	2.76	-0.86	

Figure 9: Maturities' premia in bps - 2016 – 2020



4.2.3 Sector

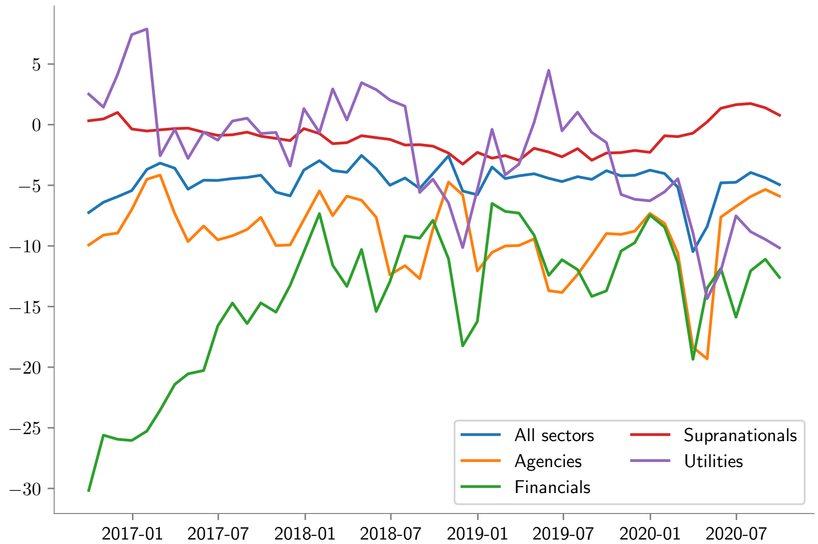
Table 7 reports the average monthly premium per sector on the entire period of observation. All sectors except industrials and local authorities have negative premia on average, however only financials and agencies exhibit significant negative premia with more marked negative premia for the former.

Table 7: Breakdown per sector

Sector	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All sectors	-4.66	1.37	-10.47	-4.40	-2.54	-2.03	6.49	-3.40	***
ABS	-4.78	3.44	-10.45	-4.67	5.00	1.10	1.90	-1.39	
Agencies	-9.08	3.11	-19.31	-8.94	-4.16	-1.19	2.40	-2.92	***
CMBS	-19.83	13.65	-61.91	-13.89	-7.44	-1.95	3.39	-1.45	
Covered	-5.27	4.95	-29.99	-4.29	-0.56	-2.87	12.23	-1.07	
Financial-Institutions	-14.30	5.76	-30.16	-12.95	-6.50	-0.98	0.34	-2.48	**
Industrials	28.09	23.52	-30.81	21.93	86.06	0.66	0.78	1.19	
Local-Authorities	2.68	3.98	-2.73	1.31	12.97	1.05	0.54	0.67	
Sovereign	-4.52	9.58	-26.02	-4.62	13.27	-0.12	-0.52	-0.47	
Supranational	-1.05	1.27	-3.25	-0.99	1.74	0.45	-0.37	-0.82	
Treasury	-4.26	5.69	-13.26	-4.18	6.25	0.15	-1.17	-0.75	
Utilities	-2.25	4.91	-14.35	-0.73	7.89	-0.31	-0.17	-0.46	

Figure 10 shows the trend of the four main sectors that make up the "green portfolio". Three kinds of trends are shown. Supranationals and agencies see their premia fluctuate in a range around 0 bps for the former and around -10 bps for the latter, albeit with a different thickness. Regarding Financials, their premium rose from -30 bps to -7 bps by the end of 2017, before entering a range between -7 bps to -19 bps, with the lowest values being reached during the recent crisis. The observed trend is that of utilities. It is a decreasing trend that begins with positive values but worsens amid the Covid-19 turmoil to reach -15 bps.

Figure 10: Sectors' premia in bps - 2016 – 2020



4.2.4 Credit rating

In Table 8, we report the average monthly premium per rating category. Two observations can be drawn: The lower categories of ratings (A and Baa), exhibit a significant negative premium. We note also that the lower the category of rating, the lower the premium and the higher the volatility.

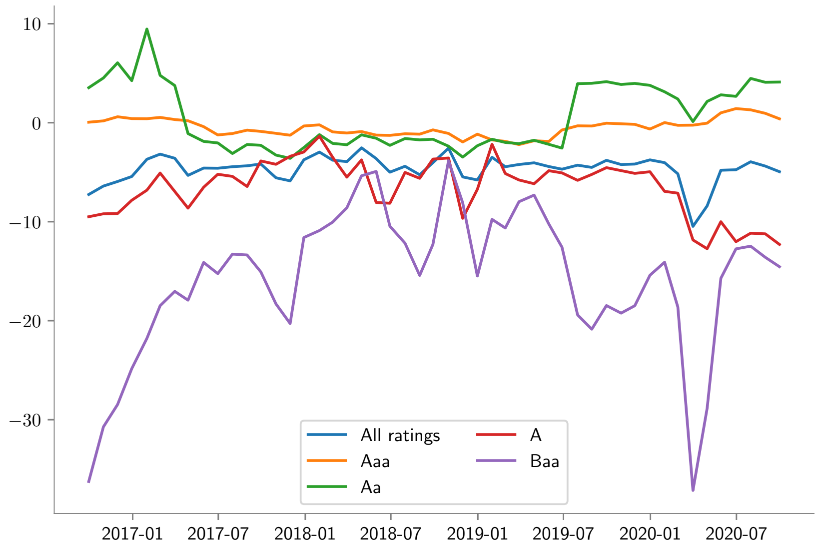
Table 8: Breakdown per credit rating

Rating	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All ratings	-4.66	1.37	-10.47	-4.40	-2.54	-2.03	6.49	-3.40	***
Aaa	-0.50	0.88	-2.21	-0.40	1.43	0.15	-0.49	-0.57	
Aa	0.57	3.28	-3.60	-1.22	9.46	0.56	-0.84	0.17	
A	-6.54	2.80	-12.73	-5.78	-1.36	-0.61	-0.33	-2.34	**
Baa	-15.76	7.29	-37.15	-14.55	-3.84	-1.13	1.54	-2.16	**

These observations are illustrated in Figure 11. It depicts a huge range for the Baa premium and a smaller range for the A premium. The evolution of Aaa premium is the exact replica of the evolution of the supranationals' premium. The Aa rating premium, mainly composed of French and Belgian sovereigns and agencies, has an atypical evolution with regard to the rating categories having generally seen a upward trend in recent periods.

It is important to note that in this method we assume that on either side of the comparison, we are comparing well-diversified portfolios, as we do not explicitly control for issuer effects. This will not be true for all sub-categories hence we attempt to address this in the next section.

Figure 11: Credit ratings' premia in bps - 2016 – 2020



5 Second method: Bottom-up approach

In this method, we assess the level of premium of green bonds compared to non-green bonds by performing an intra-curve estimate of the premium for every green bond in the universe and using the aggregate data by the relevant fixed income asset sub-categories. In comparison with the first method, we are now solely focusing on the intra-curve green premium, i.e. the premium for buying the green bond format. Any potential broader effect in the overall risk premium of an issuer that issues green bonds (often referred as "Green Halo") will thus be excluded.

The premium will not be estimated for green bonds that are not in the "green portfolio". Even though ESG investors may see the proceeds as being green, green bonds that are not rated Investment Grade, not of a benchmark size or for which the use of proceeds does not match the taxonomy or transparency requirements of the index will be excluded.

We define the green *premium* as the difference in the reference spread (S) between the green bond and a comparable conventional bond with the same issuer[23], the same currency, the same seniority[24] and the same modified duration (MD). The reference spread is either the Z-spread[25] or the G-spread[26] according to the reference curve communicated when the issuance was announced [27].

$$Premium = S_{GB} - S_{CB}$$

[23]The same name and the same Bloomberg ticker.

[24]They are Covered, Contingent Convertible, Hybrid Corporate, Lower Tier Two, Senior and Senior Non Preferred.

[25]The Z-spread or zero volatility spread is the constant yield spread over the entirety of the swaps spot curve such that the present value of the cash flows matches the clean price of the bond.

[26]The G-spread or nominal spread is defined as the difference between the yield of the corporate bond and the interpolated yield of the treasury bond of the same time to maturity.

[27]See Table 23 on page 41

For a given green bond, the spread of the comparable conventional bond is determined using a linear interpolation of the spreads of the nearest two conventional bonds CB_1 and CB_2, picked from the "benchmark". The proximity between two bonds B_1 and B_2 sharing the first three characteristics is defined as $|MD_{B_1} - MD_{B_2}|$.

$$— CB_1 —— GB ——— CB_2 —$$
$$— CB_1 ——— CB_2 —— GB —$$
$$— GB —— CB_1 ——— CB_2 —$$

Figure 12: Cases of interpolation

Three cases of interpolation, as depicted by Figure 12, are possible: the green bond may be surrounded by CB_1 and CB_2, or may have two close bonds with a lower or higher modified duration.

To keep homogenous curve segments and to minimize the differences in the slope of the credit spread, the interpolation is performed under the two following conditions of proximity:

$$\begin{cases} |MD_{GB} - MD_{NG}| & \leq |MD_{CB_2} - MD_{CB_1}| \\ \left|MD_{GB} - \overline{MD}\right| & \leq \max\left(\dfrac{MD_{GB}}{2}, 3 \text{ years}\right) \end{cases}$$

where NG is the nearest neighbor among $\{CB_1, CB_2\}$ to the green bond and $\overline{MD}$ is the average of MD of CB_1 and CB_2.

The first condition particularly targets the second and third cases of interpolation as it is obviously satisfied for the first case. If we denote D the distance between CB_1 and CB_2, the green bond should not be more than D away from CB_1 and CB_2. The second condition constrains the MD of the green bond to be half its value at most away from $\overline{MD}$. For the lowest values of MD (i.e. ≤ 6 years), we impose at most 3 years of distance.

The interpolation supposes the spread as an increasing function of the modified duration. If S_{CB_1} is higher than S_{CB_2}, we pick if possible two new non-green bonds, as we cannot determine which bond is "mispriced". The linear interpolation does not take into consideration the local concavity of the curves that we considered as negligible given the condition put on the length of the interval $[MD_{CB_1}, MD_{CB_2}]$[28].

$$— CB_{1n} — \cancel{CB_1} — GB — \cancel{CB_2} — CB_{2n} —$$

For the study, We use Bloomberg BVAL quote as price source. Some Green Bonds may not quote as readily. To avoid misleading figures or an impact of stale pricing, the bond is excluded from the set of studied green bonds. The same approach applies to the comparable non-green bonds. The market for Green Bonds has its own liquidity features that are key to consider when studying the hypothesis of a premium. On the one hand, Green Bonds tend to be smaller in size than conventional bonds and tend to be held more by buy-and-hold investors when compared to

[28] The concavity (of the spreads to duration) slightly lowers the premium.

conventional bonds, which slows down their circulation. On the other hand, they are under the spotlight of the bond markets and facing strong demand: active investors and traders can rely on their attractive selling traits. Finally, they are on average newer and more likely to quote close to par, which is another factor favouring better liquidity.

We adopt the same approach as Zerbib (2019) in order to reflect the difference in liquidity $\Delta Liquidity$ between the green bond and the comparable conventional bond:

$$\Delta Liquidity = Liquidity(GB) - Liquidity(CB) \tag{1}$$

The liquidity of bonds is traditionally assessed using the bid-ask spread (Chen *et al.*, 2007). Fong *et al.* (2017) show that the percent quoted bid-ask spread[29] is the best low-frequency measure for liquidity. Like Zerbib (2019) and Bour (2019), we adopt this proxy for the green bond and its nearest conventional neighbours whereas the liquidity proxy for the comparable conventional bond is defined as:

$$Liquidity\,(CB) = \frac{d_2}{d_1 + d_2} Liquidity\,(CB_1) + \frac{d_1}{d_1 + d_2} Liquidity\,(CB_2) \tag{2}$$

where d_1 (respectively d_2) is the distance between the green bond and CB_1 (respectively CB_2).

Along with the definition of equation 1 where the green bond is more liquid than its comparable if $\Delta Liquidity$ is lower than 0, we impose that two bonds B_1 and B_2 have the same liquidity if the liquidity of one bond does not exceed by 150% the liquidity of the other bond. In other words, the liquidity ratio satisfies the following inequality:

$$\frac{1}{1.5} \leq \frac{Liquidity(B_1)}{Liquidity(B_2)} \leq 1.5 \tag{3}$$

5.1 Results

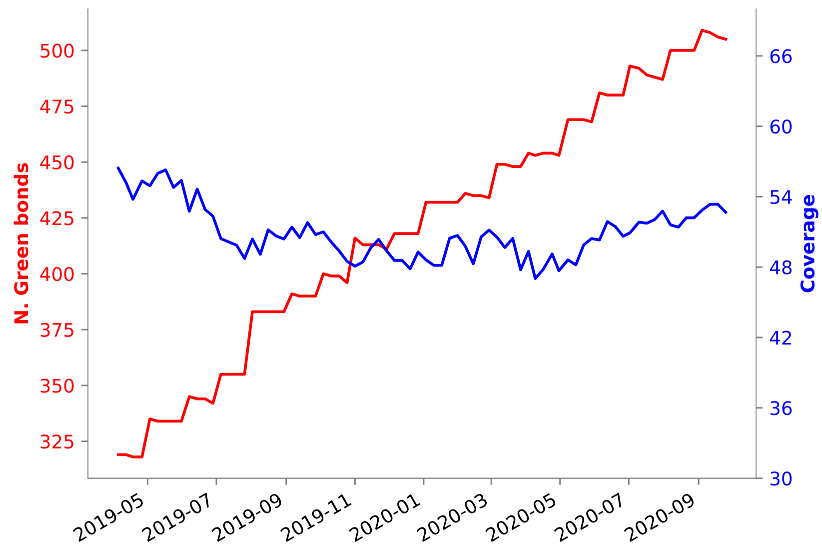
We report in red in Figure 13 the change from April 2019 to September 2020 in the number of green bonds in the "green portfolio". Their number rose steadily from 318 to 509. In the same figure, we report the ratio of the calculated premia to the total number of green bonds. We note that this ratio is around 51% on average reaching its lowest values between March and April 2020.

Table 9: Statistics

Metric	Mean	Std dev.	Min	Q_{25}	Median	Q_{75}	Max
Total green bonds	420.29	56.46	318	383	425	469	509
Calculated premiums	213.51	27.72	171	193	208	228	271
No possible interpolation	106.15	13.58	76	99	108	121	125
Not so near related bonds	56.95	10.60	36	48	59	64	80
Incoherence in spreads	49.78	13.06	18	44	53	58	72

[29] $Bid{-}Ask\ spread = 2 \cdot \dfrac{Ask\ price - Bid\ price}{Ask\ price + Bid\ price}$

Figure 13: Coverage



In Table 9, we report the reasons that did not allow the premia to be calculated. In roughly half of cases, no interpolation is possible since no two related non-green bonds can be found. When available, these two related bonds do not comply with the conditions of proximity in 25% of cases. The last 25% of cases is attributed to the spread inconsistencies since no new comparable bonds can be retrieved.

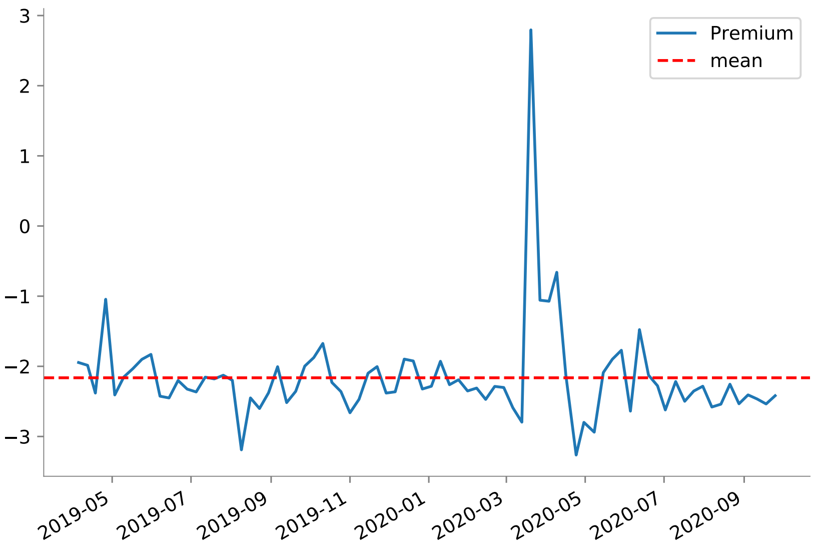
Table 10: Spreads and Premium - Statistics

Metric	Mean	Std dev.	Median	Skewness	Kurtosis	T-statistic	
CB Spread	59.59	55.34	45.36	2.18	7.80	15.73	***
GB Spread	57.42	55.16	43.79	2.25	8.24	15.21	***
Premium	-2.17	10.74	-1.04	2.35	111.79	-2.95	***
Duration	5.83	3.63	5.08	1.93	5.16	23.44	***

We report in Table 10 the metrics of the spreads of the related non-green bond, the associated premium and the modified duration. On average, the premium is negative (around -2.17 bps) and is significant at 99%. The skewness metric that measures the asymmetry of the distribution of premia is positive indicating that the mass of the distribution is concentrated to the left of the mean and that most of the outliers are present on the right side of the distribution. The high value of kurtosis confirms the presence of heavy tails in the data set of premia. Figure 16 displays per date the number of outliers that are above 4 times the standard deviation or below -4 times the standard deviation. The Covid-19 crisis exacerbated the number of outliers and in particular the number of those in the right of the distribution. There may be a reason for this: in times of sell-off, liquidity is poorer, and prices take more time to adjust. Under the assumptions that Green Bonds are more in demand ceteris paribus, in such an environment they are the first ones to be sold (and to have their price adjusted)[30].

Figure 14 shows that the premium has evolved in a narrow range around −2 bps over the last year. The recent crisis knocked it out of its range peaking at 3 bps in mid-March 2020 before retracing.

Figure 14: Evolution of the premium (in bps)



If we look closer and drill down per currency (Table 11), we note that premia are negative and that among the main currencies, only EUR and USD have a significant premium, albeit at 95% and 90% confidence levels. These results are in line with those of Kapraun and Scheins (2019). Compared to the EUR premium, the USD premium is tighter and twice as volatile. Its distribution is right-skewed (i.e. most of outliers are on the right) whereas the distribution of EUR premia is moderately left-skewed. The high level of the kurtosis is reflective of the presence of outliers in both currencies.

Table 11: Breakdown per currency

	Premium							Av Spread	Av MD
Currency	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
EUR	-1.62	8.02	-1.41	19.85	9 194	-2.19	**	53.70	6.39
USD	-3.74	16.27	3.04	74.26	4 609	-1.77	*	73.95	5.16
CAD	-2.19	6.98	-0.01	0.05	1 015	-1.13		67.47	6.12
AUD	-1.01	2.79	-0.93	1.31	834	-1.19		40.07	4.80
Other Currencies	-0.95	6.07	-2.12	9.46	1 002	-0.56		19.74	4.34

Table 12 shows that premia are negative if we perform a breakdown per category of rating. However, only Aaa bonds have a statistically significant premium at a 95% confidence level. We note that the volatility of the premium is an increasing function of the rating. According to the

[30]First-method shows different results during this period.

skewness, all ratings except the A rating, exhibit asymmetric distributions of premia: left-skewed for Aaa and right-skewed for Aa and Baa. The higher level of kurtosis of Aa compared to the other ratings (of order of x9 to x10) indicates the presence of its outliers on the rightmost side.

Table 12: Breakdown per credit rating

	Premium							Av Spread	Av MD
Rating	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Aaa	-1.94	6.97	-5.44	56.11	4 991	-2.22	**	18.66	5.42
Aa	-1.38	6.70	13.75	562.17	3 986	-1.47		44.51	6.18
A	-3.13	13.30	0.56	77.38	4 264	-1.74	*	67.97	5.92
Baa	-2.25	14.74	3.43	56.05	3 399	-1.01		116.33	5.93

Table 13: Breakdown per fixed-income category

	Premium							Av Spread	Av MD
Sector	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Covered	-0.21	1.23	0.15	1.43	967	-0.61		3.73	5.18
Financials Corporates	-1.19	13.16	5.97	146.38	4 258	-0.67		73.64	4.19
Non-financial Corporates	-3.64	14.42	0.20	29.78	3 803	-1.76	*	85.37	6.84
SSA	-2.23	7.01	-3.90	37.51	7 626	-3.14	***	41.23	6.33

In Table 13, we report a sectoral breakdown. We distinguish four main groups: SSA (Supranational, Sovereigns and Agencies), Financial corporates, Non-financial corporates and Covered[31]. We note the negative sign of the premium for each sector group. However, only the premium of the SSA is significant at 99% and Non-financial corporates at 90%. It is interesting to note that within the credit universe, green bond investors give a lower premium to Non-financial corporates in comparison to Financials (-3.6 bps vs -1.2 bps, when the average spread of the asset classes are close at 85.4 bps vs 73.6 bps). These findings hold in the EUR universe[32] as detailed in Table 14 with lower levels of skewness and kurtosis.

Table 14: EUR universe: Breakdown per fixed-income category

	Premium							Av Spread	Av MD
Sector	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Covered	-0.28	1.11	0.32	1.26	880	-0.85		2.81	5.28
Financials Corporates	-1.15	7.32	-0.25	3.82	3 042	-0.98		66.02	4.08
Non-financial Corporates	-3.36	13.05	-0.92	9.20	2 151	-1.35		71.46	6.31
SSA	-1.24	4.08	-1.50	11.89	3 121	-1.93	*	43.81	9.00

In Table 15, we report the breakdown per sector in a more granular way. We split off the Spec finance sector from the financial sector. This sector encompasses bonds from Real-Investment

[31] Covered bonds are secured bonds issued by banks. Most issuances use mortgages as collateral.

[32] In Appendix A.3, we detail all the breakdowns in the EUR universe.

Trusts or infrastructure owners. We notice that only supranationals, agencies and utilities exhibit significant negative premia at 95% for the former and 90% for the latter. As we can expect, the volatilities of premia of covered bonds, sovereigns, agencies and to a lesser extent those of supranationals are lower than the respective volatilities of corporates. Financials and spec finance appear to be the only sectors with positive skewness and higher kurtosis indicating right-skewed distributions with outliers on the rightmost side.

Table 15: Breakdown per sector

	Premium							Av Spread	Av MD
Sector	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Agencies	-1.72	5.54	-1.94	11.91	4 443	-2.34	**	48.85	6.23
Covered	-0.21	1.23	0.15	1.43	967	-0.61		3.73	5.18
Financials	-1.01	11.33	3.97	201.45	3 161	-0.57		60.36	3.65
Other Corporates	-2.34	12.09	-0.54	4.30	674	-0.57		85.71	4.94
Sovereigns	-0.47	5.87	-0.24	3.88	699	-0.24		70.12	9.72
Spec finance	-1.73	17.39	6.95	82.33	1 097	-0.37		111.88	5.75
Supras	-3.63	9.12	-4.37	33.94	2 484	-2.25	**	19.48	5.55
Utilities	-3.92	14.86	0.30	31.68	3 129	-1.67	*	85.30	7.24

If we focus per region (Table 16), we note that all regions[33] exhibit a negative premium but only Europe has a statistically significant premium. If we compare American bonds to European bonds, we draw the same conclusions as for the currency breakdown, in terms of averages, volatilities, skewness and outliers.

Table 16: Breakdown per region

	Premium							Av Spread	Av MD
Region	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Europe	-1.88	7.70	-1.43	20.21	10 735	-2.86	***	46.64	6.05
North America	-3.07	16.94	2.51	66.11	3 513	-1.21		78.28	6.06
Asia & Pacific	-3.16	10.61	-1.09	4.60	1 659	-1.37		84.21	4.37
Others	0.09	10.32	20.74	519.84	747	0.03		54.81	4.89

An interesting result is found in the breakdown by the Amundi ESG rating[34] (Table 17). For a large share of ESG investors, Green Bonds are a unique opportunity to incorporate into their portfolios issuers that are lagging in terms of ESG scoring[35]. The rationale is that the efforts made by the green bond issuers to add green projects, bring transparency, and update the green strategy with the green issuance are actually a way to spot ESG improvers. Besides the fact that premia, if we exclude unrated bonds by Amundi, are negative, we find a decreasing relation between the

[33] To supranationals, we assign the region of their country of domicile.

[34] See Appendix A.1 for the definition of the Amundi ESG rating.

[35] Aside from general poor practices, low ESG ratings can also be explained by a lack of transparency in extra-financial communication of issuers.

spread and the ESG rating: the lower the ESG rating, the higher the spread[36], the higher the premium and the higher the volatility of the premium. Compared to the best in-class, all ratings, and in particular E-F ratings[37] exhibit a higher excess yield. We obtain the same results (Table 24) if we perform the breakdown by the Environmental pillar of the Amundi ESG rating[38].

Table 17: Breakdown per ESG-rating

	Premium							Av Spread	Av MD
Rating	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
A	-3.04	8.29	-4.26	38.19	3 226	-2.36	**	30.69	5.79
B	-2.35	7.30	-5.17	52.99	2 620	-1.86	*	48.53	6.04
C	-2.15	10.30	3.22	86.20	5 750	-1.79	*	58.70	5.89
D	-2.20	13.42	3.31	123.27	2 624	-0.95		82.78	6.05
E-F	-1.73	16.90	2.83	59.60	1 527	-0.45		96.01	4.87
NR	0.65	5.76	-3.74	40.65	907	0.38		31.68	5.98

In terms of time to maturity[39], all premia are negative on average (Table 18). Only the 5-7 years, 7-10 years and 10-20 years buckets have significant premia at 95% or 90%. If we exclude the last bucket, the premium seems to be a decreasing function of the maturity: the higher the bucket, the lower the premium. We note that only the 5-7 years bucket is not skewed. All other buckets are skewed: those below 10 years are right-skewed however, long-term buckets are left-skewed.

Table 18: Breakdown per time to maturity

	Premium							Av Spread	Av MD
Maturity	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
1 - 3 yrs	-1.03	12.54	3.11	166.03	2 910	-0.50		32.18	2.07
3 - 5 yrs	-1.38	7.60	8.69	323.87	4 434	-1.36		48.98	3.89
5 - 7 yrs	-3.01	9.87	0.11	103.84	3 404	-2.02	**	52.62	5.60
7 - 10 yrs	-2.79	11.33	3.04	58.78	4 073	-1.78	*	72.21	7.72
10 - 20 yrs	-5.23	9.85	-2.55	7.19	972	-1.87	*	66.77	12.99
Beyond 20 yrs	-0.39	16.57	-0.75	7.20	861	-0.08		124.67	12.45

Table 19 reports the implication in terms of premia if the green bond is more or less liquid than its comparable conventional bond. We note that liquid green bonds tend to exhibit a lower premium (-0.88 bps). This result suggests the existence of a bond liquidity premium since the bond liquidity is positively correlated to the green premium. Wulandari *et al.* (2018) argues that this liquidity premium is due to the insufficient supply and excess demand in the green bonds market, which implies a thin market.

[36] This result is consistent with Ben Slimane *et al.* (2019) who find that ESG has a positive impact on the cost of debt and this relationship has become stronger since 2014.

[37] We regroup E and F into one cluster, as the number of F ratings is too small.

[38] ibid

[39] We apply the next-call date convention regarding callable bonds and in particular perpetual bonds.

Table 19: Breakdown per liquidity

Liquidity	Premium							Av Spread	Av MD
	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
GB less Liquid	-1.71	9.72	5.31	142.44	7 936	-1.77	*	56.13	5.56
GB more Liquid	-2.59	11.58	0.76	93.29	8 703	-2.36	**	58.65	6.08

In the meantime, Table 20 shows that if we adjust the sample with greens that are comparable with non-greens of same liquidity, we lower the premium from -2.17 bps in the full sample to -2.88 bps. Duration and spread metrics of the samples are close to each other (5.93 years vs 5.83 years and 56.13 bps vs 57.42 bps).

Table 20: Breakdown per liquidity

Liquidity	Premium							Av Spread	Av MD
	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Different Liquidity	-1.64	8.46	0.02	45.20	9 496	-2.13	**	58.44	5.76
Same Liquidity	-2.88	13.14	3.08	105.94	7 143	-2.10	**	56.13	5.93

Table 21 shows the breakdown per certification. We split the certified bonds into two groups: Those certified by CBI[40] and those certified by other reviewers. Compared to uncertified bonds, we note that certified bonds exhibit a lower and significant premium and that among these certified bonds, CBI certified bonds even have the lowest premia on average (-1.12 bps vs -0.40 bps).

Table 21: Breakdown per certification

Certification	Premium							Av Spread	Av MD
	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Not Certified	-1.80	15.19	5.17	94.54	2 531	-0.67		79.53	6.01
Certified	-2.23	9.73	0.17	93.74	14 123	-3.09	***	53.46	5.80
Certified by CBI	-2.92	11.23	5.72	148.86	2 290	-1.41		72.15	6.41
Certified by others	-2.10	9.40	-1.64	70.17	11 833	-2.75	***	49.84	5.68

5.2 Determinants of the green premium

To investigate the determinants of the green premium, we run a panel data regression model with fixed time effects using the bonds for which we calculate a premium and discarding those whose premium does not belong to the $[-4\sigma_p, 4\sigma_p]$ range, σ_p being the premium distribution standard deviation. The percentage of discarded premia does not exceed 0.72% of the total number of premia.

[40] CBI is one of the external reviewers.

Let $\text{Premium}_{i,t}$ be the green premium of Bond i at time t. We assume that the premium depends linearly on the bond's intrinsic characteristics such as age, duration, natural logarithm of the size, currency, sector and country or on external features such as certifications or Amundi E-ratings[41]:

$$\begin{aligned}
\text{Premium}_{i,t} \quad = \quad & \alpha_t + \beta_{md} \cdot \text{MD}_{i,t} + \sum_{j=1}^{N_{\mathcal{S}ector}} \beta_{\mathcal{S}ector}(j) \cdot \mathcal{S}ector_{i,t}(j) + \\
& \beta_{dm} \cdot \text{Domestic}_{i,t} + \sum_{k=1}^{N_{\mathcal{R}ating}} \beta_{\mathcal{R}ating}(k) \cdot \mathcal{R}ating_{i,t}(k) + \\
& \beta_{ag} \cdot \text{Age}_{i,t} + \sum_{l=1}^{N_{\mathcal{R}egion}} \beta_{\mathcal{R}egion}(l) \cdot \mathcal{R}egion_{i,t}(l) + \\
& \beta_{liq} \cdot \Delta\text{Liquidity}_{i,t} + \sum_{m=1}^{N_{\mathcal{S}eniority}} \beta_{\mathcal{S}eniority}(m) \cdot \mathcal{S}eniority_{i,t}(m) + \\
& \beta_{sz} \cdot \ln \text{Size}_{i,t} + \sum_{n=1}^{N_{\mathcal{C}urrency}} \beta_{\mathcal{C}urrency}(n) \cdot \mathcal{C}urrency_{i,t}(n) + \\
& \beta_{cf} \cdot \text{Certified}_{i,t} + \beta_{cbi} \cdot \text{CBIcertified}_{i,t} + \varepsilon_{i,t} \qquad (4)
\end{aligned}$$

where $\text{MD}_{i,t}$, $\text{Size}_{i,t}$, $\Delta\text{Liquidity}_{i,t}$, $\text{Age}_{i,t}$ are respectively the modified duration, the size of the bond, the difference in liquidity proxy and the age of Bond i at time t. All the other variables are categorical variables. When Bond i is denominated in local currency, $\text{Domestic}_{i,t}$ equals 1 otherwise 0. $\mathcal{S}ector_{i,t}(j)$, $\mathcal{R}ating_{i,t}(k)$, $\mathcal{R}egion_{i,t}(l)$, $\mathcal{S}eniority_{i,t}(m)$ and $\mathcal{C}urrency_{i,t}(n)$ are dummy variables for the j^{th} sector[42], the k^{th} E-rating[43], the l^{th} region[44], the m^{th} seniority[45] and the n^{th} currency[46].

Finally, we introduce two additional variables regarding the external certifications. $\text{Certified}_{i,t}$ (resp. $\text{CBIcertified}_{i,t}$) equals 1 when the Bond i is certified by an external reviewer (resp. when Bond i is certified by CBI) otherwise 0.

For the purpose of this regression, we group together the two lowest Environmental ratings E and F into E-F. The proposed model does not include categorical variables related to credit ratings as sectors and ratings are highly correlated: supranationals are AAA-rated, utilities are BBB-rated.

We omit the financial sector, the European region, the senior seniority, the EUR currency, and the A E-rating dummy variables to avoid the multi-collinearity problem as the model already includes a constant. The betas associated with one specific sector (resp. region or seniority or currency or E-rating) represent the excess premium with respect to the financial sector (resp. the European region or the senior seniority or the EUR currency or the A E-rating).

[41] The results using Amundi ESG ratings are similar and reported in Table 25 on page 42.

[42] We have $\mathcal{S}ector_{i,t}(j) = 1$ if the i^{th} corporation belongs to the j^{th} sector at time t, otherwise zero.

[43] We have $\mathcal{R}ating_{i,t}(k) = 1$ if the i^{th} corporation has the k^{th} E-rating at time t, otherwise zero.

[44] We have $\mathcal{R}egion_{i,t}(l) = 1$ if the i^{th} corporation has its main country risk in l^{th} region at time t, otherwise zero.

[45] We have $\mathcal{S}eniority_{i,t}(m) = 1$ if the i^{th} bond has the l^{th} seniority, otherwise zero.

[46] We have $\mathcal{C}urrency_{i,t}(n) = 1$ if the i^{th} bond is denominated in n^{th} currency, otherwise zero.

Table 22: Panel regression statistics using E-ratings

	No certif.	Certified	CBI Certified	All
Intercept	1.95**	3.92***	3.28***	4.62***
Modified Duration	-0.10***	-0.11***	-0.05***	-0.07***
Age	-0.02	-0.05	-0.02	-0.04
Size	0.03	0.06	0.15	0.16
Domestic	-2.18***	-2.26***	-2.31***	-2.36***
Δ Liquidity	4.27***	4.20***	4.34***	4.29***
Certification				
CBI Certified			-3.08***	-2.85***
Certified		-1.56***		-1.14***
Seniorities				
Subordinated	6.17***	6.35***	6.21***	6.34***
Secured	-0.56**	-0.55**	-0.31	-0.32
Non-preferred Senior	-2.83***	-2.80***	-3.42***	-3.36***
Countries				
North America	1.17***	0.96***	1.05***	0.91***
Asia & Pacific	-0.97***	-1.07***	-0.39	-0.51*
Other countries	0.25	0.28	2.69***	2.54***
Sectors				
Agencies	-0.97***	-0.78***	-1.00***	-0.86***
Sovereigns	1.12***	1.38***	0.23	0.49
Spec finance	-1.73***	-1.68***	-1.89***	-1.84***
Supras	-2.23***	-2.21***	-3.23***	-3.14***
Utilities	-1.96***	-2.03***	-2.42***	-2.44***
Other Corporates	0.14	0.45	-0.28	-0.03
Currencies				
AUD	-1.20***	-1.40***	-1.16***	-1.30***
CAD	-1.51***	-1.70***	-1.61***	-1.74***
USD	-3.30***	-3.58***	-3.35***	-3.55***
Other currencies	-1.09***	-1.19***	-1.26***	-1.32***
E Rating				
B	0.56**	0.42	0.72***	0.60**
C	-0.33	-0.52*	-0.70**	-0.81***
D	-0.28	-0.58*	-0.53*	-0.73**
E-F	2.21***	1.53***	2.24***	1.75***
NR	3.40***	3.36***	3.12***	3.11***
Stats				
R^2 (%)	8.59	8.96	9.69	9.88
F-stat	59.4	59.9	65.32	64.35
VIF (max)	5.58	5.62	5.63	5.65
VIF (mean)	2.13	2.11	2.14	2.13
N. Obs.	16 534	16 534	16 534	16 534

From regression (4), we derive four models whether or not we include the external certification or the CBI certification and report in Table 22 several statistics of the models and the different betas. The outcome of the F-test confirms the rejection of the null hypothesis $H_0 : \beta_{md} = ... = \beta_{cf} = \beta_{cbi} = 0$. The VIF statistic is the acronym of the variance inflation factor, a measure of multi-collinearity of two exogenous variables. As a rule of thumb (O'Brien, 2007), a VIF lower than or equal to 5 indicates a low dependence between the independent variables. We verify that VIF[47] is low and remains almost unchanged even after the inclusion of the certifications' variables.

The coefficient of determination R^2, that calculates the explanatory power of the model, is in the [8.5%, 10%] range for 16 534 observations. The relatively low R^2 represents the scatter around the regression line[48] and means only that the model cannot be used to perform precise predictions regardless of significance of the coefficients of the independent variables. Obviously, the "All" model has the highest R^2 as it includes all variables. We note that the inclusion of the CBI certification variable to the first model with certification has a relatively higher impact (+110 bps) on R^2 than including the certification by an external reviewer (+37 bps).

The outcome of the analysis shows a statistically significant negative relationship between modified duration and premium. GBs issued with short durations tend then to have higher excess yields. However, this is to be tempered as the level of beta is relatively small. The ΔLiquidity, in the contrary, is an increasing function of the premium. GBs with different liquidity than their comparable CBs exhibit higher premia. The above relationships are statistically significant at the 1% significance level. These two results are in line with the findings of Tables 18 and 20. The analysis shows, albeit being non-significant, a positive sign for size and a negative sign for age. Unlike Kapraun and Scheins (2019), we observe lower premia in the secondary market when bonds have smaller issue amounts. Aged issues seem also to be prized too. The shortage of supply and the large demand may be a reason.

If we focus on the Domestic variable, we come to the same conclusion as Nanayakkara and Colombage (2019) on bonds denominated in local currencies. Their credit spreads are tighter than for bonds issued in foreign currencies. This can be explained by the fact that investments in bonds denominated in local currencies are low-risk investments even when investing overseas.

As documented in other studies, we find that certifications lower the premium. All other things being equal, being externally certified lowers the premium by 1.14 to 1.56 bps. The CBI certification lowers the premium by an additional 3 bps. These findings are in line with those of Baker *et al.* (2018), Hyun *et al.* (2020) and Kapraun and Scheins (2019) mentioned above. The CBI certification, one of the most stringent form of certification, dispels worries of investors of investing in green bonds that do not bring any sustainable benefit, generating then a buying pressure for these bonds and thus lower yields and premia.

If we look at currencies, non-EUR denominated bonds exhibit lower premia compared to EUR-denominated bonds. This result is significant at 99% whatever model we take. Finally, we have confirmation of our finding on the worst-rated bonds in terms of E-ratings: Their premium is significant and higher than those of the best-rated bonds.

Regarding seniorities, subordinated bonds (resp. non-preferred seniors and secured bonds) exhibit higher premia (resp. lower premia) compared to senior bonds. In terms of geography, compared to bonds whose country of risk is in Europe, bonds whose risk is located in Asia and Australia

[47] We report the highest and the mean VIF of each pair of exogenous variables.
[48] The closer to the line, the higher coefficient of determination.

show lower premia, whereas North-American bonds have a higher premium (+1.17). This last result seems to be in contradiction with the findings of Table 16.The positive beta associated with American issued bonds is in fact a EUR-denominated beta, so for instance, to assess the level of beta associated with American USD-denominated bonds, one should add the beta associated to USD to find a negative beta of $-2.13 = 1.17 - 3.30$.

In terms of sectors, all sectors except sovereigns, have lower premia compared to financials. If we rank them from bottom to top, we find supranationals, utilities then spec finance.

6 Conclusion

6.1 Findings

The purpose of this study is to determine if investors are rewarded with lower yields when they invest in Green Bonds. We present two methods to assess whether a green bond premium exists. We consider the green bond constituents of the Bloomberg Barclays MSCI Global Index. In the first method, we build a synthetic conventional portfolio from a global aggregate bond index by dissecting it using four criteria and then re-weighting, applying the weights of the portfolio of green bonds. The premium is defined here as the difference in OAS of the green bond portfolio and re-weighted aggregate bond index. In the second method, we match, when it is possible, each green bond with two conventional bonds that have the same issuer, the same currency and the same seniority under some constraints of proximity in terms of duration. We either interpolate or extrapolate the spreads to find the spread of a theoretical bond having the same duration as the green bond. The difference in spreads is then the premium we seek.

Both methods show small negative and significant premia of respectively -4.7 bps and -2.2 bps. The second method by asset sub-class breakdowns are the following: -2.2 bps for Supranationals, Sovereigns and Agencies significant at 99%, -3.6 bps for Non-Financial Corporate issuers significant at 99%, -1.2 bps for Financials and -0.2 bps for Covered Bonds, with the last two categories being not statistically significant. The same order of magnitude of premia is observed in the EUR universe, which is the main currency of the considered index.

According to both methods, this premium is significant in several market segments: EUR-denominated bonds, A rated bonds, bonds issued by agencies and bonds whose time to maturity is between 5 and 10 years. In our first method, we confirm the findings of Zerbib (2019) regarding bonds issued by financial institutions and low-rated bonds whose negative premia are more pronounced. We take advantage of the presence of the synthetic conventional portfolio to compare its performances with that of the green portfolio and observe the existence of a put payoff for the outperformance[49] of the green portfolio. If we focus on the first method, the premium is also significant for USD-denominated bonds, bonds specifically of supranationals, and utilities, bonds rated Aaa, bonds whose country of risk is located in Europe and bonds certified by external reviewers. We also found that the premium and its significance increases with the ESG quality of the issuer, i.e. beyond the use of proceeds, green bond investors reward a more negative premium to issuers with better extra-financial standards at the company level. Finally, within the Credit segment, the premium is three times lower for Non-financial corporates than for Financial

[49] Or a call payoff for the performance.

issuers, with comparable sample size and average spread of both segments. Moreover, using a panel regression with control variates, we find that the premium is a decreasing function of the duration and that domestic bonds and bonds certified by the CBI tend to show low premia. We show further that all sectors except sovereigns (resp. that the AUD, CAD, and USD currencies) exhibit lower premia compared to the financial sector (resp. to the EUR). We also find that the green premium lowers with smaller-sized bonds, as well as with age, although not significantly.

Finally, as described broadly in this paper, the green bond market has different liquidity features than the overall market. As such, it would be arguable that the existence of a liquidity bias can explain part of the green bond premium found. To circumvent this argument, we filtered our universe to retain bonds with similar liquidity characteristics. After neutralizing the liquidity factor in the search of the premium, we find a green bond premium, which is even lower at -2.9 bps compared to -2.2 bps. At least, we deduce from this specific result that the overall green premium found is not hiding a liquidity premium.

6.2 Discussion

There are several arguments in favor of a negative premium. Green bonds provide two major features to investors: a commitment to dedicate a least an equivalent amount raised to a pool of specific, detailed green projects and transparency on the use of the proceeds, with reporting on the impact of those projects. The issuance of a green bond also has a financial cost for the issuer[50]. Against a backdrop of strong demand, one may argue that green bond issuers may seek financial compensation to at least offset the additional cost of issuance..

The issuance of green bonds compared to total issuance is still limited today. In the meantime, the demand for “Green” or “Impact” investments more generally is increasing at its a pace independent of supply. This potential mismatch of supply and demand can trigger scarcities and thus larger negative premia. However, most ESG investors are not ready to give up returns to hold green bonds, which may counter-balance the pace of demand for green bonds. Furthermore, in the long-run, whilst one can expect that the Green Bond market is far from having reached its maximum size; considering that best practices require green bonds to finance tangible green projects, there must always be a significant size gap between the green bond universe and the broader bond universe.

As we have discussed in our study, green bonds show strong liquidity features in favor of the seller. It is easier to find a buyer of a green bond than an equivalent non-green with the same characteristics.

Finally, and perhaps the strongest argument for a negative premium, climate risk is increasingly a concern (Hong *et al.*, 2020) for institutional investors (Krueger *et al.*, 2020), governments and public policymakers. As such, it is foreseeable that at some point in the future regulators or public investors, will actively distort the markets to better price climate risk in asset prices[51], including in

[50] To assess the full impact on cost of debt for green issuers, rather than the secondary market, we would need to consider the primary issue prices. Indeed, on average, yields at issuance incorporates an additional New Issue Premium (NIP) in favour of investors. Not covered by this study, this NIP may be actually lower for Green Bonds than for conventional bonds.

[51] Le Guenedal *et al.* (2020) identify that outside the power generation sector, corporates' emission intensity trajectories are not in line with a 2 degrees scenario. This confirms the necessity for asset-owners and investment

the fixed-income space. In terms of investment forces, like any ESG investor, large public investors can play a role. The European Central Bank, which has a massive Asset Purchasing Program to channel its monetary policy, is often referred to as the next game changer[52]. Furthermore, in terms of regulatory forces, one can imagine tax discounts or green adjusted capital requirements to financial institutions[53]. For now, no such groundbreaking public measures have been implemented and there appears little anticipation by financial markets given the small size of the negative premium that we have found. In this context perhaps an active investor should not be dissuaded by this negative premium, as this could be compensated by future excess returns.

Yet, despite these different potential arguments justifying a green bond negative premium, there are still other more convincing ones against it. When buying a green bond, the green investor does not own any rights to the projects to be financed. On the contrary, the investor bears the exact same Credit and ESG risks as the owner of a non-green bond with the exact same financial characteristics. In addition, green bonds create high and potentially onerous expectations among ESG investors. Namely in terms of alignment of the use of proceeds and reporting with the commitment at the issuance. As such, and this is important to consider, unlike other ESG bonds[54], a green bond bears the additional risk of controversy on the use of proceeds (and thus the risk of suffering a bond-specific sell-off). This controversy risk approach reduces the rationale for a negative green premium.

In this study, we focused on the prices in the secondary market. The levels we have seen indicate that although the negative premium on Green Bonds is significant, it is still marginal. If the idea of a green premium has been so popular among bond investors, this is probably due to the lower average new issue premium offered by green bonds over non-green bonds at issuance (Cuilliere *et al.*, 2020). There are even few recent memorable cases of issuers coming to market with green bond at a huge discount to the regular secondary curve. According to Bloomberg, the €1 billion 10-year green bond issued by the automaker Daimler AG priced more than 13 basis points tighter than its conventional spread curve. Likewise, Volkswagen AG sold eight-year and 12-year green benchmarks with a volume of €2 billion, 15.4 and 13.6 basis points lower in yield versus the rest of its bonds[55]

However, considering that we have found a relatively small negative premium in the secondary market, could what investors observe as a negative green bond premium be in fact a more generally negative premium on green bond issuers, whether the particular issue is green or not? The results of method one vs method two is somewhat consistent with this as issuers of green bonds can be compared to non-green bond issuers. With the wave of ESG integration into bond markets, research has found that ESG is increasingly part of the premium prices into bonds. Through an integrated ESG-credit pricing model, Ben Slimane *et al.* (2019) find some evidence that ESG affects the cost of capital in a positive way: issuers with higher ESG scores have lower costs of capital than

managers to keep their focus on the climat transition and a long-term assessment of corporates' emission intensity track-record.

[52]However, even if climate risk is integrated into ECB purchasing programs, this is more likely that a climate filter would be applied at the issuer level rather than at the format level.

[53]https://www.climatebonds.net/policy/policy-areas/tax-incentivess

[54]Namely Sustainability-Linked Bonds that offer an insurance premium or step-up coupon in case the issuer does not meet its ESG commitment.

[55]In the case of Daimler, Amundi Portfolio Management models assess the premium 13 days after the issuance at only -4 bps (from -13 bps at issuance).

issuers with lower ESG scores for the same credit rating. Among ESG risks, the Environmental or Climate risk is generally viewed as the most relevant, material, and more damaging for debt issuers. An issuer coming to market with a green bond is offering the whole market (and not only green bondholders) transparency, an update on its green strategy and commitment towards green projects investments. Whenever the green risk is material, either because it is key in a specific sector, or because a controversial issuer is on a path to green redemption by the market: a green tightening becomes financially rational. The correct question to ask then is, does the green benefit accrue to the entire issuer curve or is it restricted to the green bonds?

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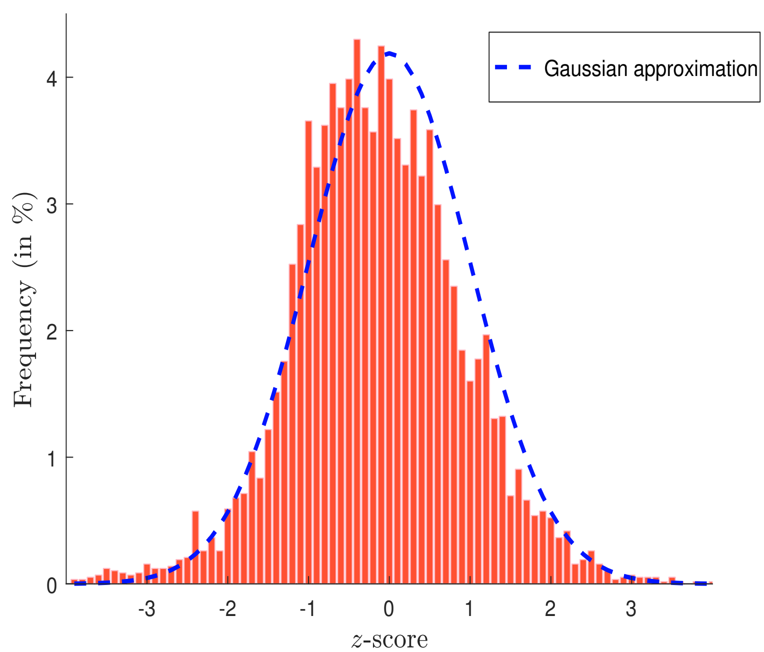
A Appendix

A.1 Amundi ESG scores and ratings

We consider the scoring system provided by the Amundi ESG Research department. For each company and each month, we assess the ESG score and its three components: E (environmental), S (social) and G (governance). These scores are based on the data of four external providers and are reviewed and validated by internal ESG analysts. The scores are normalized sector by sector to obtain a z-score shape, implying that they generally have a range between -3 and $+3$. This also means that the scores are sector-neutral, and they are approximately distributed as a standard Gaussian probability distribution. An example is given in Figure 15, which shows the empirical distribution of the global ESG score at the end of December 2018. The Gaussian approximation is very good even though we observe that the empirical distribution exhibits a low positive skewness. On average, the z-score is then equal to zero if we consider all the corporations together or if we consider a specific sector. The sector-neutrality of z-scores is an important property of many ESG scoring systems.

Figure 15: Empirical distribution of the ESG score (December 2018)



We define the ESG rating as a letter grade by mapping the z-score as shown below. This procedure is performed also on each pillar of the **ESG** score.

Rating	z-score
A	$+2.5 \leq z\text{-score}$
B	$+1.5 \leq z\text{-score} < +2.5$
C	$+0.5 \leq z\text{-score} < +1.5$
D	$-0.5 \leq z\text{-score} < +0.5$

Rating	z-score
E	$-1.5 \leq z\text{-score} < -0.5$
F	$-2.5 \leq z\text{-score} < -1.5$
G	$z\text{-score} < -2.5$

A.2 Full sample: Additional tables

Table 23 indicates the type of spread used, depending on the currency and the sector.

Table 23: Z-spread or G-Spread

Currency	ABS	Agencies & Supras	Banking	Industrials	Covered & Real-Estate	Sovereigns	
						EMU	Non-EMU
AUD	G	G	Z	Z	Z	G	Z
CAD	G	G	G	G	G	G	G
CHF	Z	Z	Z	Z	Z	Z	Z
CNY	G	G	G	G	G	G	G
DKK	Z	Z	Z	Z	Z	Z	Z
EUR	G	G	Z	Z	Z	G	Z
GBP	G	G	G	G	G	G	G
HKD	G	G	G	G	G	G	G
JPY	G	G	G	G	G	G	G
NOK	Z	Z	Z	Z	Z	Z	Z
SEK	Z	Z	Z	Z	Z	Z	Z
SGD	G	G	G	G	G	G	G
USD	G	G	G	G	G	G	G

Table 24 reports the breakdown per E rating. We note that the premium is negative and the worst-rated bonds exhibit higher excess yields than the best-in class rated bonds.

Table 24: Breakdown per E-rating

	Premium							Av Spread	Av MD
Rating	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
A	-3.52	8.91	-2.13	8.55	1 326	-1.63		33.78	4.68
B	-2.05	8.28	-2.48	73.87	4 666	-1.92	*	41.77	5.78
C	-2.17	9.35	3.19	100.05	6 379	-2.10	**	58.50	6.19
D	-2.66	17.61	3.62	69.79	2 461	-0.85		93.16	5.79
E-F	-2.29	12.13	-3.92	71.61	915	-0.65		93.33	5.21
NR	0.65	5.76	-3.74	40.65	907	0.38		31.68	5.98

Table 25 reports the results of the panel data regression when we consider ESG ratings instead of E ratings. We notice that all significant results obtained in Table 22 hold.

Table 25: Panel regression statistics using ESG ratings

	No certif.	Certified	CBI Certified	All
Intercept	2.83***	4.78***	4.03***	5.42***
Modified Duration	-0.08***	-0.10***	-0.04*	-0.05***
Age	-0.06	-0.08*	-0.06	-0.08
Size	-0.05	-0.02	0.06	0.07
Domestic	-2.35***	-2.43***	-2.46***	-2.50***
Δ Liquidity	4.24***	4.16***	4.31***	4.24***
Certification				
CBI Certified			-2.81***	-2.59***
Certified		-1.58***		-1.20***
Seniorities				
Subordinated	6.34***	6.54***	6.41***	6.56***
Secured	-0.63***	-0.62***	-0.36	-0.37
Non-preferred Senior	-2.54***	-2.51***	-2.95***	-2.89***
Countries				
North America	0.89***	0.76***	0.69***	0.61**
Asia & Pacific	-1.70***	-1.69***	-1.28***	-1.30***
Other countries	0.13	0.18	2.28***	2.15***
Sectors				
Agencies	-1.28***	-1.14***	-1.42***	-1.30***
Sovereigns	0.62	0.96**	-0.38	-0.04
Spec finance	-1.56***	-1.59***	-1.68***	-1.69***
Supras	-2.92***	-2.95***	-3.76***	-3.72***
Utilities	-2.37***	-2.49***	-2.95***	-2.99***
Other Corporates	0.30	0.55	-0.13	0.09
Currencies				
AUD	-1.30***	-1.51***	-1.25***	-1.42***
CAD	-1.31***	-1.56***	-1.35***	-1.54***
USD	-3.37***	-3.67***	-3.39***	-3.61***
Other currencies	-1.27***	-1.38***	-1.44***	-1.51***
ESG Rating				
B	-0.85***	-0.89***	-0.92***	-0.95***
C	-1.25***	-1.35***	-1.46***	-1.51***
D	-1.55***	-1.77***	-1.75***	-1.90***
E-F	1.20***	0.67	1.23***	0.82**
NR	2.53***	2.59***	2.32***	2.38***
Stats				
R^2 (%)	8.71	9.09	9.66	9.88
F-stat	60.26	60.82	65.1	64.31
VIF (max)	6.37	6.38	6.38	6.39
VIF (mean)	2.36	2.34	2.36	2.34
N. Obs.	16 534	16 534	16 534	16 534

A.3 EUR Universe

1. Bottom-up approach

    (a) Table 26: This Table is the EUR-equivalent of the overall results presented in Table 10 on page 24. We note that the premium is significant at 95% and that the distribution of premia is left-skewed.

    (b) Table 27: EUR-equivalent of the breakdown per credit rating presented in Table 12 on page 26. The premium is negative but only Aaa is significant at 95%

    (c) Table 28: EUR-equivalent of the breakdown per sector presented in Table 15 on page 27. The premium is negative but no sector is significant.

    (d) Table 29: EUR-equivalent of the breakdown per region presented in Table 16 on page 27. The premium is negative and significant for bonds labelled in EUR and whose country of risk is located in Europe.

    (e) Table 30: EUR-equivalent of the breakdown per ESG rating presented in Table 17 on page 28. The premium is higher for worst-rated bonds.

    (f) Table 31: EUR-equivalent of the E rating presented in Table 24 on page 41. Like the ESG rating, the premium is higher for worst-rated bonds.

    (g) Table 32: EUR-equivalent of the breakdown per time to maturity presented in Table 18 on page 28. The premium is negative but only significant for bonds whose time to maturity is between 10 and 20 years.

    (h) Table 33: EUR-equivalent of the breakdown per liquidity presented in Table 19 on page 29. The result differs from the one obtained for the full sample. Here, less liquid GB exhibit significant lower premia due to a negative skewness.

    (i) Table 34: EUR-equivalent of the breakdown per liquidity presented in Table 20 on page 29. Thes results are in line with the result obtained for the whole universe. The premium is 24 bps lower than in full sample.

    (j) Table 35: EUR-equivalent of the breakdown per certification presented in Table 21 on page 29. The results are in line with the result obtained for the whole universe.

2. Top-down approach

    (a) Table 36: EUR-equivalent of the breakdown per time to maturity presented in Table 6 on 18.

    (b) Table 37: EUR-equivalent of the breakdown per sector presented in Table 7 on 19.

    (c) Table 38: EUR-equivalent of the breakdown per rating presented in Table 8 on 20.

Table 26: EUR Universe: Spreads and Premium - Statistics

Metric	Mean	Std dev.	Median	Skewness	Kurtosis	T-statistic	
CB Spread	55.32	47.14	44.42	2.19	7.80	12.74	***
GB Spread	53.70	46.45	43.67	2.20	7.57	12.55	***
Premium	-1.62	8.02	-0.88	-1.41	19.85	-2.19	**
Duration	6.39	4.00	5.40	1.79	4.05	17.32	***

Table 27: EUR Universe: Breakdown per credit rating

	Premium							Av Spread	Av MD
Rating	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Aaa	-1.18	2.88	-0.77	1.80	1 843	-1.99	**	20.90	7.34
Aa	-0.80	3.61	-0.28	2.06	2 593	-1.29		41.03	7.02
A	-2.08	8.91	-1.85	6.69	2 704	-1.37		56.36	5.87
Baa	-2.43	12.56	-0.51	10.47	2 054	-0.99		95.64	5.43

Table 28: EUR Universe: Breakdown per sector

	Premium						Av Spread	Av MD
Sector	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat		
Agencies	-1.21	4.04	-2.34	17.02	2 152	-1.57	47.47	8.17
Covered	-0.28	1.11	0.32	1.26	880	-0.85	2.81	5.28
Financials	-1.11	6.94	-0.80	2.96	2 447	-0.90	57.04	3.73
Other Corporates	-2.93	10.13	-2.41	11.42	231	-0.50	68.80	4.05
Sovereigns	-0.30	4.39	0.36	2.59	454	-0.17	44.64	12.25
Spec finance	-1.31	8.73	0.91	4.63	595	-0.41	102.96	5.53
Supras	-2.22	3.72	-0.28	0.36	515	-1.53	27.78	9.63
Utilities	-3.41	13.36	-0.84	8.90	1 920	-1.27	71.78	6.58

Table 29: EUR Universe: Breakdown per region

	Premium							Av Spread	Av MD
Region	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Europe	-1.91	8.17	-1.35	20.11	8 250	-2.41	**	53.32	6.58
North America	2.27	4.37	0.26	0.47	359	1.11		62.65	5.23
Asia & Pacific	-0.54	8.26	-1.62	5.24	346	-0.14		63.44	4.62
Others	1.19	3.09	1.07	2.80	239	0.67		39.55	4.08

Table 30: EUR Universe: Breakdown per ESG-rating

	Premium							Av Spread	Av MD
Rating	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
A	-1.63	4.97	0.32	5.58	1 212	-1.30		51.48	7.87
B	-2.87	8.04	-5.19	45.66	1 944	-1.78	*	54.29	6.67
C	-1.74	9.03	-0.40	10.98	4 396	-1.45		53.21	6.04
D	0.56	6.22	1.01	6.83	1 310	0.37		58.26	5.94
E-F	0.21	10.10	-2.05	4.82	161	0.03		65.82	3.52
NR	-2.36	2.36	-0.54	-0.21	171	-1.48		29.20	7.87

Table 31: EUR Universe: Breakdown per E-rating

	Premium							Av Spread	Av MD
Rating	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
A	-1.66	4.15	-0.34	2.92	626	-1.13		50.87	4.90
B	-1.90	7.51	-4.59	43.36	2 950	-1.56		48.45	6.40
C	-1.56	8.71	-0.29	11.75	4 563	-1.37		55.62	6.80
D	-0.59	8.95	-0.13	4.70	723	-0.20		67.97	5.43
E-F	-1.61	7.16	-1.77	8.92	161	-0.32		68.62	3.16
NR	-2.36	2.36	-0.54	-0.21	171	-1.48		29.20	7.87

Table 32: EUR Universe: Breakdown per time to maturity

	Premium							Av Spread	Av MD
Maturity	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
1 - 3 yrs	-1.55	7.22	-2.42	13.80	1 302	-0.88		36.08	2.07
3 - 5 yrs	-1.12	5.70	-0.73	4.52	2 316	-1.07		50.02	3.99
5 - 7 yrs	-1.55	6.33	-0.35	3.50	2 043	-1.25		50.09	5.70
7 - 10 yrs	-1.36	5.46	-0.61	6.60	2 083	-1.29		51.76	8.05
10 - 20 yrs	-5.44	10.13	-2.51	6.80	873	-1.80	*	60.76	13.11
Beyond 20 yrs	0.87	18.53	-0.85	6.58	577	0.13		117.41	12.04

Table 33: EUR Universe: Breakdown per liquidity

	Premium							Av Spread	Av MD
Liquidity	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
GB less Liquid	-2.07	7.68	-2.02	26.81	4 208	-1.98	**	54.72	6.23
GB more Liquid	-1.23	8.28	-1.02	15.37	4 986	-1.19		52.85	6.52

Table 34: EUR Universe: Breakdown per liquidity

	Premium						Av Spread	Av MD
Liquidity	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat		
Different Liquidity	-1.49	8.03	-1.61	21.74	6 021	-1.63	53.84	6.08
Same Liquidity	-1.86	8.01	-1.03	16.39	3 173	-1.48	53.44	6.97

Table 35: EUR Universe: Breakdown per certification

	Premium							Av Spread	Av MD
Certification	Mean	Std dev.	Skew	Kurtosis	N. Obs	T-stat			
Not Certified	-1.26	6.03	-0.43	0.61	559	-0.56		54.26	4.43
Certified	-1.64	8.13	-1.42	19.94	8 635	-2.12	**	53.67	6.52
Certified by CBI	-3.58	9.61	-2.87	9.62	1 422	-1.59		48.89	7.10
Certified by others	-1.26	7.75	-0.81	23.36	7 213	-1.56		54.61	6.40

Table 36: EUR universe: Breakdown per time to maturity

Maturity	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All maturities	-7.30	2.39	-13.16	-7.82	-3.41	-0.45	-0.28	-3.06	***
1 - 3 yrs	-1.25	3.21	-7.43	-1.86	6.17	0.60	0.09	-0.39	
3 - 5 yrs	-0.73	6.04	-9.38	-1.47	21.23	1.70	4.06	-0.12	
5 - 7 yrs	-9.52	5.22	-23.24	-10.40	3.79	0.18	1.11	-1.82	*
7 - 10 yrs	-14.64	4.51	-24.83	-14.31	-7.19	-0.24	-0.61	-3.25	***
10 - 20 yrs	-6.20	5.41	-18.85	-5.68	2.28	-0.30	-0.96	-1.15	
Beyond 20 yrs	-5.20	4.71	-11.86	-6.24	5.38	0.89	0.15	-1.10	

Table 37: EUR universe: Breakdown per sector

Sector	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All sectors	-7.30	2.39	-13.16	-7.82	-3.41	-0.45	-0.28	-3.06	***
Agencies	-12.25	4.38	-24.82	-11.05	-5.71	-0.85	0.37	-2.79	***
Covered	-6.83	5.33	-29.99	-5.61	-2.19	-3.46	13.39	-1.28	
Financial-Institutions	-17.99	8.05	-43.98	-15.05	-8.33	-1.55	2.04	-2.23	**
Industrials	4.01	7.81	-16.26	4.52	18.00	-1.03	1.41	0.51	
Local-Authorities	4.42	6.86	-3.99	2.22	24.62	1.66	2.58	0.64	
Sovereign	-4.16	9.46	-28.04	-6.19	13.27	-0.24	0.02	-0.44	
Supranational	-0.72	2.35	-4.04	-1.62	5.92	1.50	1.54	-0.31	
Treasury	-4.26	5.69	-13.26	-4.18	6.25	0.15	-1.17	-0.75	
Utilities	-2.61	8.73	-22.66	-1.73	14.40	-0.30	-0.01	-0.30	

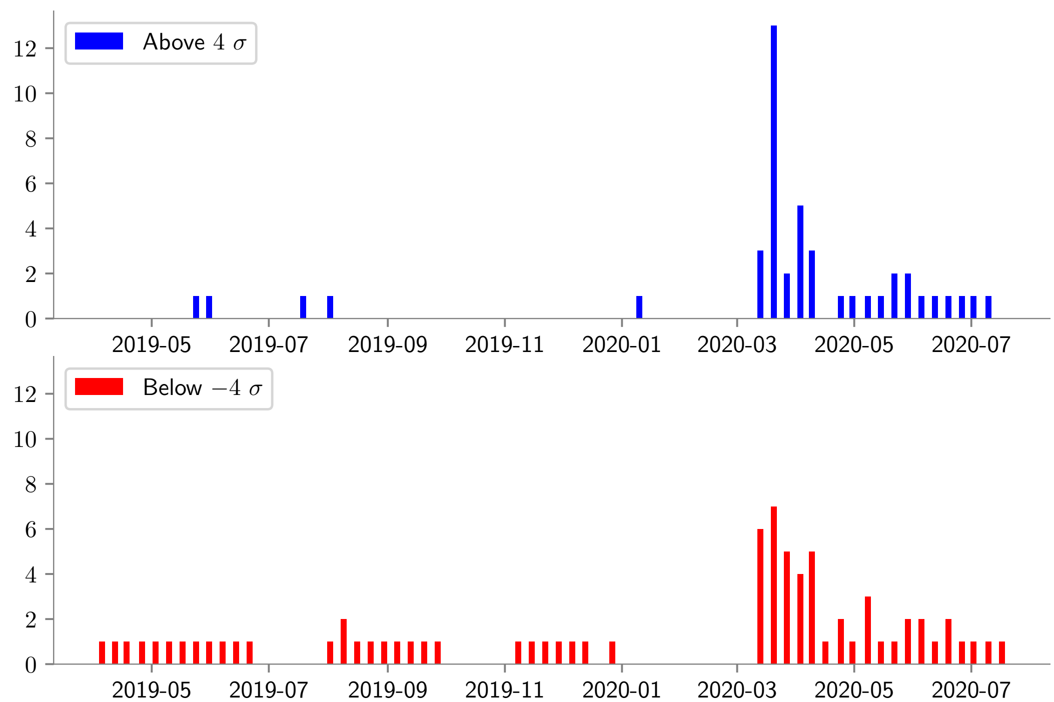
Table 38: EUR universe: Breakdown per credit rating

Rating	Mean	Std dev.	Min	Median	Max	Skewness	Kurtosis	T-statistic	
All ratings	-7.30	2.39	-13.16	-7.82	-3.41	-0.45	-0.28	-3.06	***
Aaa	-1.23	1.97	-4.03	-1.50	2.87	0.49	-0.88	-0.62	
Aa	0.64	4.52	-4.80	-1.18	15.86	0.89	0.78	0.14	
A	-9.33	4.38	-23.94	-8.18	-2.38	-1.15	1.79	-2.13	**
Baa	-27.37	13.68	-66.24	-24.49	-7.24	-1.02	0.75	-2.00	**

A.4 Figures

Figure 16 shows per date the number of the outliers whose premium is below -4σ or above 4σ, with σ is the premium distribution standard deviation.

Figure 16: Overall Premium: Number of outliers



A.5 Mathematical results

For a given bond, the relationship between the excess return R and the changes in spread yield δy follows in first approximation the relation:

$$R = -OASD \cdot \delta y \tag{5}$$

where $OASD$[56] is the spread duration. We apply Equation (5) to a portfolio of bonds and we calculate the weighted spread change δy^p:

[56] OASD is the acronym for Option Adjusted Spread Duration.

$$\delta y^p = \frac{\sum_{i \in Q} \omega_i \cdot OASD_i^p \cdot \delta y_i^p}{\sum_{i \in Q} \omega_i \cdot OASD_i^p} \tag{6}$$

where ω_i, $OASD_i^p$ and δy_i^p are the weight, spread duration and spread change for sector i, and the sums are over all portfolio sectors.

At time t, the outperformance ΔR, defined as the difference in excess returns between the green portfolio and the global bond index, can then be written as follows:

$$\Delta R = R^G - R^B = \left(-OASD^G \cdot \delta y^G\right) - \left(-OASD^B \cdot \delta y^B\right) \tag{7}$$

where R^G, $OASD^G$ and δy^G (resp. R^B, $OASD^B$ and δy^B) are the excess return, spread duration, and the overal change in spreads for the green portfolio (resp. the global bond index). Equation (7) can be rearranged to show a decomposition between allocation and selection returns:

$$\Delta R = \underbrace{-\left(OASD^G - OASD^B\right) \cdot \delta y^B}_{\text{Allocation return}} \underbrace{-OASD^G \cdot \left(\delta y^G - \delta y^B\right)}_{\text{Selection return}} \tag{8}$$

Table 39 displays the correlations between the three returns defined above. We make use of the weekly excess returns of both green portfolio and the global bond index. We deduce that ΔR is driven by the selection return since the correlation with the selection return is high (+82%) while the correlation with the allocation return is close to zero (−8%).

Table 39: Correlations between returns

	ΔR	Allocation return	Selection return
ΔR	1		
Allocation return	−0.08	1	
Selection return	+0.82	−0.64	1

In Table 40, we report for the three returns the correlation with the premium and ΔP, where ΔP is the variation in premium between two weeks. We note that both ΔR and selection return are negatively correlated with the premium and its variation and the correlations with the variation of premium are more pronounced.

Table 40: Correlations between returns and premium

	Premium	ΔP
ΔR	−0.17	−0.51
Allocation return	+0.24	+0.35
Selection return	−0.27	−0.60

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