RISK AND RETURN ANALYSIS ON GREEN BOND EXCHANGE TRADED FUNDS

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Abstract

In the last couple of years, fixed-income funds have emerged as new players in the environmental impact investing field of the capital market, however, investors have narrow knowledge about the trading activity of sustainable debt instruments. Especially, green bond portfolios are increasingly at the center of attention, but investors are less confident as its risk and return behavior remain uncertain. Thus, this paper models return volatility of existing green bond exchange-traded funds, while contrasting them with that of a vanilla bond ETF and concluding with suggestions for optimal asset allocation to green bond portfolios. The volatility of returns will be obtained by GARCH process.

To adjust my work with current economic reality, the paper also addresses the impact of Covid-19 triggered economic crisis on the performance of these ETFs and depicts their degree of persistence.

As a result of the analysis, I found that in ordinary market conditions, the green ETFs closely followed the broad bond market with daily volatility between 0.2 to 0.4 percent. During the Covid-19 pandemic, however, the broad bond market experienced 12 times higher while the green bond ETFs experienced around up to 8 times higher volatility during its peak than their normal rate.

Key words: green bond, ETF, sustainability, investment, risk, volatility

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Introduction

Oil and minerals have been profitable and favorable investment products in the financial sphere for decades, while in recent years, the financial sector has shown great interest in green technology financing or the so-called Environmental, Social, and Governance (ESG) investing which refers to the investment in sustainable, green, or social bonds. These special labeled bonds are relatively new concepts in the securities market, and they all intended to bring positive income in the future without harming the nature, but they differ in the levels of environmental impact and credit ratings.

In the last couple of years, fixed-income funds have emerged as new players in the environmental impact investing field of the capital market in the wake of increased climate bond issuances as well as the emergence of ESG indexes. Sustainable investing is now closer than ever to the broad investors and moreover, these funds have attracted many U.S. as well as European wealth investors and institutions with long-term financial and sustainable objectives.

In this research analysis, I intend to analyze the performance of fixed income exchange-traded funds (ETF) whose primary asset holdings are green bonds. These funds offer investors the opportunity to allocate money in investment grade (AAA to BBB) global green bonds guaranteed to finance climate or other environmental sustainability projects and issued by the supranational, government, and corporate issuers globally in multiple currencies.

Generally, sustainable investing is on the rise, but the broad population of financial participants is not fully aware of the characteristics of this green debt instrument and confusion exists regarding its investment risk and return. Also, in contrast to abundance of research available on sustainability financing as well as climate risk on the whole financial market, there's no research yet features the growing importance of fixed income funds in the development of green and sustainability-linked bond market and no work has studied their characteristics in the financial trading. Therefore, I would like to estimate and model volatility of price returns of the green bond ETFs as one of the risk measurements to help understand investing benefits and risks and guide potential investors in making appropriate decisions. The volatility modeling will be executed through the widely accepted "The Generalized Autoregressive Conditional Heteroskedasticity (GARCH)" modeling process.

To provide a more comprehensive understanding of their risk and return behavior, I will analytically compare green bond ETFs price returns with that of its non-green peer. This may help ETF investors in constructing the optimal risk-minimizing portfolio mix between green and vanilla bonds.

Also, I would like to mention that this paper includes a special part that addresses Covid-19 impact on the performance of these ETFs. The current global health crisis threatening the entire universe has incurred an unprecedented and exogenous shock on the economy and the financial world. The pandemic situation has dragged down the performance of not only stocks but also bonds and the whole investment community is concerned about safer and less volatile security that can endure the economic stress. Thus, I will evaluate how these green fixed-income assets are doing compared to high investment grade non-green portfolios.

Finally, the thesis ends with policy recommendations for regulatory actions that can improve conditions for green bond trading through fixed-income funds and help financial actors to increase liquidity.

The motivation of the study comes from the question of how the financial sector can contribute to the transition to a greener economy. The result of the analysis will show how ETFs adopting this new green asset into their financial services and acting as a new financial source for the environment.

For terminology, please see <u>Glossary</u>

Chapter 1 - Background to green bond market and literature review

In this section, I will refer to some important recent academic papers and reports on green bonds as well as green finance in order to provide a complete understanding of the subject.

Climate change has been the most overwhelming and of critical concern in the last decade that is setting new rules for every aspects of our life given the rapidly growing climate risk threat. Environmental issues are becoming more and more economy related as countries unite on the idea to take concrete action to promote and drive a rapid transition to a low carbon, climate resilient economy using their possible economic and financial resources. To move away from long-continued, carbon-dependent industries and create sustainable future, governments started to seek new ways of attracting investment and one of them is the green bond, the subject of this research.

Countries believe that it is crucial to encourage green financial commitment towards capital intensive sectors that need innovation for sustainable future. Europe was the first to foresee bond market's potential to finance against climate change action and European Investment Bank (EIB) first issued green debt instrument dedicated for environmentally friendly projects in 2007 to help meet its goal set under the Climate change agreement of 2005. (Pauline & Frederic, 2019) Since then, with the issuances from governments, municipalities, banks, corporations, various multilateral agencies and financial institutions, global green debt market is now totaled over \$257 billion (Climate Bonds Initiative, 2020) and green bond has grown to not only an government debt source but also has become surprisingly an attractive financial product with a high growth potential in the future. Marcin & Jakub (2018) mentioned green bonds as a kind of 'theme' bonds like, for example, war bonds which was introduced during war time.

Even though governments, banks and corporations issued bonds for building renewable plants or for their other environmentally friendly projects before, labelling bond as 'green' or certification for green bond became widely accepted only recently after "The Green bond Principles (GBP)" was formulated and published in 2014. A consortium of investment banks, such as Bank of America Merrill Lynch, Citi, JP Morgan Chase, BNP Paribas and Goldman Sachs have recognized the necessity to standardize and systemize green and sustainable bond issuance and consequently, built GBP to promote and guide the issuers and market participants. (Antje, 2015). Since then, several organizations that assesses and grants green certification to bonds have emerged around the world to increase trustworthiness for the investors.

So, what are the green projects that are allowed to raise investment through this process? As GBP defines, the eligible green project categories are the following:

- Renewable energy
- Energy efficiency
- Pollution prevention and control
- environmentally sustainable management of living natural resources and land use
- terrestrial and aquatic biodiversity conservation
- clean transportation (e.g. electric, hybrid)
- sustainable water and wastewater management
- climate change adaptation
- eco-efficient and/or circular economy adapted products, production technologies and processes
- green buildings

Except for the above-mentioned criteria for the use of proceeds to fall into one of these categories, another important requirement an issuer needs to comply is that the issuer needs to provide full transparency to its stakeholders and needs to report the project's ongoing processes

and management. Financial analysts consider this green bond's transparency feature as an innovative approach that can also set a new standard to traditional bonds which investors typically are not aware of whether the accumulated investment indeed achieved its initial purpose of issuance. (ICMA, 2018)

Normally, the green label comes at high cost for the issuers due to the multi-level inspection, however, as much as it is difficult to obtain, these bonds are rated mostly AAA, AA, A, or minimum BBB investment-grade bonds.

Figure 1 below shows the immense expansion of green bond market recognized in the last seven years and especially, the last year was a historic year for this segment that according to the "Climate bond initiative" (CBI), an international organization for green bond principles and climate bonds standard, volume and the issuance rose sharply by over 50%, from \$171bn in 2018 to \$257.7bn in 2019 with strong rates from Europe and Southeast Asia.



Figure 1. Global green bond and loan issuance

Source: ASEAN Green Finance State of the Market report, 2019, Climate Bonds Initiative From the supply side perspective, the most active issuers are the Supranational (e.g. EIB,

multinational corporations driven by their corporate social responsibility policy are also quickly emerging as the underwriters.

Bert and Sophie (2019) discussed the role of banks in driving sustainable development banks and found that banks with high sustainability scores are associated with significantly less default risk and so as corporations because banks sustainability performance can spill over to the whole financial system. Therefore, in the last couple of years, more and more financial institutions are concerned about climate-related risks to their profitability and this led to growing number of institutional investors to consider greening their portfolio and participate in green financing.

CBI is a non-profit organization based in London that has been actively tracking green bond market since 2016 and publishes reports and information to increase awareness of the sustainable investing theme to the public. Two of the important reports to look at are their annual "Green Bond Treasurer Survey" and "Green Bond European Investor Survey".

In "Green Bond Treasurer Survey 2020", 86 treasurers (or equivalent role) from a variety of institutions were asked to share their experiences of issuing green bonds. The results of this survey suggest that green bonds offer organizations the opportunity to prepare for the impacts of climate change, initiate the transition process to a greener business model or fund green activities by providing access to low cost capital via well understood and labelled products. More than two-thirds of respondents said that their green bond brought new investors and gained more attention than their vanilla equivalents. Therefore, 88% of respondents said they will issue more green bonds, but named standardization as their main obstacle given it usually takes around a year to plan and issue one.

Regarding demand side, in "Green Bond European Investor Survey 2019", CBI surveyed 48 of the largest Europe-based fixed income asset managers to gain a comprehensive understanding of how the fixed income investment community is addressing or intending to address climate change through investment decisions. Main results of the survey were that all respondents are concerned about potential climate risks, and thereby, are keen to be involved in financing of sectors where energy transition is needed the most. Almost two-thirds of respondents (64%) said they prefer green bonds where available and competitively priced (over vanilla equivalents) and 93% of respondents preferred the corporate issuance the most.

Investors can invest in green securities in the primary market as well as in the secondary market through mutual funds or exchange-traded funds. In addition, a rising rate of green issuances prompted the world's biggest stock exchanges (17 stock exchanges as of January 2020) in creating a dedicated section for green bonds that enable secondary market players to provide liquidity easily to potential investors. (CBI, 2020) The demand is mainly realized in European pension funds and institutional investors with also fast-growing interests from individual investors of environmental concerns. But it's no secret that lower liquidity can be found in the secondary market for green bonds compared to traditional bond since current investors involved in green bond trading mainly are impact-oriented that selling off before maturity is less common. (Pension Fund Service, 2017)

Chapter 2 – Investing in green bonds via ETFs

Even though exchange-traded funds are a relatively young segment of the capital market, the market is now \$6.3 trillion industry globally with a 32% annual growth rate (BBH, 2020) and are regarded as sophisticated investment vehicle with highly structured and diversified range of products.

As clear from its name, ETF shares are traded on exchanges just like other publicly traded securities and functioning of ETFs have brought numerous significant innovative and transformative effects on stock, bond, and commodity trading over the last decade. Investing in ETF is an easy, cost-effective, and efficient way of investing that the underlying holdings are constantly changed and monitored by professional asset managers. Moreover, as most of the ETFs are index funds, the investor will have exposure to the holdings listed in the benchmark index, and thereby, it diversifies away risks unlike owning an individual share of a particular company. (Luca, 2020)

Ilan Guedj and Jennifer Huang (2014) compared performance of 320 ETFs against 296 OEFs (Open-Ended Mutual Funds) over the period of 1992-2006. As a result, they derived various important conclusions and one of the conclusions say that ETFs are efficient vehicle when the benchmark is specific to certain type and holds less liquid assets.

ETFs are experts in offering investible products well-fitted to modern investors' demand and the overwhelming sustainability trend in recent years posed excellent occasion for asset management firms to expand their range of services and create new business opportunities. By the virtue of big asset management firms like Blackrock and Vanguard group who took the initiatives of the establishment of ESG fixed-income funds, the ESG market has come closer to average investors who are interested in contributing to the creation of climate-resilient future. ETF market now circulates and manages \$52 billion worth ESG products internationally. (BBH, 2020)

However, ETFs dedicated solely for green bonds were established only in the past three years and as soon as these ETFs were launched, they received significant attention and positive response from media, economic analysts, financial actors as well as wealth and institutional investors, particularly pension funds. (World Bank, 2017) Total five green bond ETFs are operating currently on the market with combined assets under management (AUM) amounts to half-billion as of June 2020 and analyzing their characteristics and performance is the core intention of my research.

We have historical data of up to only 3 years which may not enough to do advanced empirical analysis yet, but it is still essential to evaluate their performance so far given growing investors need for market-grounded analysis on this sustainable financial asset.

Even though these funds are called "green bond" funds, they don't 100% invest in green bonds: 80-90% of their holdings are actually green bonds certified by third party agencies and the remaining are climate-aligned sustainable or social bonds which are mostly used for hedging purposes. Moreover, the most noteworthy feature of these funds is that since their primary asset, green bonds, are typically rated investment grade or AAA-BBB, these ETFs are extremely high credit quality funds. Besides, the five ETFs track three different benchmark indices of the green bond, and four of them follow passive and one follow active management strategy. Table 1 shows a brief overview of the funds with some well-known performance metric

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Table 1. Overview of green bond ETF

Benchmark	Solactive Green Bond EUR USD IG (the Index)	S&P Green Bond U.S. Dollar Select Index.	Bloomberg Barclays MSCI European Green Bond Issuer Capped EUR Index	Bloomberg Barclays MSCI Global Green Bond Select (USD Hedged) Index.	Bloomberg Barclays MSCI Euro Green Bond Index	as of 01/06/2020
Duratio n	7.87	5.39	8.01	7.97	8.98	
Quality (AAA-BBB)	98.98%	76.56%	94.20%	90.98%	98.78%	
Expense Ratio	0.25%	0.20%	0.35%	0.20%	0.30%	
Closing Price	54.42	26.98	106.4	54.04	25.75	
UI I	0.98%	1.92%	-0.91%	1.61%	-0.35%	
Total Assets	€301.08 M	\$31.48 M	€21.31 M	\$75.51 M	€21.14 M	
Fund curre ncy	Euro	USD	Euro	USD	Euro	
Launch date	22-Feb-17	3-Mar-17	20-Nov-18	13-Nov-18	29-Apr-19	
Type	Passive	Passive	Passive	Passive	Active	
Fund company	LJZQL International Asset Management S.A.S	Van Eck Associates Corporation	Structured Invest SA	BlackRock Inc	Franklin Templeton International Services S.g. L.L	
ETF Name	LXX. Green Bond (DR) UCITS EIF	Langer Vectors Green Bond EIF	UC MSCI European Green Bond EUR UCITS ETF	iShares Global Green Bond ETF	Franklin Liberty Euro Green Bond EIF	
Ticker	CLIM	GRNB	ECBI	BGRN	FLRG	

Chapter 3 – Research methodology

Green bond ETFs or fixed-income socially responsible funds are relatively new concepts and there is an absence of works on studying their performance and return volatility. However, green bond market volatility was studied by few analysts previously using indices. Linh Pham (2016) performed univariate GARCH modeling on S&P green bond index for the period of 2010 to 2015 and multivariate GARCH modeling to first study it in association with the conventional bond market and found a positive correlation between the two.

Following this paper, Daehyeon, Jiyeon & Doojin (2020) further examined whether the stock market shocks spill to the green bond market by including S&P 500 Index and achieved a quite interesting conclusion that it does respond to positive shocks but negative shocks do not cause the green market to move downwards.

My analysis will be based on Linh Pham's univariate modeling methodology as well, however, I am contributing to the area by first studying performance and return volatility of green bond funds that buy and sell on the market.

Furthermore, since 2015, the green bond market has grown to more than six times and market sentiment has changed significantly, but the research studies are lagging from the trend. Thus, to fill this gap, by studying green bond ETF performance and return volatility through the most reliable, convenient and robust GARCH model, my paper intends to contribute to the awareness of overall risk and return behavior of the green bond as an ETF asset, especially in this time of unprecedented event happening in the global economy where everyone is concerned over safe, long-term investment opportunities.

The volatility of financial assets is a primary indicator of risk underpinning many investment decisions in financial practice that tells the range of price change a security experience over traded time and measured by the standard deviation of returns.

There's no firm fact that high or low volatility is good; however, many researchers argue that a stable and low volatility strategy pays off in the long run. On the contrary, high volatility strategy can quickly deliver nourishing profits in the uprising market, however, as high return does not stand for a long time, an investor can lose quickly what it gained previously that often risk-taking, experienced, and optimistic investors would pursue. (Ken ,2015)

Hence, I am interested in what portfolio strategy these green ETFs follow for this environmentally friendly asset of 5 to 10-year maturity and I would like to obtain a volatility model.

A simple standard deviation of returns is not enough for econometric volatility analysis, we need rolling standard deviation to estimate time-varying conditional variance (σ_t^2) as well as volatility clustering¹ observation for the modeling which GARCH technique can do. GARCH was first formulated by Bollerslev (1986) and Taylor (1986).

To analyze bond price returns in a standardized manner, we assume that the conditional covariance matrix follows a univariate GARCH process which allows the conditional variance to depend on the previous lags. The classical univariate GARCH (p,q) process is the following mathematical formula:

¹Financial time series often exhibit a behavior that is known as volatility clustering or autoregressive conditional heteroskedasticity: the volatility changes over time and its degree shows a tendency to persist, i.e., there are periods of low volatility and periods where volatility is high.

 $z_t \sim iidN(0,1),$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^q (\alpha_i \varepsilon_{t-i}^2) + \sum_{i=1}^p (\beta_i \sigma_{t-1}^2)$$

Where:

Standardized residual returns: z_t (i.e. iid random variable with zero mean and variance 1)

The number of lag variances: p > 0,

The number of lag residual errors: q > 0,

$$\alpha_0 > 0, \alpha_i \ge 0, i=1, ..., q, \beta_i \ge 0, i=1, ..., p$$

One-step ahead volatility equation for GARCH (1,1) model:

Conditional mean equation: $r_t = \mu + \varepsilon_t$,

Conditional variance equation: $\sigma_t^2 = \omega + \alpha_I \varepsilon_{t-1}^2 + \beta_I \sigma_{t-1}^2$

Where:

Daily return:
$$r_t = ln \ (P_t / P_{t-1})$$
Average return: $\mu_t = \mu \ (constant)$

volatility persistence: $\alpha_1 + \beta_1 < 1$

Annual volatility is calculated by multiplying rolling 21-day volatility or moving average of 21-day volatility by $\sqrt{252}$ accounting only trading days.

Data

This research is focused on ETFs that holds green bond as their primary financial asset and I gathered daily closing price series data for each from Yahoo Finance, an online financial data platform, for further econometric analysis for estimating return conditional variance.

Limiting Factor

Because all of them were launched very recently, a limited range of historical price and information are a clear limiting factor for my study. Nevertheless, we should recognize that the green bond is a new evolving market or new segment of the fixed income market that are still new concept for most investors.

Chapter 4 – Empirical results and analysis

As a first look for the return series, I present summary statistics of returns transformed through first differentiation of their natural logarithm in Table 2.

Table 2. Returns basic statistics

Ticker	Observation period	Minimum	Maximum	Mean	Variance	Stdev	Skewness	Kurtosis
CLIM	2017-02-22 to 2020-	-0.045856	0.033662	0.000096	0.000015	0.003861	-1.718283	40.943546
	05-27							
GRNB	2017-03-08 to 2020- 05-27	-0.016715	0.017772	0.000117	0.000011	0.003344	-0.194752	2.348045
BGRN	2018-11-28 to 2020- 05-27	-0.017189	0.009161	0.000186	0.000009	0.002928	-1.630488	7.757583
ECBI	2018-11-21 to 2020- 05-27	-0.015375	0.009024	0.000172	0.000008	0.002884	-1.345919	6.234317
FLRG	2019-04-30 to 2020- 05-27	-0.030335	0.007788	0.000101	0.000009	0.002972	-4.482976	42.66248

From the summary return statistics, I observe that distributions of daily returns are clearly nonnormal for all ETFs with negative skewness and excess kurtosis. CLIM has the highest mean return and standard deviation while FLRG have highest skewness and kurtosis.

4.1. Volatility modelling for each individual ETFs

In this section, each ETFs independently modeled through the first order GARCH process which was explained in the previous section. Optimal parameters of the models were computed using 'rugarch' package in R and Python programming and the outcomes are depicted in figures respectively with brief analytical explanations.

Lyxor Green Bond (DR) UCITS ETF (ticker: CLIM)

Lyxor Asset Management Group became the first ever investment company to launch ETF that is certified as "green bond" in March 2017. The ETF is based in Luxembourg and passively replicate its benchmark as close as possible following both its upward and downward movement that their tracking error was 0.08% last year. The fund's investing area is Europe and invests in only labelled green bonds confirmed by the CBI.

Their main holdings include European Investment Bank's renewable energy and energy efficiency projects as well as Grand Paris Express project by Société du Grand Paris for renovating transport infrastructure of Paris towards minimum greenhouse gas emissions and Orsted, a Danish energy company's transformation from a black (coal, oil, and gas-based) energy business to a green one.

	Estimate	Std. Error	t value	Pr(>/t/)
ти	0.00016	0.00008	1.993	0.046258
omega	0.000001	0.00000	2.9222	0.003476
alpha1	0.210162	0.027602	7.6141	0.000000
beta1	0.632296	0.027713	22.816	0.000000

Table 3. CLIM: GARCH (1,1) model optimal parameters

 β_1 parameter implies that current value of volatility is 63% dependent on its previous value as well as the estimated volatility persistence is very high indicating GARCH (1,1) as a good fit for the series.

Figure 2. CLIM daily conditional volatility



Since inception, the fund delivered more or less stable returns over the time between 0.002 to 0.004. The noticeable jump in volatility corresponds to COVID-19 pandemic time when the volatility reached 0.023 during its peak.

VanEck Vectors® Green Bond ETF (ticker: GRNB)

VanEck, one of the earliest and leading investment management firms, entered to green bond market almost at the same time as Lyxor but replicates S&P Green Bond U.S. Dollar Select Index. The fund offers its investors exposure to global U.S. dollar-denominated environmentally friendly bonds designated as "green" by the Climate Bonds Initiative and issued by the supranational, government, and corporate issuers. In addition, GRNB holds up to 20% sub-investment-grade issues.

This fund is much more heavily weighted to the U.S., which accounts for 31.9%, China is next at 15.38% and supranational organizations account for just over 13% out of \$301 million AUM.

	Estimate	Std. Error	t value	Pr(>/t/)
ти	0.000079	0.000205	0.38392	0.701037
omega	0.000001	0.000002	0.53492	0.592708
alpha1	0.057314	0.011994	4.77855	0.000002
beta1	0.917241	0.01467	62.52673	0.000000

Table 4. GRNB: GARCH (1,1) model optimal parameters

In this series, the volatility dependence on its first lag is quite high and significant at 91.7%.



Figure 3. GRNB daily conditional volatility

GRNB showed also stable and same variance over the time as CLIM but the returns were much less impacted by the pandemic that the peak was only 2 times higher than the ordinary times.

The iShares Global Green Bond ETF (ticker: BGRN)

Blackrock is the world's one of the biggest ETF providers based in the U.S with actively operating 1042 ETFs globally. In the last few years, the firm is ambitious in leading the ETF business within the sustainability area and introduced 14 ESG products with \$3.6 billion AUM

in total. The group's iShares Global Green Bond ETF is green bond focused and provides broad exposure to green assets listed by Bloomberg Barclays MSCI Global Green Bond (USD Hedged) Index. To be eligible for inclusion in the index, bonds must carry an investment-grade rating and evaluated by MSCI's Green Bond Principles.

There are 1.5 million units outstanding, with an average daily trading volume of 15000. The portfolio's effective duration is 7.9 years which is much higher than that of GRNB but it offers superior credit quality (90.8% investment grade).

The Ishares fund exclusively pays attention to their impact-oriented investors and constantly provide transparency reports. In their latest report, BGRN reported that one million US dollar investment in their green portfolio would equal to 694Mwh/year of renewable energy generated or prevent 1331tCO2/a year emissions. (Blackrock, 2019)

Table 5. BGRN: GARCH (1,1) model optimal parameters

	Estimate	Std. Error	t value	Pr(>/t/)
ти	0.000348	0.000124	2.806140	0.005014
omega	0.000001	0.000001	0.372190	0.709753
alpha1	0.122628	0.034512	3.553210	0.000381
beta1	0.813409	0.031378	25.922690	0.000000





UC MSCI European Green Bond EUR UCITS ETF (ticker: ECBI)

Structured Invest, a subsidiary of UniCredit Bank AG, has partnered with MSCI ESG to launch the UC MSCI European Green Bond EUR UCITS ETF, the first ETF to enable investors to access a broadly diversified range of liquid euro-denominated green bonds. The fund achieves the desired exposure by fully replicating also Bloomberg Barclays MSCI European Green Bond Issuer Capped EUR Index.

The same withholding rules apply as the iShares fund but ECBI's investment is limited by issues from one of the following countries: Austria, Denmark, Finland, France, Germany, Italy, Lithuania, Netherlands, Norway, Poland, Spain, Sweden, and the United Kingdom.

	Estimate	Std. Error	t value	<i>Pr</i> (>/ <i>t</i> /)
ти	0.000309	0.000109	2.836500	0.004561
omega	0.000000	0.000001	0.251610	0.801339
alpha1	0.146959	0.045033	3.263340	0.001101
beta1	0.836219	0.037526	22.283770	0.000000

Table 6. ECBI: GARCH (1,1) model optimal parameters

Figure 5. ECBI daily conditional volatility



ECBI had 0.1 basis point higher volatility on average during the second half of 2019 compared to its first half which had 0.25 basis points average daily variance.

Franklin Liberty Euro Green Bond UCITS ETF (ticker: FLRG)

The fund is another first in green ETF business that it has an active management strategy for its green bond portfolio in the European market. FLRG invests 30% in bonds with concrete climate-aligned social bonds for its hedging purposes and the fund's share is priced cheapest at \$25 among above ETFs. Bloomberg Barclays MSCI Euro Green Bond Index is used as a reference for performance.

	Estimate	Std. Error	t value	Pr(>/t/)
ти	0.000313	0.000227	1.379600	0.167695
ar1	0.615981	0.142382	4.326200	0.000015
ma1	-0.25687	0.171321	-1.499300	0.133790
omega	0.000001	0.000000	4.071400	0.000047
alpha1	0.166999	0.044147	3.782800	0.000155
beta1	0.712445	0.028898	24.653600	0.000000

Table 7. FLRG: ARMA (1,1)-GARCH (1,1) model optimal parameters

Figure 6. FLRG daily conditional volatility



Before the recent pandemic when the highest volatility of around 0.012, the ETF's returns were mostly positive and daily volatility was quite stable between 0.002 to 0.003.

4.2. Comparison with non-green ETF

From the above information, we see that these ETFs' investment opportunities are limited by their ESG investment strategy and there is a broad market opinion that having an ESG focus may result in poorer performance than the general securities market. To examine this questionnaire, I have selected an ETF that best represents the broad bond market and compared its return volatility in this section.

Vanguard Total Bond Market Index Fund ETF (ticker: BND)

This ETF was established in 2007 and tracks one of the major standard benchmarks, Bloomberg Barclays U.S. Aggregate Bond Index, the most widely used U.S. total investment-grade bond benchmarks for decades. Its tracking difference from the benchmark is only -0.11% on average that we can rely on as an indication for the broad conventional bond market.

The index includes all major types of bonds, including taxable corporate bonds, treasury bonds, and municipal bonds. BND has \$269 billion in assets and is regarded as the best bond ETFs for cheaper access to extremely high-quality debt instruments that nearly 68% of its assets are rated AAA. The management fee is 3.5 basis points.

Table 8. BND: GARCH (1,1) model optimal parameters

	Estimate	Std. Error	t value	Pr(>/t/)
ти	0.000084	0.000066	1.277830	0.201310
omega	0.000001	0.000001	0.577530	0.563580
alpha1	0.201581	0.008590	23.466200	0.000000
beta1	0.674560	0.006556	102.899000	0.000000

Figure 7. BND daily conditional volatility



To compare the performance, I have conducted the same GARCH modeling for BND but limited the time horizon to 3 years considering the first green bond ETF is 3-year old.

Figure 7 tells that same as green bond portfolios, the daily conditional variance range is observed between 0.2 to 0.4 basis points in ordinary market times but to depict it more clearly, I have plotted both return and return volatility (annualized) series of all ETFs in single figures below.





Figure 9. Annualized return volatility of green bond ETFs vs BND, GARCH (1,1)



Figure 9 summarizes the result of univariate GARCH modeling for green and non-green bond ETFs between the period of May 2019 to May 2020.

I see that the green bond ETFs very closely followed the broad market movement and the differences in volatility between the green and the non-green ETF was decreasing more in the last quarter of 2019 until March 2020 which can be possibly explained by growth and an increased liquidation of the green credit market in the last quarter of 2019 (Figure 1). The March 2020 and onwards picture suggests another interesting conclusion and I will discuss it separately in the following part.

4.3. Covid-19 effect on performance of ETFs

A recent unprecedented event in the capital market triggered by the COVID-19 global health crisis has dragged down the performance of not only stocks, commodities but also bonds. Just as oil demand plunged to the record low, the securities market has also experienced extreme liquidity issues as investors preferred holding cash and began to withdraw their investments. Nevertheless, this pandemic situation provides a great opportunity to empirically test the performance of green bond portfolios. To address this historical impact on the performance of green bond ETFs as well as on a standard vanilla bond ETF, I depicted Figure 9 as starting from March when the market started shaking.

Figure 10. Covid-19 effect on annual volatility of green bond ETFs vs BND, GARCH (1,1)



From Figure 10, we see that BGRN and ECBI who tracks Bloomberg Barclays MSCI Global Green Bond Select Index as well as GRNB which replicates S&P Green bond Index performed the lowest and very similar volatility series. FLRG managed to quickly recover from the negative volatility through its active management after experiencing a sudden surge in volatility in the first two weeks of March. CLIM, the first and biggest green ETF, faced the highest volatility among five green ETFs and is slowly returning its normal rate. As we observed from the previous graph that BND showed slightly lower volatility in normal market times than green bond ETFs, however, when the Covid-19 driven extreme supply and demand chain disruptions occurred in the economy alongside with high degree of uncertainty, BND depicted higher volatility with the peak at 48% in mid-March.

To summarize, the Covid-19 brought 12 times higher volatility to the broad bond market during its peak while green bond ETFs experienced around up to 8 times higher volatility.

These two comparison figures imply us that choosing environmentally conscious investment option may not mean more risk not only in normal market times but also in the shaky times.

Chapter 5 - Conclusion

The following four objectives were determined to examine in this research:

- Introduce green bond trading practice through fixed-income investment vehicles
- Perform GARCH modeling for historical data of the green bond ETFs to understand price, return, and volatility.
- Contrast green bond and non-green ETFs in terms of their change in return
- Test these ETFs' ability of persistence during non-ordinary, downward economic conditions

My hypothesis was that green bond portfolios would provide a stable and equivalent return as its non-green peer but when temporary shock occurs in the market, returns for green bond ETFs would be less volatile than that of non-green bond ETFs concerning its impact-oriented, sticky investors.

This paper uses daily price data to construct daily and annual volatility series and the readers should note that the analysis focused on purely empirical econometric computations of return volatility as one of the risk measurements of ETFs and other risk factors or idiosyncratic risks are not taken into account. The primary data analysis was performed using "rugarch" package in R and Python programming.

The study is designed to help provide investors with an understanding of green asset investing benefits and risks and guide them in making appropriate decisions. The results might appeal to the growing number of investors who are incorporating ESG factors or criteria into their investment analysis, allocation, risk measurement, security selection, and performance attribution process. The quantitative results may be used to construct the optimal riskminimizing portfolio mix between green bonds and vanilla bonds for ETF investors. My research findings are:

- The first ETF dedicated to the green bond was introduced in March 2017 and today there is a total of 5 green bond ETFs are operating in the U.S and Europe. The ETFs differ in their underlying benchmark, fund structure, geographic focus, currency focus, etc.
- All green ETFs have relatively small capitalization and total AUM amounts to \$500 million as of June 1st, 2020.
- On average, 90% of the holdings of our representative five funds are rated investment grade and green bond shares are 70-90%.
- The average duration of the holdings is 5-9 years, FLRG holding has the longest maturity which implies that it's more susceptible to interest rate changes.
- The funds make monthly distributions, the amount and time of which may vary.
- Owners of the green bond shares regularly get reports on the funded projects achieved environmental impact.
- Management fees are between 0.20-0.35% which are quite high compared to plain vanilla bond ETFs.
- In ordinary market conditions, the ETF's returns were mostly positive and daily volatility was quite stable between 0.2 to 0.4 percent. GRNB has the highest average volatility and FLRG the lowest since its inception.
- Figure 9 strengthens our belief that investing in green bonds is a straightforward way to more sustainably invest in fixed-income without hurting financial gains.

• The last obtained figure clearly shows that Covid-19 induced extreme variation in returns for all portfolios. The sharp contraction in markets due to recent pandemic adversely impacted all funds significantly, however, a regular bond fund experienced more acute negative volatility during the period. Covid-19 brought 12 times higher volatility to the broad bond market during its peak while green bond ETFs experienced around up to 8 times higher volatility.

There may be 3 possible underlying reasons why the pandemic impact was less for green bond portfolios:

- First, green bond underwriters historically tend to have lower default risk regardless of their ESG profile given their size and well-established capital structure.
- Second, a big share of these green funds is owned by insurance companies and pension funds which have long-term investment strategy along with sustainable-impact objectives and thereby, less likely to withdraw their investment when temporary shock occurs on the market
- Third, green bond issuances are rarely from recreation, travel, transportation, services as well as oil sectors which are the ones being hit hard in the COVID-19 crisis.

All in all, the analysis proposes that these ETFs are closely following regular bond equivalents' movement in normal times of the market but showing greater persistence during turbulent times. And I believe this recent experience has triggered the market participants to look ahead and stresses the importance of taking a long-term, ESG factors when evaluating the credit quality and resilience of security.

Chapter 6 - Policy recommendation

By the virtue of improved regulation, guidelines and government support, green market size has increased exponentially over the years and thus, opened door for secondary market actors to start engaging in the green business. However, there are still several challenges the existing funds face and prevent new players to enter the business.

First and foremost is the lower liquidity. There is strong global demand from institutional investors and insurance companies with environmental goals, however, the supply of this green debt instruments remain unmatched with the demand. The issuance increase in the past was mostly recognized in the developed countries but there is lack of initiatives from developing countries. Besides, less frequent green issuance may also due to the cost and time of receiving green certification. Therefore, it is important to encourage engagement of international governments and corporations in globalizing the green debt market, and harmonizing certification process would make green debt securities to be traded efficiently as regular ones.

Second, sustainability investing is becoming fashionable, but confusion exists and there is lack of awareness of the benefits and financial characteristics of this asset class. Hence, it will be a smart step to exploit ETF vehicles' excellent tracking ability, marketing strategy, competitive return as well as transparent nature in receiving broad recognition and encourage uptakes in the market. I believe that ETFs could see the potential growth in this investment area in the coming years and pathways laid out by these ESG ETFs will soon be followed by other asset management firms that it's only a matter of time ETF market take over the sustainable investing marketplace and bring significant change in its development, offering more range of ESG products.

Glossary

Green bond- (also known as *climate bonds*) are any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects that provide clear environmental benefits.

Social bond - bonds that raise funds for new and existing projects with positive social outcomes, such as loans to small and medium enterprises for employment generation in lower-income regions, loans to social housing projects, and financing the delivery of healthcare, etc. *Sustainable bond*- are bonds where the proceeds will be exclusively applied to finance or refinance a combination of both Green and Social Projects.

Environmental, Social, and Governance (ESG) - refers to the three central factors in measuring the sustainability and societal impact of an investment in a company or business. These criteria help to better determine the future financial performance of companies (return and risk).

Sustainable investing- also known as socially responsible investing, is the process of incorporating environmental, social and governance factors into investment decisions.

The Green Bond Principles (GBP) - are voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the Green Bond market by providing issuers with guidance on the key components involved in launching a credible Green Bond

Benchmark Index – is a standard against which a security's performance is compared with securities of the same or similar class and includes group of securities representing some aspect of the total market.

Exchange traded fund (ETF) - is an investment fund traded on stock exchanges, much like stocks. An ETF holds assets such as stocks, commodities, or bonds and generally operates with an arbitrage mechanism designed to keep it trading close to its net asset value

Investment grade bond - or high-grade bonds that are believed to have a lower risk of default and receive higher ratings by the credit rating agencies, namely bonds rated BBB or above. These bonds tend to be issued at lower yields than less creditworthy bonds.

Sub-investment-grade - a credit rating below investment grade

Expense ratio - the amount that an investment company charges investors to manage an investment portfolio, a mutual fund, or an exchange-traded fund. The ratio represents all management fees and operating costs of the fund.

Tracking difference - is the discrepancy between ETF performance and index performance that tells you the extent to which a fund has out or underperformed its benchmark index.

Covid-19 - An outbreak of an infectious respiratory illness caused by a novel coronavirus, was first detected in China on December 2019 and has spread globally. This outbreak has resulted in travel restrictions, closed international borders, prolonged quarantines, cancellations and supply chain disruptions etc.

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