Journal of
Risk and Financial Management

MDPI

Review

Green Bond: A Systematic Literature Review for Future Research Agendas

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Abstract: Green bonds (or climate bonds) are one of the most used sustainable investment instruments, and under the Paris Climate Agreement of 2015, the climate bond market is expected to thrive in the near future. Green bonds are gaining increasing popularity between environmentally responsible investors, as well as investors who "simply" attempt to benefit from portfolio diversification, including green issuances, that are close to other fixed bonds. This paper aims to take advantage of previous literature contributions on the green bond market to indicate the way forward for future research. Herein, through a systematic literature review on the green bond market, our ultimate goal is to provide investors, main markets actors, and policymakers with some helpful insight on the role of environmental investments in reshaping the financial markets and fostering the sustainability of the economy.

Keywords: green bond; systematic literature review; climate bond

Citation: Cortellini, Giuseppe, and Ida Claudia Panetta. 2021. Green Bond: A Systematic Literature Review for Future Research Agendas. *Journal of Risk and Financial Management* 14: 589. https://doi.org/10.3390/jrfm14120589

Academic Editor: Babu George

Received: 4 November 2021
Accepted: 2 December 2021
Published: 7 December 2021

1. Introduction

With the expression *green bond*, we generally refer to a fixed-asset class, which is similar in the financial structure to conventional corporate and government bonds (pricing mechanism, rating, etc.) that differ in the use of their proceeds earmarked by the issuer in projects with environmental benefits (Reboredo 2018). Green bonds work with any bond formats, such as use-of-proceeds bonds (or plain vanilla bonds), project bonds, securitized bonds (ABS), etc. The form assumed by green bonds affects the scope of legal recourse in the case of issuer default (see Table 1).

The year of 2007 is generally considered the year of climate bonds' birth: 14 years ago, the European Investment Bank (EIB) issued the first green bond, the new fixed-income instrument labelled as the Climate Awareness Bond (CAB), which raises around 0.9 USD billion funds to allocate in eligible green projects. From that time, green bonds have continuously gained importance among the set of green financial instruments available on the market. According to the Climate Bond Initiative (CBI), in 2020, approximately USD 290 billion[1] were issued, an increase of +9% compared with 2019 (see Figure 1).

In the early stages (2007–2013), the green bond market was substantially driven by supranational issuers—multilateral development banks (i.e., EIB, World Bank)—probably lacking a world agreed definition of green bond and common ground of settings for this emergent instrument (Monk and Perkins 2020).

A clear, unmistakable landmark of green bond market development was the release of Green Bond Principles in 2014: A voluntary coalition of banks, issuers, and investors named ICMA[2] developed guidelines and issued non-prescriptive recommendations for the best practices in the market, the so-called "Green Bond Principles" (GBP). This first internationally recognized standard became a key catalyst for subsequent market development and the basis for many existing green labels (Ehlers and Packer 2017)[3]: The distinction between labelled and unlabelled bonds, sponsored by the GPB, boosted the growth of green bonds issuance. Following the release of GBP, there was a significant increase of

green bond issuances of about 36.6 billion USD, more than triple the 2013 issuance (Climate Bond Initiative (CBI) 2015). From that year, government and private institutions entered this market[4] and played a crucial role (Ehlers and Packer 2017; Broadstock and Cheng 2019; Monk and Perkins 2020)[5].

Table 1. Main features of the most used types of green bonds.

Green Bond Type	Key Features
Use-of-Proceeds Bond	• Proceeds are earmarked for green projects in the issuer's portfolio • Recourse it to the issuer's entire balance sheet
Use-of-Proceeds Revenue Bond	• Proceeds are earmarked for green projects in the issuer's portfolio • Recourse is limited to an issuer's pledged revenue stream, not its entire balance sheet
Project Bond	• Proceeds are earmarked for a specific project or group of projects • Recourse is limited to those project(s) assets and balance sheet
Securitized Bond	• Bond is collateralized by one or more revenue-generating green project, e.g., loan repayments on rooftop solar packages • Project revenue is used to repay the bond, and recourse is limited to the collateralized asset

Source: Jones et al. (2020).

The setting of GBP led to the higher market integrity, and it set a global standard to define a "green bond". In addition, it stated an issuance framework (based on transparency, pre-issuance disclosure, post-issuance reporting, third party verification) to help the investors assess the greenness of the climate bonds and the reliability of the issuers. Moreover, the Climate Bond Initiative (CBI) established its standard (Climate Bond Standard—CBS). Based on GBP, the Climate Bond Standard went further, setting a clear taxonomy of eligible green projects and requiring an external verification on pre- and post-issuance disclosure to obtain the CBS certification. Although the GBP created a well-recognized standard, many regional green bond regulations have arisen. Several regional standards are based on the general approach of GBP, but they have their characteristics in terms of eligible green projects and external verification. The context in which issuers (and investors) move assets is still fragmented from a regulatory point of view and costly.

Some of the leading international and regional green bond frameworks/guidelines are synthesized in Table 2.

The framework/guidelines compliance and green certifications involve additional costs for green bond issuers in the range of 0.3–0.6 bps of the total amount (Hachenberg and Schiereck 2018). These charges could be challenging for small issuers (Forsbacka and Vulturius 2019), especially considering, on the one hand, the possible limited area (geographical) of the application of each framework and, on the other hand, the reduced possibility to reach a more significant number of investors.

Table 2. Main green bond standard initiative worldwide.

Agency (Acronyms)	Year (Version)	Initiative	External Review	Use of Proceeds Allocation
International Capital Market Association (ICMA)	2014 (v 1) 2018 (v 2)	Green Bond Principles	Voluntary	Do not provide a close taxonomy of eligible green areas
Climate Bond Initiative (CBI)	2015 (v 2.0) 2017 (v 2.1) 2019 (v 3.0)	Climate Bond Standard	Mandatory	Climate Bond Taxonomy
EU Commission	December 2019	EU Green Bond Standard	Mandatory	• EU green bond proceeds shall finance projects contributing substantially to at least one of the Environmental Objectives as defined in the EU Taxonomy Regulation, not significantly harming any of the other objectives. • Projects shall be complying with minimum safeguards (e.g., international bill of human rights)
People's Bank of China (PBOC)	June 2020	China Green Bond Endorsed Project Catalogue	Voluntary, recommended	Official list of eligible green areas (China Green Bond Endorsed Project Catalogue)
ASEAN Capital Market Forum (ACMF)	2018	ASEAN Green Bond Standards	Voluntary, recommended	Do not provide a close taxonomy of eligible green areas

In 2015, the Paris Agreement which contains 195-countries' commitments to reduce global warming through a first-ever legally binding global climate deal (Bachelet et al. 2019), paved the way for extraordinary growth in the issuance of green bonds. Subsequently, different stock exchanges have launched a dedicated green bond section (the first in Norway, January 2015), which is crucial in showcasing this asset class (Jones et al. 2020). Finally, in 2017, green bonds also appeared in Islamic countries through the issuance of Malaysia's "green Sukuk" (Tang and Zhang 2020), leading to a consistent geographical diversification in green bond issuances, spreading from Europe to many emerging countries, particularly in China (see Figures 1 and 2).

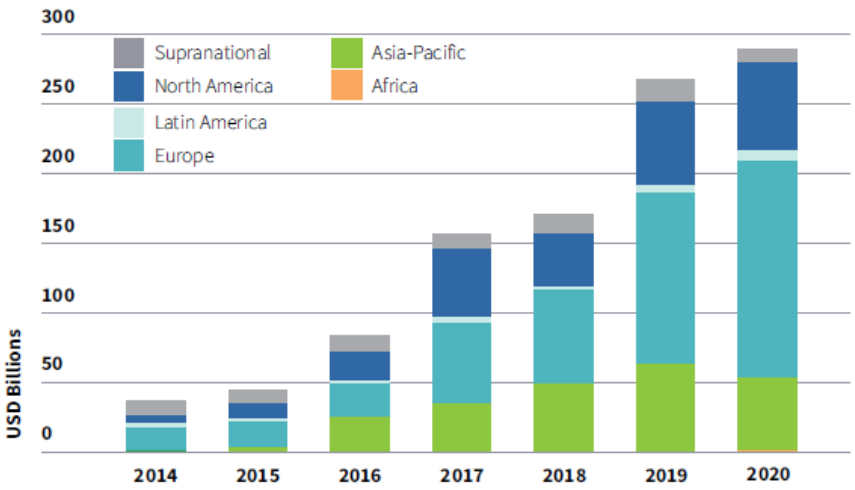

Figure 1. Green bond issuance by region (2014–2020). Source: Harrison and Muething (2021, p. 6).

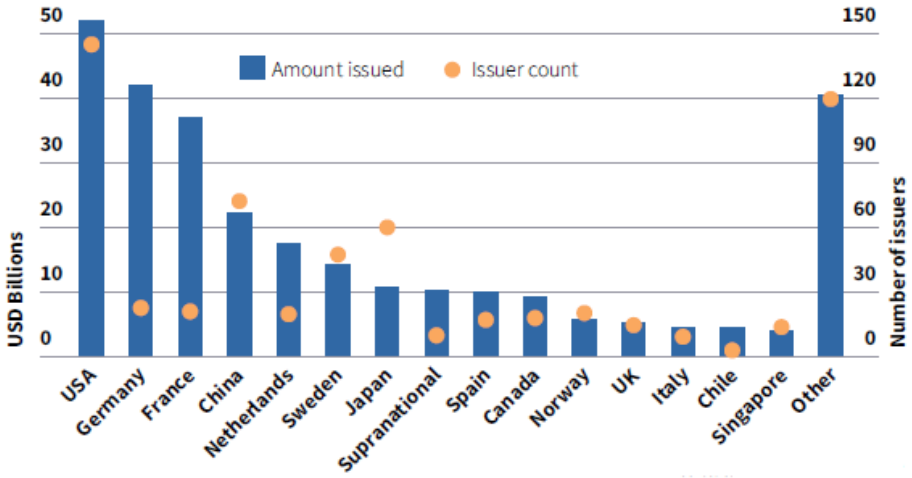

Figure 2. Amount of green bond issued by country (2020). Source: Harrison and Muething (2021, p. 7).

Although the green bond market has practically doubled its size year by year (Bachelet et al. 2019), it still constitutes a small portion of the overall bond market, accounting for around 3% of total global bond issuances in 2019 (Syzdykov and Lacombe 2020).

According to the OECD (2017), to reach the Paris Agreement's objective, an amount of USD 6.9 trillion globally per year will be needed for the next 15 years for the infrastructure investment. The European Commission estimated a European annual investment shortfall of EURO 179 billion to reach the Paris Agreement targets for 2030 (European Commission 2018). The financing system will play a key role in attracting new climate-concerned investors and shifting financial flows to climate-aligned projects, in order to converge into a new green economy system.

The surge of green finance and the need for even more rapid market development to achieve the internationally agreed goals call for a more profound knowledge of green bonds, among other instruments, to boost climate change. Green Finance captured the interest of scholars and academics in the last few years, and the literature on green bonds was enriched with new contributions. Media, policymakers, market institutions, and scholars are studying this relatively new financial instrument, and, month after month, the economic literature on green bonds is now becoming increasingly significant, moving in different directions. Consequently, in our opinion, there is a need for a narrative literature review on this topic to make some order on the ongoing academic works in this novel field of research. In addition, it is important to point out that the empirical green bond works are not so broad as to be unmanageable to review, which is a vital aspect of any literature review. The awareness that green bonds can contribute to the construction of a more sustainable economy (World Bank 2019; Tu et al. 2020a, 2020b; Tolliver et al. 2020a, 2020b), which is an urgent need today, increases the importance of everything that can contribute to a deeper understanding of the phenomenon, in order to promote its development and contribute to the creation of a circular economy. Consequently, the ultimate objective of this paper is to suggest some unexplored (or non-updated) paths of research for future studies and support this method for the development of the markets.

This paper aims to analyze the state of the art of literature on green bonds, focusing on empirical academic works. The review included only academic contributions, such as peer-reviewed publications or conference papers, in order to include papers that are presumed to be as rigorous as possible. Furthermore, we considered no more than empirical studies, excluding narrative and theoretical ones, to center the analysis on green bond market evidence that is as practical as possible, giving the reader a clear and pragmatic view of how green bonds and their market behave. A systematic literature review has been performed to provide a rigorous research framework for choosing the academic studies that are subject to judgment. The expected main outputs are the identification of more significant research trends, their classification into macro-areas, the picture of any research

gap in this novel field of study, and the visualization of future research directions. To the best of our knowledge, only Liaw (2020) and MacAskill et al. (2021) analyzed the academic literature on green bonds. In contrast with our paper, both of the previous literature reviews have focused only on the so-called "Greenium" or "green bond premium", as highlighted in Table 3. As shown in the following section, despite the fact that Greenium is one of the most exciting and controversial phenomena studied by academics, different profiles on green bonds have been explored in the last years. Additionally, in contrast with Liaw (2020), this paper performs a systematic literature review, using a standardized literature selection model. Moreover, in contrast with MacAskill et al. (2021), our paper focuses on any aspects of green bond that are deepened by empirical economic literature and not exclusively on the topic of Greenium. Liaw (2020) and MacAskill et al. (2021), through the analysis of the state-of-art of Greenium literature, aimed to detect whether there was academic consensus on that phenomenon. This paper, instead, focuses on the broad systematic literature analysis with the objective of giving scholars a clear view of all the significant research trends in the green bond empirical literature and providing some suggestions for future works.

Table 3. Main characteristics of previously green bond literature reviews.

Title	Authors	Topic	Methodology
Survey of Green Bond Pricing and Investment Performance	Liaw (2020)	Green bond premium	Not a standardized literature selection model
Is there a green premium in the green bond market? Systematic literature review revealing premium determinants	MacAskill et al. (2021)	Green bond premium	Systematic literature review

The remainder of this paper is organized as follows: Section 2 briefly describes the methodology and sample construction of this study. Section 3 presents the results of the systematic review. Herein, the results are embedded in our proposed taxonomy and then discussed by macro-areas that review any literature research gaps. Finally, the conclusions are provided in Section 4.

2. Materials and Methods

Understanding the green bond phenomenon cannot be possible without a precise comprehensive analysis of the previously related academic studies. It is important to provide readers with a clear and complete state-of-art literature on the investigated topic. To this aim, a systematic literature review has been conducted. According to the PRISMA Statement, "systematic review is a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review" (Moher et al. 2010). This method seems to be an acceptable rigorous approach to broadly discover and synthesize research that attains a definite topic (to answer a specific research question), using "organized, transparent, and replicable procedures at each step in the process" (Stechemesser and Guenther 2012). The scope should be to find any research gaps in order to suggest future investigation paths. Since one of the major characteristics of a systematic literature review is the selection of the studies in a reproducible way for an external reader, the following subsections describe the study process performed according to Fink (2019) and the PRISMA Statement.

2.1. Research Questions, Databases, and Appropriate Research Terms

The first methodological step was to determine the research questions in order to base the literature review: "How far the empirical economic literature on green bonds went to investigate this new financial instrument?" and "What are the major empirical research trends in academia about green bonds?".

Following the PRISMA Statement procedure, a *query* of the inquiry of a *sample* of bibliometric databases was defined as the second step. The scholarly databases used in this study were Scopus Elsevier (Scopus) and Web of Science (WoS), two of the most famous peer-reviewed literature databases. The research was limited to English-written articles published in peer-reviewed journals and conference papers (very limited in the sample). We screened the selected databases directly using the filtering out method, in order to include only academic essays and conference/proceeding papers. By excluding other types of research outputs, a limited number of studies were included. Green bonds have been the subject of several industry reports that were carried out by banks, regulators, international institutions (i.e., Preclaw and Bakshi 2015; Harrison and Boulle 2017; Ehlers and Packer 2017). Industry reports constituted the first attempt to define and study green bonds, especially at the early stage of green bond analysis, when academia showed less interest in the phenomenon. The choice to include only scientific works assures the reproducibility and completeness of the literature sample.

Here, we considered studies published between 2007 and 2020 (or at least accepted for publication)). The starting period was chosen according to EIB's first world green bond issuance (2007), while 2020 was supposed to include studies published as close as possible to the release date of this paper.

The database query was based on a combination of the following keywords: "Green bonds", "green bond pricing", "green bond premium", "green bond market", "greenium", "municipal green bonds", "corporate green bonds", and "yield spread green bond". The inquiry was performed according to the publication titles, abstracts, and author-selected keywords. Keywords choice is supported by a pre-simulation test, which is performed to capture all of the existing literature in the databases. To exclude any articles that are not referred to in economics, we focused on papers pertaining to the following subject areas: (i) "Economics, Econometrics and Finance" and "Business, Management and Accounting" on Scopus; and (ii) "Business finance", "Economics", "Business", "Management", "Law", "Environmental sciences" on Web of Science.

2.2. Sample Screening Criteria

The academic records that were identified through database interrogations resulted in a total of 216, which was refined to a total of 154 after accounting for duplications.

To obtain a refined sample of green bond empirical literature review, a further filter was needed. First, based on a comprehensive reading of the abstracts, excluding the studies that were unrelated to the selected topic was possible. Next, we removed from the sample all of the studies (79 papers) that were not available for full-text reading. Finally, the narrative, descriptive, and theoretical publications were excluded, leaving a total of 53 empirical studies in the final sample. The steps implemented during the sample construction are shown in Figure 3.

According to the objective of this paper, after an extensive reading of the studies included in the sample, we were able to develop a "*taxonomy of green bond research*". The selected academic works were grouped into six categories related to the subject and phenomena that the authors researched. Subsequently, taxonomy discussion was realized by summarizing the major articles' findings/results on an individual basis.

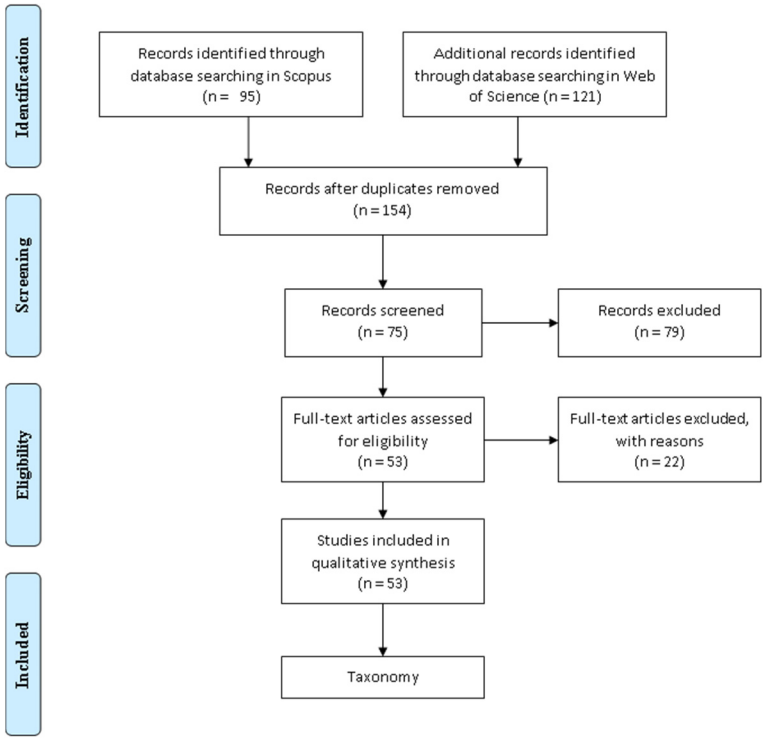

Figure 3. Systematic review methodology.

2.3. Sample Overview and Taxonomy

According to the implemented methodology, this paper reviews the current (empirical) literature on green bonds. As a first result, we observe a particularly recent academic interest in the topic, since, as shown in Figure 4, the first empirical work was published in 2016 (Pham 2016). In addition, since 2018, green bonds have gained the attention of academia with an exponential increase of empirical research in this phenomenon. The year 2020 was the most productive year, with a total of 32 out of 53 studies. The year 2018 was one of the key years of green bond empirical research, with the release of some of the most innovative works on which academics based their subsequent researches (Reboredo (2018); Hachenberg and Schiereck (2018); Karpf and Mandel (2018); Febi et al. (2018)).

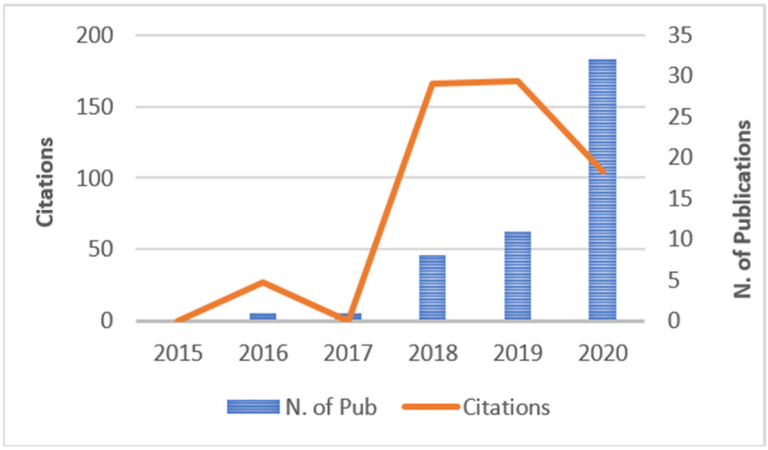

Figure 4. Number of publications/citations per year.

The temporal distribution of the selected paper is due to the limited analysis of the empirical research. Considering that the first emission was in 2007, not enough data were available to conduct robust analyses in the first years selected.

The evolution of citations, which progressively and constantly increased during the period analyzed, tends to drop in 2020 due to the limited time elapsed from this paper. This tendency influences the mean journal SJR[6] of the sample to 1.22.

After the full-text reading of the sampled paper, it was possible to provide a comprehensive taxonomy that identifies six empirical literature macro-strands on green bonds, based on the main findings/objectives of the studies. The first group of studies, named "*Greenium*", collects empirical research that analyzes the green bonds' pricing structure with their comparable conventional (non-green) bonds. These studies aim to identify the potential mispricing between green and non-green bonds in primary or secondary markets. The second group of the empirical literature, named "Green bond connectedness w/other financial instruments", gathers a set of studies focused on price correlations and spillover effects between green bonds and other financial instruments. Then, we grouped in the strand "*Green bond and stock reaction*" all of the analyzed research centered on the effect of the issuer's stock price after a green bond issuance. The fourth group, defined as "*Green bond—supply-side*", is related to studies focusing on factors that influence the issuance of green bonds from the issuer point of view. In the "Green bond market performance analysis" group, we considered empirical studies by comparing market performance parameters between the green bond market and other financial markets. Finally, the last group of the empirical literature is a residual sphere of studies, which is addressed to various fields and cannot be referred to the previous research areas.

As shown in Table 4, and detailed in Appendix A, a major part of the academic interest in empirical research on green bonds was headed in the direction of shedding light on the Greenium phenomenon and the correlations/connections between green bonds and other non-green financial assets and markets. The extensive academic works on this topic demonstrate the importance of investigating the pricing structure of green bonds in primary and secondary markets. This research field was well anticipated by several institutional reports that first investigated this evidence (Preclaw and Bakshi 2015; Harrison and Boulle 2017; Ehlers and Packer 2017). As reported in the previous pages, these reports are not examined in the paper according to the methodology chosen.

Table 4. Taxonomy of green bonds empirical literature.

Group	Number of Articles
1. Greenium	14
2. Green bond connectedness with other financial instruments [1]	15
3. Green bond—supply-side analysis	11
4. Green bond and stock reaction [2]	7
5. Green bond market performance analysis [3]	4
6. Other	6

[1] Kanamura (2020) was also included in the first group: [2] Tang and Zhang (2020) and Wang et al. (2020) were also included in the first group; [3] Febi et al. (2018) was also considered in the Greenium group.

Figure 5 specifies some research trends among the selected macro-areas. The Greenium research topic has constantly been growing over the past years, since the pioneering works of Hachenberg and Schiereck (2018), Karpf and Mandel (2018), and Febi et al. (2018). The following works were intended to investigate the existence of Greenium in several market segments (primary and secondary markets) and different geographical areas (e.g., China or EU). A great academic interest was aimed at the connectedness between green bonds with other financial instruments in 2020. In the last year, 11 studies were published on this topic, causing the previously related works to double in size.

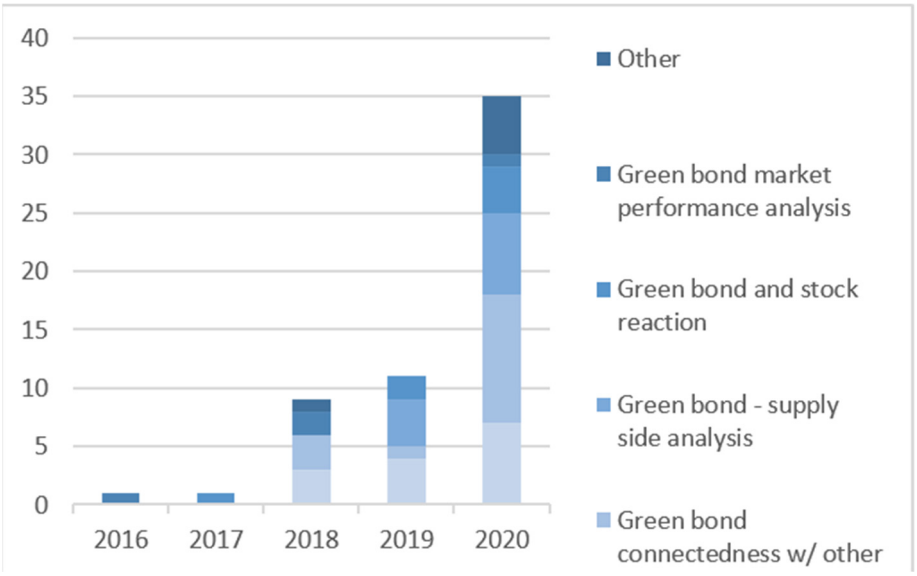

Figure 5. Research trends within taxonomy.

Two other recent research trends appeared in 2019–2020. In addition, there a significant increase in studies, which is focused on issuers' equity reaction at the green bond issuance and the broad effect/economic incentives of green bond issuance on issuers (green bond—supply-side group). The growing salience of green bonds possibly prompted academia to focus on the effects of this new type of financial instrument on firms' lives.

It is important to denote that 51 out of 53 studies are peer-reviewed articles, and conference proceedings account for only two studies.

3. Results: Suggestions for Further Research

After the bird's eye view on the sample, in the following sub-sections, we provide a more detailed analysis of the sampled papers, according to the taxonomy proposed in Table 4.

3.1. Greenium

The Greenium or "*green bond premium*" implies that green bonds can be priced at a lower level (thus, a lower interest rate) than the risk-paired traditional bonds. This pricing evidence has a considerable remark due to the issuer's incentive to obtain fresh financial resources, which lowers his debt cost. In addition, it is essential to show if investors are willing to renounce some risk-adjusted returns to invest in sustainable financial instruments. Many authors detected the existence of the green bond premium at the issuance of green bonds (primary market) and on an ongoing daily negotiation (secondary market). However, as shown in Table 5, within academics, there is no consensus on this phenomenon.

Focusing on green bond pricing in the primary market, Nanayakkara and Colombage (2019) analyze a sample of global 82 corporate green bonds. Here, they find that green bonds are traded with a tighter credit spread (Greenium) of 63 bps compared to the similar corporate bond issues. Similarly, Wang et al. (2020) documented that corporate green bonds have a lower yield (credit) spread of 34 bps than the corresponding conventional bonds in the Chinese green bond market. The authors show that Greenium tends to increase in the case of green bonds certified by CBI, firms with high CSR scores, less concentrated ownership structure, and green bonds held by long-term institutional investors.

Table 5. Green premium empirical literature by the type of sample, methodology, and main results.

Author(s) (Year)	Characteristics of the Sample				Methodology		Main Results		
	Time Span	Geographical Scope	Sample Size	Market Segment	Methods	Size-Effect Type	Greenium Evidence	Premium Dimension	Level of Statistical Significance
Febi et al. (2018)	2013–2016	UK e Lux	64	Secondary market	Fixed effect panel regression model	Credit spread (difference between green bond yield and government bond yield)	Controversial	−69.2 bps in 2016	10% in 2016 no significance other years
Hachenberg and Schiereck (2018)	2015–2016	World	63	Secondary market	Matching method, yield curve, Wilcoxon test, Panel regression model	Spread between green bonds and similar conventional bonds	Controversial	−1.18 bps (entire sample)	no significance
Karpf and Mandel (2018)	2010–2016	US	1880	Secondary market	Yield curve, Mixed regression model, Oaxaca—Blinder decomposition	Yield to call (yield to maturity priced out the value of this option attached)	Yes	−7.8 bps (part of premium explained by green purpose)	n.a.
Bachelet et al. (2019)	2013–2017	World	89	Secondary market	Matching method, Regression model (OLS, FE)	Spread between green bond ask yield and matched conventional bond ask yields	Controversial	+5 bps (entire sample) −4 bps (subsample government/institution issuers)	1%
Gianfrate and Peri (2019)	2013–2017	EU	121	Primary and secondary market	Propensity score matching	Secondary market yield bond spread	Yes	between −5 and −13 bps (on average depending on temporal windows of the study)	different significance levels
Nanayakkara and Colombage (2019)	2016–2017	World	82	Secondary market	Panel data regression with hybrid model	Daily option adjusted spread (OAS)	Yes	−63 bps	1%
Zerbib (2019)	2013–2017	World	110	Secondary market	Matching method, Fixed effect panel regression	Daily ask yield between green bonds and synthetic conventional bonds	Yes	−2 bps (in the entire sample)	1%
Hyun et al. (2020)	2010–2017	World	60	Secondary market	Matching method, OLS, and fixed effects generalized least squares (FEGLS) regression model	Liquidity-adjusted ask yield spread between green bonds and paired conventional bonds	Controversial	−6 bps (in case of third party verification) −15 bps (in case of CBI certification)	1%
Kanamura (2020)	2014–2018	World	n.a.	Secondary market	Risk-Expected return model	Market indexes	Yes	n.a.	n.a.

Table 5. *Cont.*

Author(s) (Year)	Characteristics of the Sample				Methodology		Main Results		
	Time Span	Geographical Scope	Sample Size	Market Segment	Methods	Size-Effect Type	Greenium Evidence	Premium Dimension	Level of Statistical Significance
Larcker and Watts (2020)	2013—2018	US	640	Primary market	Matching method, kernel density estimator, Nearest neighbors matching, Wilcoxon test	Initial offering credit spread	no	+0.5 bps (but in 85% of the cases yield spread is null)	1%
Partridge and Medda (2020)	2013–2018	US	453	Primary market	Matching method, Yield curve, Panel regression model	Initial yields at issue	Controversial	−0.1 bps (in 2018)	no significance
				Secondary market		Daily traded market yields	Yes	−4 bps (entire sample)	1%
Tang and Zhang (2020)	2007–2017	World	1510	Primary market	Matching method, Regression model, Diff-in-diff analysis	Yield spread at the issuance	Controversial	−6.94 bps (entire sample) no pricing difference when issuer's characteristics are considered	5%
Wang et al. (2020)	2016–2019	China	159	Primary market	Matching method, univariate and multivariate analysis	Credit spread (spread between the "at-issue green bond yield" and the yield on a treasury security of comparable maturity)	Yes	−34 bps	1%
Immel et al. (2021)	2007–2019	World	466	Secondary market	OLS regression	Secondary market yield bond spread	Yes	between −8 and −14 bps	1%

Note: Papers are displayed by year and in alphabetical order.

Zerbib (2019) detected a small negative premium of about 2 bps (green bonds priced tighter than the conventional bonds), using a sample of 110 GBP-compliant green bonds issued worldwide and matched with similar conventional bonds. This is due to the pro-environmental investor's preferences. In particular, the author shows that the premium is greater for financial firms and low-rate bonds. Karpf and Mandel (2018) investigated a sample of 1880 US municipal green bonds and showed that the green bond return is 23 bps lower than the conventional municipal bonds. Contrary to Zerbib (2019), the authors claimed that the issuer's characteristics mainly explain the pricing spread rather than the green nature of green bonds (Greenium explained by green characteristics is around 7.8 bps). Similarly, Partridge and Medda (2020) found a strong evidence of Greenium in the US municipal green bond secondary markets (4 bps), but not a clear evidence of discounted pricing for municipal green bonds with comparable non-green ones in the primary markets.

Immel et al. (2021) focused their work on the existence and magnitude of Greenium according to the green bond's degree of greenness (measured by the level of ESG rating) on a global sample of 466 green issuances. The authors found that the green bonds issued by ESG rated the issuer's experience as a higher negative premium (between −9 and −19 bps) compared with the un-rated green bond issuances (between −8 and −14 bps). Moreover, the authors denoted that a higher ESG rating follows a higher negative green bond premium. Surprisingly, within the ESG rating, the G-score (issuer's governance characteristics) is the primary driver of green bond premium.

Gianfrate and Peri (2019) found evidence of green bond premium when investigating both primary and secondary EU green bond markets, using a propensity score matching analysis. The authors detected Greenium in both market segments, but with a stronger evidence in the primary market. Other evidence of Greenium has been found by Kanamura (2020).

On the contrary, other authors had controversial results when investigating the Greenium phenomenon in the secondary market. Hachenberg and Schiereck (2018) found that green bonds, on average, are priced tighter than the conventional bonds of about 1 bp, by studying a sample of 63 global investment-grade green bonds. Nevertheless, their results vary according to the rating classes (AAA-rated are priced wider than their similar non-labelled bond, whereas AA-BBB-rated green bonds show a Greenium) and issuer industry (government trade is marginally wider, whereas corporate and financial issuer green bonds trade are tighter than the non-green bonds). Similarly, Hyun et al. (2020) found no robust and significant yield premium/discount on average, by comparing the liquidity-adjusted yield premiums of green bonds versus conventional synthetic bonds. However, the authors detected a Greenium where green bonds are certified by an external reviewer (6 bps) when they are certified by CBI (15 bps).

Bachelet et al. (2019) reported that green bonds have a higher yield and are less risky than the comparable "*brown*" bonds. However, the authors exhibit controversial results since, in their sample, a Greenium is detected when considering public-related green bonds and third-party verified green bonds. Moreover, Febi et al. (2018) found a 69.2 bps negative yield differential (Greenium) between a green bond and non-green bond in 2016, but non-significant yield difference in the 2013–2015 period, by studying a sample of 64 green bonds listed in the UK and London stock exchanges during the period 2013–2016.

Tang and Zhang (2020), focusing on the primary market, analyzed a sample of 1510 global corporate green bonds' issuance over 2007–2017. The authors found that, on average, green bonds have a lower yield of about 7 bps compared with the similar conventional bonds, but considering a yield spread comparison between the same issuers in the same year, they did not find any evidence of Greenium.

In addition, some evidence of the opposite phenomenon (positive yield spread between green and non-green bonds) was found. Larcker and Watts (2020) analyzed a sample of 640 US municipal green bonds and found that a small positive premium (0.5 bps) determined that green bonds are slightly more expensive than non-green bonds for the issuer.

The authors also concluded that there is no pricing differential with comparable non-green bonds, since, in 85% of cases, the differential yield is precisely zero.

Within the scholars who found evidence of green bond premium, the explanations of the reasons behind this phenomenon are various. One of the main investor-side explanations is that investors are willing to pay "*to go green*". Therefore, pro-environmental and social preferences are strong enough to push an investor to accept a lower risk-adjusted return for a green bond than the conventional one (Zerbib 2019). Similarly, Bachelet et al. (2019) claimed that Greenium can be explained by investor preferences or lower stakeholder risks, but only if linked to an established issuer reputation (or conversely a green certification) to reduce asymmetric investor information and to assure investors against the greenwashing risk.

Karpf and Mandel (2018) gave an issuer-side explanation to Greenium. The authors thought that the lower green bond pricing relied on the green bond issuer characteristics, assuming that these issuers have more creditworthiness and more robust economic fundamentals. In this case, it would lead investors into requiring a lower yield on green bonds compared to the conventional ones.

Partridge and Medda (2020) justified the Greenium existence in the secondary market rather than the primary market with the capacity of bond traders to resell green bonds for higher prices, due to the relative shortage of this instrument. Following authors' considerations, a green bond issuer (and the banks constructing their offering deals) cannot have equal information in their offers to achieve a better performance, similar to traders in the secondary market.

As shown in Table 5, the studies included in the sample give no clear evidence regarding Greenium. As highlighted in Figure 6, there is no academic consensus regarding the potential mispricing between the green bonds and conventional/non-green bonds in primary and secondary markets. In the primary market, the previous authors detected Greenium in 40% of the studies, but the quote of controversial and contrary evidence is 40% and 20% of the surveys. In the secondary market, the evidence of Greenium is quite majoritarian (around 63% of the cases), and no contrarian evidence is detected within the sample of studies. These results should be interpreted, taking into account that secondary market studies are slightly double the size of the primary market ones.

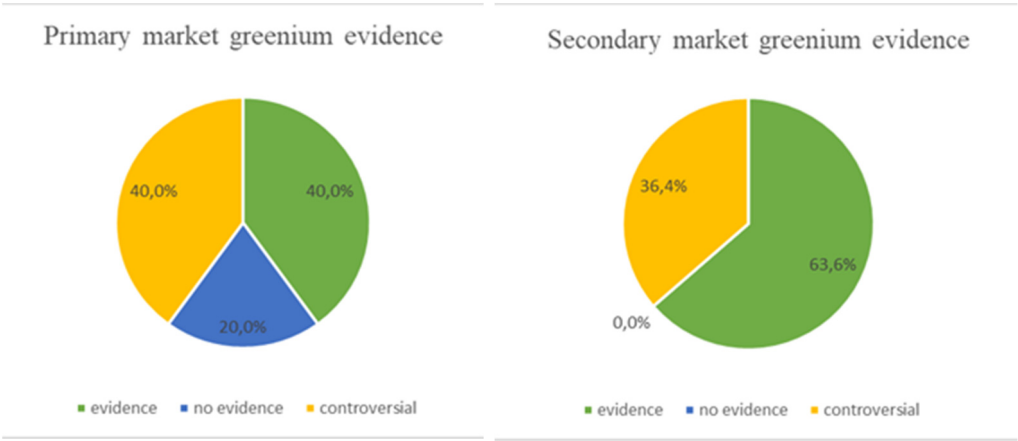

Figure 6. Greenium evidence within market segments.

As displayed in Table 5, some research gaps regarding the Greenium strand can be highlighted. Academia seems to have paid less attention to the geographical scope, time frame, and methodology.

For instance, by focusing on US-based research, the authors exclusively studied the green bond US municipal markets (both in primary and secondary markets). Even then, there is still space remaining to investigate the US corporate green bond market. Regarding time coverage, the evidence suggests that it is possible to refine the previous evidence by

updating the analysis that counts on increased data access in these fast-growing financial instruments. Moreover, time coverage is a critical issue in the EU-based studies, since the most updated study (Gianfrate and Peri 2019) data are updated up to 2017. The European green bond market can be studied in-depth, deploying the methodology used by other authors in the sample (in particular, the matching method analysis). The unique China-based study of the sample is focused on the primary green bond market (Wang et al. 2020). Future works can analyze the evidence of a Greenium in the Chinese secondary green bond market. The large majority of the papers on the Greenium within the sample are global-referred, and they do not consider the phenomenon on a regional/country basis.

New research might be addressed on investigating more in-depth global primary markets of green bonds, as well as updating the period of the analysis, in order to shed light on this phenomenon in a more conclusive way with a consideration of the geographical dimension (due to the different levels of capital markets development and regulation and standard applicable).

3.2. Green Bond Connectedness with Other Financial Instruments

The "Green bond connectedness w/other financial instruments" area regroups studies that focus on price/volatility dependence between the green bond market and other financial markets. Within-markets behavior is a precious indication for asset managers to develop their risk, hedging, and portfolio strategy management. Moreover, it is helpful for policymakers to gain a better comprehension of regulating the green bond market. The main characteristics of the analysis performed are synthesized in Table 6.

Table 6. "Green bond connectedness w/other financial instruments" empirical literature by type of sample and methodology.

Author(s) (Year)	Time Span	Geographical Scope	Methodology
Daszyńska-Żygadło et al. (2018)	2014–2018	World	Multivariate Garch framework
Draksaite et al. (2018)	2007–2016	EU	Covariation and regression based analysis
Reboredo (2018)	10/2014–08/2017	World	Time-invariant and time-varying copula approaches
Broadstock and Cheng (2019)	28/11/2008–31/7/2018	US	Dynamic conditional correlations (DCC), dynamic model averaging (DMA)
Reboredo and Ugolini (2020)	10/2014–06/2019	World	Structural VAR (Vector Autoregressive) model parameters
Hammoudeh et al. (2020)	6/2014–2/2020	World	Time-varying Granger causality test
Huynh et al. (2020)	12/2017–01/2020	World	Tail dependence as copulas, volatility interconnectedness via the Generalized Forecast Error Variance Decomposition
Huynh (2020)	12/2008–11/2019	World	Copulas modelling approach
Jin et al. (2020)	12/2008–12/2018	World	Dynamic hedge ratio models: DCC-APGARCH, DCC-T-GARCH, and DCC-GJRGARCH models
Kanamura (2020)	11/2014–12/2018	World	Structural price model, Dynamic conditional correlation (DCC) model
Liu et al. (2021)	07/2011–2/2020	World	Time-invariant and time-varying copula approaches with CoVaR
Nguyen et al. (2021)	12/2008–12/2019	World	Rolling window wavelet correlation approach
Park et al. (2020)	01/2010–01/2020	World	BEKK model, dynamic conditional correlation-generalized autoregressive conditional heteroskedasticity (DCC-GARCH) model
Reboredo et al. (2020)	10/2014–12/2018	US, EU	Wavelet analysis, Structural VAR (Vector Autoregressive) model parameters
Saeed et al. (2021)	01/2012–11/2019	US	Quantile based VAR model

Note: Papers are displayed by year and in alphabetical order.

Reboredo (2018) is one of the first and increasingly cited contributions in this field of research. The author explored the co-movement between four international green bond market indexes with other non-green financial market global indexes. Utilizing a copula model, Reboredo found a heavy price co-movement between the green bond and other fixed-income markets (both treasury bond market and corporate bond market) on average and in extreme values. The green bond market is a net receiver of price spillover from the corporate and government bond markets. In contrast, the green bonds poorly co-move with the stock market and energy commodity market. The same author that refined his model in cooperation with Reboredo and Ugolini 2020, using a structural VAR model, added that the green bond market correlates closely with the USD currency market. The results reveal that high-yield bonds co-move weakly with the green bonds, even if the green bond and corporate non-green bond markets are strongly connected. Finally, Reboredo et al. (2020), in order to study the network connectedness between the green bonds and other asset classes in the EU and US, performed a wavelet-based model that focuses on different time horizons effects. Green bonds have a strong price connectedness with treasury and corporate bonds in the short and long run in the EU and US. Moreover, green bonds are weakly price correlated with the high-yield corporate bond, stock, and energy stock markets in different time horizons. Previous findings reveal that green bonds have some strategy portfolio implications, such as the hedging and diversification effect with some financial markets.

Broadstock and Cheng (2019) investigated the relationship between the US green bond market and the US broad bond market. The authors found a negative correlation before mid-2013, then the correlation turned positive afterwards. This evidence seems to be accounted for the significant expansion of the green bond market and private issuer market opening that occurred in 2013-2014. Moreover, the authors found that the connection between the green and non-green bond markets is sensitive to the financial market stability, economic policy uncertainty, daily economic activity, oil prices, and news-based market sentiment. Daszyńska-Żygadło et al. (2018) found evidence in line with Reboredo (2018), using a multivariate GARCH model to study the volatility patterns between four international green bond market indexes and the overall conventional bond market. Green bonds seem to be significantly correlated with non-green bonds and, due to the market's small size, they receive rather than transmit volatility shocks from the conventional bond market. Draksaite et al. (2018) derived the same conclusions by studying an EIB issued green bonds sample. Huynh (2020) demonstrated the co-movement effect between the green bonds and a selection of AAA-rated government bonds.

Liu et al. (2021) explored the relationship between the green bonds and clean-energy stock indexes. The authors found a clear positive dependence between these two markets with some spillover effect from the green bond market to the clean energy stock market and vice versa, but in an asymmetric way (more pronounced in downturn phases). Park et al. (2020) denoted similar conclusions with general stock markets.

Kanamura (2020) reported that green bonds are negatively correlated with WTI and Brent oil prices, by focusing on green bond-oil market dependence. Jin et al. (2020) found a high inverse connectedness between the green bonds and carbon future returns, particularly in volatile solid periods. These authors showed shreds of evidence of the hedging attributes of green bonds versus oil/carbon markets.

Another remarkable work, carried out by Saeed et al. (2021), went beyond the previous studies (included Saeed et al. 2020) and attempted to analyze the connectedness between green (green bonds) and dirty assets in extremely positive and negative shocks. The authors denoted higher return correlations in the case of extreme shocks, concluding that the mean-based measures of return connectedness are unfit. The authors also highlighted the diversification appeal of green bonds towards other "dirty" assets, since they are pretty isolated from the system of return spillovers.

Huynh et al. (2020), Hammoudeh et al. (2020), and Nguyen et al. (2021) showed evidence in line with the previous academic literature on market connectedness between green

bonds and other financial instrument markets through different methodology approaches or by analyzing other market segments.

This phenomenon has been well analyzed by the authors on a geographical, sectoral, methodological, and temporal basis (Table 6). The authors seem to agree on the diversification benefit of green bonds compared with stocks, energy, oil, and carbon commodity.

Based on the analysis, future studies seem to have little space, except for the case of new methodologies, to give more evidence to the correlation/connectedness/spillover between green/non-green instruments/markets and the possibility to focus on a specific market segment (as external certified green bonds or labelled/unlabeled green bonds, etc.). This last possible research direction could be conditioned to a lack of targeted market indexes.

Finally, another possible research gap in this sample is derived from the concentration of the market connectedness analysis through the global indexes analysis (a total of 11 out of 15 studies) or the US and/or EU market indexes (a total of 4 out of 15 studies). Further works can be directed to investigate the green/non-green market spillovers between other geographical spheres, particularly emerging green markets, such as China and other Asian countries.

3.3. Green Bond and Stock Reaction

The proposed field of works named the "*Green bond and stock reaction*" group, particularly reviewed papers by academics that studied how green bond issuances affect the issuer's stock prices. The authors included in this group wanted to verify if green bond emission has a signaling effect on investors and issuer shareholders' wealth. Scholars substantially agree that green bond issuance positively affects the issuer's stock prices in the days immediately after the issuance. The pioneering study in the field was by Mohd Roslen et al. (2017), who investigated how the announcement of a global sample of 118 green bonds issued by publicly traded firms affected its stock prices the following day. They detected a positive reaction (AAR—average abnormal return over market return) of 1.166% on the day after the announcement. Of note, they documented a negative CAR of –2.198% (cumulative abnormal return over market return) on a 2-day event window around the announcement date (the day before + announcement day). The negative investor view might explain the latter evidence due to the increase of issuer indebtedness.

Baulkaran (2019) found that in a 21-day window around the green bond issuance date (–10 to +10 days), the price of the issuer's share had a CAR of 1.48%, through the study of a sample of 54 self-labelled green bonds issued by corporate listed firms. Moreover, some issuer characteristics are positively related to the stock reaction, such as size and growth opportunities. Baulkaran confirmed that the shareholders consider green bonds as value-added financing tools.

Zhou and Cui (2019) confirmed the positive relation between the green bond issuance and stock price reaction, by focusing on 144 green bonds issued by 70 Chinese listed firms. Moreover, the authors found a positive influence on corporate profitability, operational performance, innovation capacity, company reputation, and CSR practices in the long-term. The authors concluded that green bond emission attracts new investors for merely virtue signaling and real issuer commitment, which leads to economic and environmental improvements.

Jakubik and Uguz (2021) investigated the impact of the green bond policies announcement on the equity prices of the listed European insurance companies. The authors did not find a statistically significant (positive) impact on share prices when the insurers announced new green policies. Instead, when policies are singularly considered, the issuance of green bonds and launching of green funds seem to affect the equity prices positively (on the contrary of the announcement of new investments on green bonds). Other evidence of the positive stock market reaction to the green bond issuance was detected by Wang et al. (2020) and Tang and Zhang (2020).

Contrarily Lebelle et al. (2020) reported adverse market reactions on green bond issuance announcements and on the following day. In their work, the authors detected a CAR in the range of -0.5–0.2% depending on the methodology used (CAPM, Fama and French's three-factor model, Carhart's four-factor model). The authors provided evidence that the investors react in a similar way to green bonds as for conventional or convertible bonds.

Despite the evidence provided by Lebelle et al. (2020), academia had quite a consensus regarding the positive impact of the green bond's issuance announcements on the firm's share prices. This evidence in the green bond market seems to be contrary to the non-green corporate bond market evidence, in which a bond issuance announcement is followed by a decrease of firm price share (Dann and Mikkelson (1984), Ammann et al. (2006), Hemmingson and Ydenius (2017)). Conversely, issuing a green bond is a signal of the firm's green/sustainable commitment to help attract new investors that are always keener on including a sustainability footprint in their portfolio investment decisions.

As shown in Table 7, this area of study was mainly investigated on an international and Chinese geographical base (two studies), and the time horizon subject for the investigation is recent. The main methodology used in the sample is an event windows analysis (six out of seven studies). Moreover, the analyses performed within the works are well diversified in terms of the type of issuers (public/non-public, listed/non-listed, financial/non-financial, rated/non-rated, first-time green bond issuers/usual issuers).

Table 7. "Green bond and stock reaction" empirical literature by the type of sample and methodology.

Author(s) (Year)	Time Span	Geographical Scope	Sample Size	Type of Green Bond (and Issuer) Analyzed	Methodology
Mohd Roslen et al. (2017)	2010–07/2015	World	156 GB issuances and 118 GB issuance announcements	Listed issuer (financial institutions and non-financial issuers with extraordinary finance operations were excluded)	Event study analysis of average abnormal return (AAR) and cumulative abnormal return (CAR)
Baulkaran (2019)	n.d.	World	54 GB issuers	Listed corporate GB issuer, with height market capitalization	Event study method; regression analysis
Zhou and Cui (2019)	2016–2019	China	144 GB issuances, 70 Chinese listed issuers	All types of listed issuers (financial and non-financial, private and public); only long-term issuances are considered	Event study approach, propensity score matching (PSM), difference-in-differences (DID)
Jakubik and Uguz (2021)	2012–2019	EU	15 issuers	Listed EU Insurance company with GB policy	OLS regression
Lebelle et al. (2020)	2009–2018	World	475 GB issuances, 145 GB issuers	Private, listed GB issuers (financial and non-financial); securitized GB excluded	Event study method CAPM, Fama-French three-factor model, Carhart four-factor model
Tang and Zhang (2020)	2007–2017	World	1510 GB issuances, 132 GB issuers	Private, listed GB issuers	Event study analysis and cumulative abnormal return (CAR)
Wang et al. (2020)	01/2016–06/2019	China	159 GB issuances, 56 GB issuers	Listed, private (non-financial), rated and Chinese GB issuers	Matching method, Zerbib method—event study method

Note: GB: Green bond; papers are displayed by year and in alphabetical order.

It would be possible to extend this research area to other countries/regions other than China, particularly the US, EU, and emerging markets. In addition, it could be interesting to analyze if there is a differentiation in the magnitude of stock reactions when comparing the issuers that belong to different countries. Moreover, another future research path is to study any difference in stock price reactions according to the industry of issuers. Currently, academia has deepened its understanding of the differences between financial versus non-financial issuers or public versus corporate issuers without considering sub-

sectors patterns, particularly between commonly considered "clean industries" and "*dirty industries*".

3.4. Green Bond—Supply-Side Analysis

The fourth group within the taxonomy is "*Green bond—supply-side analysis*", which includes studies that focus on the point of view of green bond/issuer characteristics from issuers (supply-side). The novelty of green bonds as a financial instrument demands looking for the determinants of green bond issuance. The following evidence can retain valuable insights for issuers and policymakers to operate in the market.

Chiesa and Barua (2019) analyzed the factors that affect the green bond issuance size. Focusing on a broad global sample of 771 corporate green bonds from 2010 to 2017, the authors studied how the bond, issuer, and economic/market characteristics influence the amount of the green bonds issue. The authors reported that the coupon rate has a negative impact and, conversely, the bond credit rating and collateral availability have a positive impact on the issue size and issuances denominated in Euro. Moreover, a higher ROA and a higher degree of leverage lead to smaller issue sizes. Furthermore, utility issuers have more chances of issuing higher-sized green bonds than industrial and real estate issuers. Nevertheless, Barua and Chiesa (2019) went beyond their previous study and analyzed how these factors influence the supply of green bonds over time, using the same sample of green bonds employed in their previous paper. The authors showed that the significant expansion of green bond markets in the last years was principally backed by a larger market participation rather than an increasing issue size.

Wang et al. (2019) focused on the factors that influence the Chinese green bond risk premium (defined as the yield spread between the bond's yield to maturity at the issuance and risk-free interest rate). The authors found that the third-party verification tends to lower the green bond yield and thus, the issuer financing cost. Other factors that lower the green bond risk premium are high bond credit rating, issue size, and maturity. Similarly, Li et al. (2020) studied the effects of the green bond financing cost from an issuer's perspective in China. The authors denoted that the high bond credit rating, green certifications (obtained after a third-party review process), and higher CSR score helped lower the cost of financing for a listed green bond issuer. Furthermore, Deng et al. (2020) found that the higher portion of proceeds that is invested in green projects leads to lower green bond yields in the Chinese market. Moreover, the green bonds that are subjected to the third-party verifications process generally have a more substantial yield advantage compared to the non-verified green bonds.

Russo et al. (2021) investigated what affects the performance of green bonds in the long-term (measured by long-term green bond yield-to-maturity), by analyzing a global sample of 306 corporate green bonds obtained from the Bloomberg database issued over 2013–2016. The authors found that the nature of the project which is financed by a green bond could influence its performance. For instance, sustainable management of natural resources, water management, and terrestrial and aquatic biodiversity conservation projects seem to affect green bond performance positively. Conversely, clean transportation and climate change adaption have a negative effect. The authors also found that a higher degree of a firm's sustainability orientation leads to better green bond performance, as well as host country sustainability orientation.

Using a Logit model, Dou and Qi (2019) aimed to explore if the difference in policy framework influences the choice to use green bond financing from an issuer's point of view. Given the Chinese regulatory framework based on a "*multi-sector supervision*", which is led by different types of corporate bonds regulated by different authorities and legal frameworks, the authors attested that a higher supervision degree at the issuance strengthens the convenience to issue green bonds. Moreover, the Chinese legal framework does not require that firms use all of the green bond proceeds to green projects (part of them could be invested elsewhere). Dou and Qui found that the higher the portion of green bond proceeds spent in green projects, the more firms are willing to issue green bonds.

Nanayakkara and Colombage (2021) examined whether a higher degree of GBP compliance determines a higher green bond, which appeals to investors. The authors studied a sample of 399 green bond issuance over the 2007–2016 period in G-20 countries. Here, they denote a higher demand for green bonds when the GBP compliance is higher (in terms of higher liquidity and yield measures). Moreover, government green bond issuances seem to reduce the negative effect of lower GBP-compliance, and fixed-rate green bonds are more attractive than floating-rate green bonds.

Using a panel data analysis, Chang et al. (2021) investigated how credit rating and liquidity affect the corporate green bond yield spread (defined as the yield spread between corporate green bonds and government treasury bonds). They confirm the traditional bond evidence, which reveals a negative relationship between the credit rating/market liquidity and yield spread.

Hyun et al. (2021) focused on the differential pricing between labelled (namely GBP) and unlabelled green bonds. Using a propensity score matching analysis, they found that the labelled green bonds are traded lower (in terms of yield) than the unlabelled green bonds of 24–36 bps.

Finally, Alonso-Conde and Rojo-Suárez (2020) performed a business case analysis to assess the funding convenience of a green project between several types of financing (green bonds bank loans). The authors concluded that green bond financing has a greater IRR for shareholders than bank loans.

The extensive aspects considered under *"the Green bond—supply-side analysis"* area require the splitting of the sample into subgroups, according to the common research objectives in order to detect future research indications easily.

The first sub-group considers the impacts of bond/issuer characteristics on green bonds performance/return. In this case, Chang et al. (2021), Hyun et al. (2021), Russo et al. (2021), Wang et al. (2019) and Li et al. (2020) can be grouped. The sampled studies denote well-diversified methodology approaches based on the regression analysis, but a geographical concentration on the China-based research. Indeed, studies based on the Chinese bond markets (Chang et al. 2021; Wang et al. 2019; and Li et al. 2020) can be replicated globally or in other countries/regional areas. Moreover, the future scholars' attention can be directed to update the exciting results/methods used by Hyun et al. (2021) and Russo et al. (2021), who use a small and, nowadays, not so up-to-date dataset (the authors analyzed green bond data respectively until 2017 and 2016).

Another subgroup is composed of works that investigate the impacts of bond/issuer characteristics on the size and demand of green bonds at the issuance. Nanayakkara and Colombage (2021), Chiesa and Barua (2019), and Barua and Chiesa (2019) are included in this group. These works show an appealing linkage between bond/issuer characteristics and green bond market supply/demand on an international scope, but they use a sample of bonds only until 2016–2017. A possible step forward can be to update the time horizon of this research.

Finally, Dou and Qi (2019) and Deng et al. (2020) analyzed the effects on green bond issuance due to two particular characteristics of Chinese green bond frameworks: (i) The presence of three green bond frameworks with different strengths of compliance/requirements; (ii) the possibility for specific Chinese frameworks to not devote 100% of green bond proceeds to green projects. These Chinese regulation features are challenging to find in other global green bond guidelines or other countries. Table 8 shows the main characteristics of the analysis performed by scholars.

Table 8. "Green bond—supply-side analysis" empirical literature by the type of sample and methodology.

Author(s) (Year)	Time Span	Geographical Scope	Sample Size	Green Bond (and Issuer) Type	Methodology
Barua and Chiesa (2019)	2010–2017	World	771 GB	All types	Cross-sectional OLS regression
Chiesa and Barua (2019)	2010–2017	World	771 GB	All types	Cross-sectional OLS regression, Blinder–Oaxaca Decomposition
Dou and Qi (2019)	2016–2018	China	308 GB	Corporate issuers, medium and long-term maturity green bonds	Logit model and maximum likelihood estimation method
Wang et al. (2019)	1/2016–12/2018	China	305 GB	ABS and project green bonds excluded	Multivariate statistical regression analysis on cross-sectional data
Alonso-Conde and Rojo-Suárez (2020)	n.a.	n.a.	n.a.	n.a.	Business case (Sagunto regasification plant)
Deng et al. (2020)	2016–2018	China	163 GB	All types	OLS regression
Hyun et al. (2021)	01/2014–12/2017	World	3578 GB	All types	Propensity score matching (PSM) OLS regression
Li et al. (2020)	01/2016–09/2018	China	114 GB	Listed green bonds	OLS regression
Nanayakkara and Colombage (2021)	2007–2016	G-20 countries	399 GB	Supranational issuers excluded	Cross-sectional regression
Chang et al. (2021)	01/2018–12/2019	China	112 GB	Corporate issuers	Panel data regression and generalized method of moments (GMM)
Russo et al. (2021)	2013–2016	World	306 GB	Corporate issuers	GLS regression

Note: Papers are displayed by year and in alphabetical order.

3.5. Green Bond Market Performance Analysis

The fifth macro-area individuated within the prosed taxonomy, called "*Green bond market performance analysis*", focuses on green bond market characteristics analysis, in order to give meaningful insights to policymakers and professionals regarding the functioning of this promising market.

Pham (2016) analyzed how volatility affects green bond markets. Employing a multivariate Garch model on two S&P indexes during five years (2010–2015), the author studied the volatility behavior of the GBP-labelled green bond market segment compared with the unlabelled ones. Pham identified a piece of exciting market evidence, in which periods with high volatility are often followed by high volatility periods, and periods with low volatility are followed by low volatility periods (volatility clustering). In addition, this evidence is stronger for the labelled green bond segment rather than the unlabelled segment. A possible explanation is that the green-labelled market segment is composed of very similar credit-rated bonds relating to a more diversified unlabelled green bond market segment and conventional bond market. Another evidence is the presence of a positive correlation and volatility spillover between the green bond market and conventional bond market and vice versa. This last evidence tends to increase over time.

Pham and Huynh (2020) found a correlation between investor attention (measured by the Google Search Volume Index) and green bond market performance (measured by five green bond market indexes) during the 2014–2019 period. The authors found that the investor's attention is strongly connected with the return and volatility of the green bond market, and varies over time (more robust in the short-run than in the long run).

Febi et al. (2018) investigated how liquidity risk affects the green bond market. Using two liquidity measures (bid-ask spread and LOT liquidity measure), they demonstrated

that during the 2014–2016 period, green bonds were on average more liquid than the comparable conventional bonds. Moreover, liquidity metrics are positively related to the performance of green bonds, but the impact of the LOT measure has been declining over recently.

Finally, Shaydurova et al. (2018) found that investing in sustainable firms is a defensive investment strategy for investors, since they are less volatile in times of recession, and they seem to be less overestimated compared with common non-green stocks. This was based by comparing the main international green indexes (equity-indexes including "*green*" stock) versus common international stock indexes. Moreover, constructing a diversified international portfolio of 10 green bonds, the authors found that green bonds seem to be more defensive than conventional bonds.

Compared to the first three taxonomy groups, this last group analyzes the green bond market characteristics beyond its pricing/return structure (see Table 9). The studies previously exhibited focus on the risk, volatility, and liquidity characteristics of the green bond market. This range of topics seems to be less investigated by scholars than the previous taxonomy groups. In addition, future research may shed some light on the "*risk-side*" of green bonds rather than the "*return-side*", in terms of connectedness with other markets and firms' stock reaction to issuances.

Table 9. "Green bond market performance analysis" empirical literature by the type of sample and methodology.

Author(s) (Year)	Time Span	Geographical Scope	Methodology
Pham (2016)	30/4/2010–29/4/2015	World	Multivariate GARCH
Febi et al. (2018)	2013–2016	UK and Lussemburgo	Two-factor model; LOT liquidity measure; OLS panel regression
Shaydurova et al. (2018)	12/2015–5/2018	World	Standard analysis of the performance of the indices; VAR model
Pham and Huynh (2020)	10/2014–11/2019	World	Univariate analysis; GARCH models; Covariance stationary VAR model

Among the other papers within this group, Pham (2016) and Febi et al. (2018) presented perhaps additional food for thought in subsequent studies. It would be possible, at least, to update the sample considered in both works. Moreover, it could be stimulating to use different methodologies to investigate volatility behavior according to the labelled/unlabelled green bond nature and secondary market liquidity trend of the green bond market during last years.

3.6. Other

The "*Other*" area gathers a set of academic studies that cannot address the previous areas. It is a residual category where topics are different, and there is no linkage between the studies. Monasterolo and Raberto (2018) applied a macroeconomic model (EIRIN flow-of-funds behavioral model) to analyze different measures through which governments can support the low-carbon transition (green fiscal policy and green bond issuance). The authors demonstrated that financing green policies through green sovereign bonds is a win-win solution to pursue a low-carbon economy transition.

Tu et al. (2020a) employed a multi-criteria decision-making method, called the Analytic Hierarchy Process (AHP) method, on a group of experts who compare the importance of several factors that influence Vietnam's green bond market development. The results showed that an efficient legal framework and a stable monetary policy in Vietnam are essential factors that experts judge to scale the green bond market. This contribution constitutes an exciting and original approach to be replicated in other geographical areas, in order to equip policymakers with useful indications in orienting their decisions.

Tolliver et al. (2020a) demonstrated that countries with stringent international green commitment (high National Determine Contributions under the framework of the Paris

Agreement) have shown a large and growing volume of green bond issuances in renewable energy compared with countries that were less committed. Moreover, Tolliver et al. (2020b) went beyond their previous work, by adding evidence that the green bond market development is strongly led by macroeconomic and institutional factors.

An interesting study is Tuhkanen and Vulturius (2020), who analyzed the linkage between green bond issuance frameworks, issuer's climate targets, and ex-post reporting in a sample of 20 European corporate green bond issuances. They underlined a disconnection between the corporate climate targets and green bond issuance framework, and various shortcomings in issuers' post-issuance reporting are shown. The authors suggested regulatory improvements to reduce this information asymmetry and the risk of greenwashing.

Finally, Halkos et al. (2020) analyzed the interdependencies between the green bond markets on a country/regional base. Using the network analysis, the authors found that a few of the main countries (USA, UK, France, etc.) play a crucial role in leading the green bond market.

4. Conclusions

Climate change has become a key issue in the last few years, and individuals are increasingly developing climate-oriented needs when searching for investment opportunities. Green bonds are one of the most famous financial instruments born to finance the transition to a low-carbon economic system (World Bank 2019; Tu et al. 2020a, 2020b). Green bonds can help public and private financing flows to head towards new levels of awareness on climate use. During the last years, the stunning growth of the green bond market witnessed the surge that these new green backed-financial instruments are achieving in investors' preferences.

Academia started to gain interest in green bonds very recently. However, year by year, a constant increase of papers arose with the aim to analyze this new bond market. In addition, scholars paid attention to the characteristics of green bond markets, the connections/differences between green bonds and other financial instruments, the implications for issuers, etc. In response to this new field of research, a broad literature review on green bond thematics was needed to identify the major research trends and any gaps. This paper aims to develop a comprehensive literature review to collect, analyze, and synthesize previous academic empirical studies in the field of green bonds. Accordingly, a systematic literature review was performed to collect as many academic empirical works as possible, involving green bond thematics. After the database interrogation and screening process, a sample of 53 peer-reviewed papers was identified. The methodology used during the database interrogation was settled to obtain a comprehensive sample, in an effort to reach all of the academic empirical works published in the last years. Then, we developed a taxonomy to regroup the major lines of research found in the sample. All of the six lines of research identified were analyzed in-depth and synthesized to present the main findings, academic consensus on some evidence, and any disagreement among the authors.

The theoretical implication of this paper is to help scholars better understand the research environment in the field of green bonds and, more importantly, to supply them with some future research suggestions. All of the identified groups were analyzed in-depth to make the possible research gaps evident, as well as the not-adequately-covered thematics that future works should address to better comprehend the green bond universe.

Based on the main findings in Section 3, the "*Greenium*" area is a well-analyzed topic. However, some research gaps can be highlighted. First, no attention was given to the US corporate green bond market. Therefore, a time span update seems to be needed for green bond US municipal markets studies. Second, there is only an EU-based study, and thus future works should explore other methodologies. Third is the lack of studies on the Chinese secondary green bond market. Finally, scholars might want to investigate more in-depth global primary markets of green bonds by updating the temporal span.

The "Green bond connectedness w/other financial instruments" area is probably the best-analyzed topic within the green bond academic universe. Future works can study

the connections between the green bond market sub-segments with other traditional (non-green) markets. Moreover, a significant regional diversification of analysis should be performed. It is essential for scholars to investigate this field of research for hedging evidence, which is shown by green bonds when compared with "dirty" financial instruments (Saeed et al. 2020) and "dirty" energy commodities (Naeem et al. 2021). Furthermore, the green bond seems to have risk mitigation characteristics against long-term economic policy uncertainty, particularly during the COVID-19 outbreak (Haq et al. 2021). This latter field of study can exploit an interesting potential upside due to the limited works conducted.

An attractive research gap within the "*Green bond and stock reaction*" area spreads the analysis to other countries/regions (particularly the US, EU, and emerging markets rather than China) and other industry sub-sectors.

A possible future research in the "*Green bond—supply-side analysis*" area can be headed towards analyzing the relations between the bond/issuer characteristics on green bonds performance/return on a more diversified geographical sphere. Moreover, the sample of bonds used in these studies are quite old, and a temporal update could be helpful.

Finally, the "*Green bond market performance analysis*" area seems to be the least investigated topic. Future research can be headed in the following directions: (1) To update the methodology used by Pham (2016) and Febi et al. (2018). (2) To use different methodologies for the analysis of the volatility behavior, according to the labelled/unlabelled green bond nature and secondary market liquidity trend of the green bond market during the last years. Another interesting development of this paper is extending the systematic review to studies that deal with clean energy stocks, in order to analyze another path of research on ESG/green field matters that, jointly with green bonds, is a key catalyst in shifting to an environmental friendly economy.

The main limitation in this paper is the selection of only academic peer-reviewed and conference papers, excluding any industry/institutional reports and master/PhD thesis. This choice was made to exclude reports without clear methodology frameworks and to only analyze publications that have passed through a peer-reviewed process. Using only academic publications was essential in order to obtain a systematic review process that ensured the database inquiry's replicability, which is one of the main objectives of a systematic literature review. Including these latter types of publications can be a future development of this paper. The enhancement of the private green bond market is desirable to increase emissions reductions policies, long-run developments, and improvement of ongoing eco-friendly projects to reach the goals of the Paris Agreement (Tu et al. 2020b; Tolliver et al. 2020a), according to the insufficiency of public investment to finance low-carbon projects and circular economy. In this sense, despite the unavoidable limitations, this paper aims to be an attempt to determine the past and future contribution of academia to the desired green bond market expansion.

Author Contributions: Conceptualization, G.C. and I.C.P.; methodology, G.C.; validation, I.C.P.; formal analysis, G.C.; writing—original draft preparation, G.C.; writing—review and editing, G.C. and I.C.P.; supervision, I.C.P.; funding acquisition, I.C.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by Phd Programme in Management, Banking and Commodity Sciences—Banking and Finance curriculum—Sapienza University of Rome, 00161 Rome.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Full list of the 53 papers included in the systematic review.

Author(s)	Year	Title	Journal	Taxonomy Group *
Alonso-Conde, A.B., Rojo-Suarez, J.	2020	On the Effect of Green Bonds on the Profitability and Credit Quality of Project Financing	*Sustainability*	3
Bachelet, M.J.; Becchetti, L.; Manfredonia, S.	2019	The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification	*Sustainability*	1
Barua, S.; Chiesa, M.	2019	Sustainable financing practices through green bonds: What affects the funding size?	*Business strategy and the environment*	3
Baulkaran, V.	2019	Stock market reaction to green bond issuance	*Journal of Asset Management*	4
Broadstock, D.C.; Cheng, L.T.W.	2019	Time-varying relation between black and green bond price benchmarks: Macroeconomic determinants for the first decade	*Finance Research Letters*	2
Chang, K.; Feng, Y.L., Liu, W.: Lu, N.; Li, S.Z.,	2021	The impacts of liquidity measures and credit rating on corporate bond yield spreads: Evidence from China's green bond market	*Applied Economics Letters*	3
Chiesa, M.: Barua, S.,	2019	The surge of impact borrowing: The magnitude and determinants of green bond supply and its heterogeneity across markets	*Journal of Sustainable Finance and Investment*	3
Daszynska-Zygadlo, K; Marszalek, J; Piontek, K	2018	Sustainable Finance Instruments' Risk—Green Bond Market Analysis	*Conference paper*	2
Deng, Z.; Tang, D.Y.; Zhang, Y.	2020	Is "greenness" priced in the market? Evidence from green bond issuance in China	*Journal of Alternative Investments*	3
Dou, X.; Qi, S.	2019	The choice of green bond financing instruments	*Cogent business and management*	3
Draksaite, A; Kazlauskiene, V; Melnyk, L.	2018	The Perspective of the Green Bonds as Novel Debt Instruments in Sustainable Economy	*Conference paper*	2
Febi W.; Schäfer D.; Stephan A.; Sun C.	2018	The impact of liquidity risk on the yield spread of green bonds	*Finance Research Letters*	1, 5
Gianfrate, G.; Peri M.	2019	The green advantage: Exploring the convenience of issuing green bonds	*Journal of Cleaner Production*	1
Hachenberg, B.; Schiereck, D.	2018	Are green bonds priced differently from conventional bonds?	*Journal of Asset Management*	1
Halkos, G.; Managi, S.; Tsilika, K.	2020	Ranking Countries and Geographical Regions in the International Green Bond Transfer Network: A Computational Weighted Network Approach	*Computational Economics*	6
Hammoudeh, S.; Ajmi, A.N.; Mokni, K.	2020	Relationship between green bonds and financial and environmental variables: A novel time-varying causality	*Energy Economics*	2

Table A1. *Cont.*

Author(s)	Year	Title	Journal	Taxonomy Group *
Huynh, T.L.D.	2020	When 'green' challenges' prime': Empirical evidence from government bond markets	*Journal of Sustainable Finance and Investment*	2
Huynh, T.L.D.; Hille, E.; Nasir, M.A.	2020	Diversification in the age of the 4th industrial revolution: The role of artificial intelligence, green bonds, and cryptocurrencies	*Technological Forecasting and Social Change*	2
Hyun, S.; Park, D.; Tian, S.	2020	The price of going green: The role of greenness in green bond markets	*Accounting and Finance*	1
Hyun, S.; Park, D.; Tian, S.	2021	Pricing of Green Labeling: A Comparison of Labelled and Unlabelled Green Bonds	*Finance Research Letters*	3
Immel, M.; Hachenberg, B.; Kiesel, F.; Schiereck, D.	2021	Green bonds: Shades of green and brown	*Journal of Asset Management*	1
Jakubik, P.; Uguz, S.	2021	Impact of green bond policies on insurers: Evidence from the European equity market	*Journal of Economics and Finance*	4
Jin, J.; Han, L.; Wu, L; Zeng, H.	2020	The hedging effect of green bonds on carbon market risk	*International Review of Financial Analysis*	2
Kanamura, T.	2020	Are green bonds environmentally friendly and good performing assets?	*Energy Economics*	1, 2
Karpf, A; Mandel, A.	2018	The changing value of the 'green' label on the US municipal bond market	*Nature climate change*	1
Larcker, D.F.; Watts, E.M.	2020	Where is the Greenium?	*Journal of Accounting and Economics*	1
Lebelle, M.; Jarjir, SL.; Sassi, S.	2020	Corporate Green Bond Issuances: An International Evidence	*Journal of risk and financial management*	4
Li, Z.; Tang, Y.; Wu, J.; Zhang, J.; Lv, Q.	2020	The Interest Costs of Green Bonds: Credit Ratings, Corporate Social Responsibility, and Certification	*Emerging Markets Finance and Trade*	3
Liu, N.; Liu, C.; Da, B.; Zhang, T.; Guan, F.	2021	Dependence and risk spillovers between green bonds and clean energy markets	*Journal of Cleaner Production*	2
Mohd Roslen, S.N.; Yee, L.S.; Binti Ibrahim, S.A.	2017	Green Bond and shareholders' wealth: A multi-country event study	*Journal of globalization and small business*	4
Monasterolo, I.; Raberto, M.	2018	The EIRIN Flow-of-funds Behavioral Model of Green Fiscal Policies and Green Sovereign Bonds	*Ecological Economics*	6
Nanayakkara, K.G.M.; Colombage, S.	2020	Does compliance with Green Bond Principles bring any benefit to make the 'Green economy plan' of the G20 a reality?	*Accounting and Finance*	3
Nanayakkara, M.; Colombage, S.	2019	Do investors in the Green Bond market pay a premium? Global evidence	*Applied Economics*	1
Nguyen, T.T.H.; Naeem, M.A.; Balli, F.; Balli, H.O.; Vo X.V.	2021	Time-frequency co-movement among green bonds, stocks, commodities, clean energy, and conventional bonds	*Finance Research Letters*	2
Park, D.; Park, J.; Ryu, D.	2020	Volatility Spillovers between Equity and Green Bond Markets	*Sustainability*	2

Table A1. *Cont.*

Author(s)	Year	Title	Journal	Taxonomy Group *
Partridge C.; Medda, F.R.	2020	The evolution of pricing performance of green municipal bonds	*Journal of Sustainable Finance and Investment*	1
Pham, L.	2016	Is it risky to go green? A volatility analysis of the green bond market	*Journal of Sustainable Finance and Investment*	5
Pham, L.; Huynh, T.L.D.	2020	How does investor attention influence the green bond market?	*Finance Research Letters*	5
Reboredo, J.C.	2018	Green bond and financial markets: Co-movement, diversification, and price spillover effects	*Energy Economics*	2
Reboredo, J.C.; Ugolini, A.	2020	Price connectedness between green bond and financial markets	*Economic Modelling*	2
Reboredo, J.C.; Ugolini, A.; Aiube, F.A.L.	2020	Network connectedness of green bonds and asset classes	*Energy Economics*	2
Russo, A.; Mariani, M.; Caragnano, A.	2021	Exploring the determinants of green bond issuance: Going beyond the long-lasting debate on performance consequences	*Business strategy and the environment*	3
Saeed, T.; Bouri, E.; Alsulami, H.	2021	Extreme return connectedness and its determinants between clean/green and dirty energy investments	*Energy Economics*	2
Shaydurova, A.; Panova, S.; Fedosova, R.; Zlotnikova, G.	2018	Investment attractiveness of "Green" financial instruments	*Journal of Reviews on Global Economics*	5
Tang, D.Y.; Zhang, Y.	2020	Do shareholders benefit from green bonds?	*Journal of Corporate Finance*	1, 4
Tolliver, C.; Keeley, A.R.; Managi, S.	2020-1	Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability	*Journal of Cleaner Production*	6
Tolliver, C.; Keeley, A.R.; Managi, S.	2020-2	Policy targets behind green bonds for renewable energy: Do climate commitments matter?	*Technological Forecasting and Social Change*	6
Tu, C.A.; Rasoulinezhad, E.; Sarker, T.	2020	Investigating solutions for the development of a green bond market: Evidence from the analytic hierarchy process	*Finance Research Letters*	6
Tuhkanen, H.; Vulturius, G.	2020	Are green bonds funding the transition? Investigating the link between companies' climate targets and green debt financing	*Journal of Sustainable Finance and Investment*	6
Wang J.; Chen X.; Li X.; Yu J.; Zhong R.	2020	The market reaction to green bond issuance: Evidence from China	*Pacific-Basin Finance Journal*	1, 4
Wang, Q.H.; Zhou, Y.N.; Luo, L.; Ji, J.P.	2019	Research on the Factors Affecting the Risk Premium of China's Green Bond Issuance	*Sustainability*	3
Zerbib, O.D.	2019	The effect of pro-environmental preferences on bond prices: Evidence from green bonds	*Journal of Banking and Finance*	1
Zhou, X.G.; Cui, Y.D.	2019	Green Bonds, Corporate Performance, and Corporate Social Responsibility	*Sustainability*	4

Note: Papers are displayed by authors; * taxonomy groups are numbered in Table 4.

Notes

[1] CBI (Climate Bond Initiative) is an international not-for-profit organization aiming to mobilize larger capital flows to green climate-aligned projects. CBI operates by providing market intelligence, standards, and policy recommendations.

[2] ICMA (International Capital Market Association) is a not-for-profit association composed of private and public financial actors, such as banks, asset managers, investment funds, central banks, law firms, etc. The main objective is to assist capital/security market participants, promote market good practices and standards, etc. From the starting coalition of four institutions (Bank of America Merrill Lynch, Citi, Credit Agricole and JP Morgan), ICMA now (as of the end of March 2020) counts on 600 Members in 62 countries.

[3] According to ICMA, green bonds are any fixed income financial instruments where the proceeds will be exclusively used to finance (or re-finance) new (and/or existing) green projects where green projects are related to the followed field: Renewable energy, energy efficiency, pollution prevention, clean transportation, sustainable water management, etc. (ICMA 2018, Green Bond Principles).

[4] The state of Massachusetts issued the first municipal green bond in July 2013. The first corporate green bond was issued by "*Electricite de France*" in November 2013.

[5] In the same year, various green bond market indices were launched to sign the market progress contributing to the development of the market (Jones et al. 2020).

[6] Scopus's SCImago Journal Rank is a scientific influence index alternative to Impact Factor. The SJR measures weighted citations received by the journal. Citation weighting depends on the subject field and prestige (SJR) of the citing journal.

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