

Research on the Correlation of Green Bond Market

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ABSTRACT

Green bonds are of great help to promoting the growth of a sustainable economy. This paper critically reviews the burgeoning literature relevant to the linkage between the green bond market and other financial markets. This paper's review introduces the linkage between the green bond market and ordinary bond market as well as the stock market. This paper critically reviews the content (both in methods and findings) of around 50 articles published in recent two decades. Our analysis illustrates that this paper sees a positive relationship between the green bond market and other markets through GARCH models and MF-DCCA models. this paper concludes with suggestions as well as the outlook for the green bond market for the future. This paper gives suggestions on how investors make better investment decisions with the green bond market considering the interactivity in the whole financial market as well as using some quantitative analysis tools like the average risk spillover level.

Keywords: green bond, bond market, carbon-neutral bond, linkage effect, spillover effects.

1. INTRODUCTION

Green bonds possess an obvious characteristic that is 'green-labeled, which reflects the positive benefits of this kind of bonds raised in environment protection, climate adaptation as well as sustainable development. Providing financial support for the green industry and helping green-labeled projects to reduce the risk of maturity mismatch, green bonds are considered as a long-term, stable, and low-cost financing channel [1]. Back in 2007, the world's first green bond, 'Climate Awareness Bonds' by European Investment Bank, was successfully issued. The development of the green bond market is of significant help to the green, low-carbon, and high-quality development of the economy worldwide.

The superior performance of the green bond market has made it popular among scholars. A detailed review of the development of green bonds in China as well as in Europe is illustrated (li Jianfeng,2021) [2]. Despite the development of green bonds, in this paper, this paper is more likely to focus on the linkage effect between the green bond market and the ordinary bond market. Listed factors and effects of linkage among the markets are analyzed (Wang Yu,2021) [3]. A statistical analysis

based on the DCC-GARCH model of the linkage between the green bond market and the green stock market is thorough (Luo Xiong, 2020) [4]. Despite such researches on the linkage between the green bond market and other markets, to the best of our knowledge, no review paper exists that reviews existing literature. This paper aims at giving a review of articles that are related to the linkage effect between the green bond market and other markets. this review focuses on the following major topics: 1) the correlation between the carbon-neutral bond market and the ordinary bond market; 2) the green bond market volatility effects; 3) interaction between green bonds and the stock market; 4) the benefit of spillover between the stock market and the bond market.

This paper is organized as follows: Section 1 introduces the correlation between the carbon-neutral bond market and the ordinary bond market. Different kinds of models used are detailed in Section 1.1 and this paper reports the analytic findings. Section 2.2 illustrates the Green Bond Market volatility spillover effects with previous studies summing up detailed in Section 2.2 and also statistical findings. Section3.1 gives a review of the linkage between green bonds and

the stock market and Section 3.2 introduces the benefit spillover between them.

Finally, this paper provides a quick overview of this paper and suggestions as well as the outlook for the future.

2. THE LINKAGE EFFECT OF THE CARBON-NEUTRAL BOND MARKET AND ORDINARY CARBON-NEUTRAL BOND

Green bonds are a kind of bond that raises funds to support eligible green industrial projects. As a sub-market of the general bond market, it has some characteristics of the general bond market, but there are still some differences. This paper pays attention to the impact of changes in green bonds on the entire bond market. The study of risk-return transfer characteristics between the two markets can provide an effective reference for the healthy development of the green bond market and help investors make a better judgment on the changes of return of the green bond market.

Existing literature studies on the linkage effect of the carbon-neutral bond market and ordinary bond market mainly focus on two aspects: 1) the correlation between the carbon-neutral bond market and the ordinary bond market. 2) Spillover effect of green bond market volatility.

2.1. Research on the correlation between the carbon-neutral bond market and ordinary bond market

Correlation refers to the correlation degree of two variables, which can be used to preliminary judge whether there is a linkage effect between two markets. Because of the correlation and interaction between financial markets, the market crisis will be very easy to spread to other markets, and the impact is significant that it can even create a crisis throughout the financial system. From the existing literature, there is a lot of research focusing on the correlation between sub-markets of the macro-financial market. For example, the Spearman correlation coefficient was used for each market (He Feng, 2021) [8]. By using the rank-sum correlation, it concluded that the fund market, stock market, and bond market have a high correlation. Moreover, Zhao Mingming (2021) [7] used the AVR model to verify that the return rate of green bonds is negatively affected by the return rate of stocks in low-carbon industries, according to AIC and SC criteria.

In contrast, scholars do not pay much attention to the correlation between the green bond market and the ordinary bond market, but it is equally important to study it. Because this topic has attracted more and more attention around the world. The World Carbon Neutral

Commission, launched by former European Council President and Former Irish Prime Minister Bertie Hernia, had announced plans to launch a "world carbon neutral media network" in 2021. And also in September 2020, China put forward a point of view in the general debate of the seventy-fifth Session of the United Nations General Assembly, strove to achieve a "carbon peak" in 2030, in 2060 to achieve "carbon neutral". And the proposal of the 14th Five-Year Plan had already pointed out a point that "Green development" should be a prerequisite for all regions. And in the process of "green development", the green industry and green research need to provide a large number of funds for green finance as the basis of development. The development and change of the green bond market will have a profound impact on the whole bond market. From the aspect of professional theory, copula function was used to estimate the parameters of Copula through the maximum likelihood method (Han Guowen, 2021) [5], and it was concluded that there was a strong positive correlation between the green bond market, corporate bond, and national bond market. Wang Yu (2021) [3] used DCC-GARCH and BeKK-GARCH models for comparative analysis and concluded that the green bond market and traditional bond market maintain a positive correlation. Kabir (2018) [9] studied the dynamic conditional correlation between European, US, emerging the Sukuk markets, and the traditional bond markets from 2010 to 2014 by constructing a market-weighted Sukuk index and using the multivariate GARCH model.

In terms of the methods and results of the study of Han Guowen(2021) [5] who used the copulas connect function which described the correlation between variables. It is a class of functions that concatenate joint distribution functions with their respective edge distribution functions, it does not impose strict requirements on the function of edge distribution. So, this function is more flexible to use than other functions. Han Guowen (2021) [6] used Copula to calculate static Copula and time-varying Copula parameters. And determined the optimal Copula model by selecting the minimum AIC value. However, the optimal Copula model of the green bond market, corporate bond market, and government bond market showed an asymmetric tail correlation. Han Guowen's explanation for this is that most of the bonds selected are of short maturity and the changes of psychology in investors can also have a significant influence. The results of Han Guowen's study, though, partly explain the correlation between green bonds and conventional bonds, but this kind of correlation is conditional, not universal. Understandably, representational errors are inevitable when selecting data. But there are still some scholars who have studied it. For example, the asymmetric correlation of the bond market caused by investor psychology has been researched (Wang Yu, 2021 [3]). Different from Han

Guowen (2021) [6], Wang Yu (2021) [3] used DCC-GARCH and BEKK-GARCH models to test the correlation of selected data and introduced the "herd effect" in investor behavior to explain the result. He believes that in real life, investors do not have complete market information, so when the bond market fluctuates, investors will be affected by the behavior of other investors and engage in some imitative behavior, thus causing the asymmetry of the bond market correlation. This explanation has a certain degree of conviction. When other investors who are in the same market as an investor make a certain decision, they will also influence this investor to make the same decision. Therefore, a chain effect is generated, which increases the number of investors making such decisions by nearly exponential times, thus making the correlation of the bond market becomes time-varying. Mr. Wang, though, makes an excellent case for the asymmetry of bond market correlations, but this paper also notes that the data Wang Yu (2021) [3] used all come from China, but in today's world with deepening financial market globalization, this paper should also notice the differences between countries, which means whether the correlation of the bond market in the international financial market is the same as the Chinese market. To answer this question, Kabir (2018) [9] used the GARCH model to study the correlation between the Islamic bond market and the high-yield European bond market, and it also concluded that the selected bond market correlates.

2.2. Maintaining the Integrity of the Specifications

Just explaining the correlation between the green bond market and the general market cannot explain the specific reasons for the correlation between the two markets, so this paper needs to introduce the bond market spillover effect for further explanation. The spillover effect refers to a debt that changes will not only produce the effect of itself but influence other bonds. In this paper, spillover effects are divided into two types: Average spillover and fluctuation spillover. Average spillover generally refers to the impact of price or return changes in one market to other markets, which can be positive or negative. Volatility spillover refers to the influence of fluctuations in one market (generally measured by variance) on other markets. Such influence is not positive or negative, but only of magnitude. As for the spillover effect of the bond market, Pham (2016) [10] first compared the green bond market with the ordinary market, analyzed the volatility of green bonds of Standard & Poor by using the GARCH model, and concluded that the influence of the ordinary bond market would spill over to the green bond market. Han Guowen (2021) [6] used the COVAR method and showed that price fluctuations in corporate and national bond markets will have a great impact on the green bond market. That is, the price spillover effect is

significant. Because the measurement of fluctuation meaning is relatively abstract. To make volatility spillover more convenient for readers to understand, the risk spillover index can be used to represent the measure of variance volatility. Li Boyang (2021) [11] applied the risk spillover index model. This shows that the volatility spillover effect between financial markets is a "double channel spillover", that is, new interest shock spillover and historical volatility spillover. Under the action of these two kinds of spillover mechanisms, there is a wide and significant two-way risk spillover effect between Chinese financial markets.

According to the research results of Pham (2016) [10], which used the GARCH model to verify the existence of volatility clustering effect between the green bond market and traditional bond market, and found that positive and negative shocks had similar effects on data volatility, so it was deemed unnecessary to introduce asymmetric leverage effect. Although Pham (2016) [10] conducted a very scientific study on the volatility effect of the green bond market, they failed to accurately study the causes of specific fluctuations within the bond market. Han Guowen (2021) [6] explained the price linkage among the corporate bond market, national bond market, and green bond market by using the price spillover effect. Han Guowen (2021) [6] used the difference between COVAR and VAR to calculate the impact of extreme price fluctuations in one market to the other market and concluded that there is a significant spillover effect among the price fluctuations in the corporate, national bond markets and the price of green bonds. and puts forward some effective suggestions for investors and the government given the price spillover effect. Although Han Guowen (2021) [6] has made a reasonable explanation for the volatility effect of the green bond market, investors not only pay attention to the returns brought by bonds, they also consider the possible risks of bonds when making investment decisions. Li Boyang (2021) [11] used the principle of variance decomposition of the VAR model to measure the size and direction of risk spillover between multiple variables. Li Boyang (2021) [11] used static risk spillovers to calculate the average level of risk spillovers in the sample period and found that there are two directions of risk spillovers in financial markets. First, it has asymmetry, and second, it has simultaneous spillover of new interest shock and historical fluctuation, and because of these two kinds of spillover, it produces an extensive two-way spillover effect in the financial market. Li Boyang (2021) [11] not only quantified the risk spillover level but also found the asymmetry and two-way spillover reasons of financial market volatility.

3. LINKAGE BETWEEN GREEN BONDS AND THE STOCK MARKET

A stock market is a place where issued stocks are transferred, bought, sold, and circulated, including the exchange market and the over-the-counter market. It is also called the secondary market because it is based on the issuance market." Green bonds" refer to bond instruments that use the proceeds exclusively to finance or refinance green projects that meet specified conditions. Compared with ordinary bonds, green bonds have four characteristics: the purpose of the fund raised by bonds; the evaluation and selection procedures of green projects, the tracking management of the fundraised, and the issuance of relevant annual reports. This paper mainly describes and studies the correlation between the green bond market and the stock market. We also analyze the correlation coefficient and spillover effect between them such as mean spillover effect and volatility spillover effect. Let us further understand the green bond market for bringing more reference value in future investment.

The existing literature on the co-activity of green bonds and the stock market is mainly shown in the following two aspects: 1). the interaction between the two is described through risk, return, and asset allocation.2). Research on spillover effect between the stock market and bond market.

3.1. Interaction between the stock market and bond market

Investors' choice of financial products is dominated by stocks and bonds. With the development of the financial market, the risk of investment in a single financial product is high, so there are related studies on cross-asset allocation to achieve risk diversification. Shen Simin (2021) [14] used multiple analysis methods MF-DCCA to study the characteristics of interactive correlation between different markets. She found that this method could describe the strength of the multi-fractal of interaction between the two sequences which indicates the stronger the multi-fractal, the greater the financial risk implied in the portfolio, and the more volatile the market. Li Boyang (2021) [11] also used this method to find that there is a strong interactive correlation between China's stock market, foreign exchange market, and money market. In the case of small fluctuations, the interactive correlation is weak persistent. While in the case of large fluctuations, the interactive correlation is anti-persistent. However, due to the small sample size, inconsistent data frequency, and other problems, Li Letian (2020) [12] used the DCC-MgarCH model to solve the issue that we can only get relatively low-frequency monthly data. He priced kernel to calculate the dynamic correlation coefficient of stock market and bond market returns, and verify the

relevant rules of Chinese stock and bond markets. Based on the risk linkage of individual stocks, Dai Fangxian (2017) [16] used δ coVaR to measure the level of systematic correlation between individual stocks and the market as a whole in China's capital market. In the linkage of the two markets, the stock portfolio composed of stocks with similar characteristics often has similar market performance.

By using the MF-DCCA method, Shen Simin (2021) [14] concluded that there is a power-law interaction correlation among the yield series of stocks, national bonds, and corporate bonds. The graph of Renyi index τ XY (Q) to Q, which observed the stock to stock return series, further shows that the stock and government bond portfolio has the highest risk, while the stock and the corporate bond portfolio has the lowest risk. Fat tail distribution is the main reason for the multipleomorphism of the interaction between them. Li Letian (2020) [12] adopted the method of Pericoli(2018) and concluded that positive fluctuations of unexpected inflation and real interest rate could lead to a decline in bond yields. The bonds with longer maturities would be more susceptible to these two fluctuations, and the term premium would be lower and lower. In other words, equity returns are a hedge against rising inflation, which reduces bond yields.

3.2. Research on benefit spillover between the stock market and bond market

Bai Jie (2018) [15] selects the CSI 300 index and China Securities Government bond index as research samples, using the VAR-GarCH-BEKK model to study the mean value and volatility spillover effect of the Chinese stock market and bond market. He found that both the stock market and bond market have volatility aggregation. Bai Jie (2018) [15] found only a one-way volatility spillover effect between the stock market and bond market in her research on the volatility effect between the Stock market and bond market in China. As for the development of green bonds, there is also a correlation with the stock market. When the overall trend of the green bond market is good, investors will also be optimistic about the stock market of the green industry, and the correlation between the two markets is strong. As for the spillover effect of the two markets, Qin Shumeng (2019) [13] used the multi-variable and multi-digit CAViaR method to study the tail risk spillover effect of green stocks and green bonds which promoted the synergistic development of the two markets and provided a reference for the setting of green finance.

According to the vAR-Garch-Bekk model, there is a two-way mean spillover effect between the stock market and the Treasury bond market. There is no volatility spillover effect on the stock market, that is, there is only a one-way volatility spillover effect between the stock

market and the national debt market. Based on the mVMQ-Caviar model, we conclude that the volatility of the green stock market is greater than that of the green bond market. Because this is a newly introduced concept, the research on the green market is not perfect, and the information flow between the green bond market and the green stock market is weak, risks cannot be timely predicted.

4. CONCLUSION

This paper reviews a large amount of research on the interactivity of the bond market and bond market with other financial markets. Although the research methods these researches used are different, such as the GARCH model or COVAR method, the general results are almost the same: In the bond market, green bonds have a co-activity relationship with other traditional bonds, and green bonds also have a co-activity relationship with other financial markets, such as the stock market. After analysis, scholars found that the possible reasons for this phenomenon are the following psychology of investors and the integration of the financial market. Through studying this proposition, we believe that due to the existence of co-activity, a change of a certain market is likely to cause a change in the whole financial market. Therefore, when making investment decisions, investors should not only focus on the market they invest in, but also judge the trend of the whole market. But it is an almost impossible task to pay attention to every part of the whole market as financial markets are so vast and complex. Fortunately, scholars have developed some quantitative analysis tools such as the average risk spillover level to help investors to analyze the risk dependence between financial markets caused by co-activity. However, this kind of financial tool can only make an indirect prediction and cannot reach a very accurate and convenient level, which requires scholars to use different methods to develop more useful financial analysis tools.

AUTHORS' CONTRIBUTIONS

Junru Wang contributed to the conception of the study and manuscript preparation;

Weiyi Zhang wrote the manuscript with constructive discussions.

Wenye Zhao wrote the manuscript with constructive discussions.

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