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# A comparative study of risk spillover effects between China's green bond market and other equity markets

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***Abstract:*** *This paper uses the DCC-GARCH model to conduct a cross-sectional comparison study of the risk spillover effect between the green bond market, the traditional stock market and the low carbon industry stock market in China. The empirical results show that the risk spillover effect between the green bond market and the two stock markets is weak, while the risk spillover effect between the stock markets is the most significant; the risk spillover effect between the green bond market and the low carbon industry stock market is stronger than the dependence between it and the traditional stock market.*

***Keywords:*** *green bonds; stock market; DCC-GARCH modeling; risk spillover*

## 1. Introduction

With the gradual advancement of China's material level and economic development, the issue of ecological civilisation has become increasingly critical. With the backdrop of China's green development strategy, the green bond market, which started in 2015, has started to develop rapidly, and by 2020 China's green bonds have accumulated an issue volume of over RMB 1 trillion.

On the one hand, the healthy development of the green bond market cannot be achieved without the support and connection of the traditional financial market, of which low carbon industry stocks, as an important part of the green economy, are inseparable to its prosperity. But on the other hand, with the rapid expansion of the green bond market, the influx of large amounts of capital has increased the likelihood of risk outbreaks in the market, and ultimately the transmission of risk between markets can have a deleterious effect on the overall economic situation. Therefore, being able to properly understand the interplay of the green bond market on other financial markets is more conducive to promoting the development of China's green economy.

## 2. Overview of the green bond market and the risk spillover effects

In recent years, under the impetus of the policy, China's green finance has entered a new stage of development, and green bonds, green insurance and other diversified green financial instruments have become its important representatives.

At present, research on green finance can be divided into two main categories. One is research on the characteristics of the financial instrument itself, for example, Gianfrate and Peri in 2019 found that green bonds are considered to have higher ease of financing than other bonds [1]. And Tang and Zhang in 2020 suggest that companies that issue green bonds show that the company is socially responsible, which is beneficial to the value of the company [2].The second category explores the linkages between green bond markets and other markets. Back in 2012, Kumar and Managi found strong links between green equity markets and other financial markets [3], and Pham (2016) found that overall shocks in traditional bond markets can be transmitted to green bond markets [4].In 2020, Reboredo delved further and found that green bonds and both treasury and corporate bonds in Europe and the US have a strong correlation [5].

In terms of examining the risk spillover methods between markets, few domestic and foreign scholars have adopted a definitive approach.Pham (2016) investigates the volatility spillover effects between the S&P Green Bond Index and the conventional bond index through a multivariate GARCH model [4]. Reboredo (2018) uses static and dynamic Copula functions to investigate the dependency structure between the green bond market and the financial market [6].Domestic scholars are more likely to use DCC-GARCH models to study the dynamic correlation between markets. Hou Y (2015) finds that the US has a greater stock market impact on China than the reverse impact based on a DCC model [7]. Y Yue (2015) uses a VAR-DCC-GARCH model to find that the London Metal Exchange has a greater impact on Chinese non-ferrous metal prices [8].

Based on the above literature, there is a lack of research on China's green bond market.Therefore, this paper examines the risk spillover effects between China's green bond market and other finacial markets to provide data-based factual references for the targeted establishment of a sound green bond market regime.

## 3. Model construction

The model building in this paper can be divided into two main parts: firstly, the ARMA-GARCH model is firstly built using the log return series to obtain the residual series; secondly, the DCC-GARCH model is fitted to the residual series obtained in the previous step and the dynamic correlation coefficients are calculated and estimated to examine the volatility spillover effect.

(1)ARMA-GARCH model

In 1986, Bollerslev proposed GARCH model based on ARCH model, which is now widely applied in the study of return volatility of financial market products [9]. The ARMA-GARCH model combines a model in which the mean satisfies the ARMA process and the residuals satisfy the characteristics of the GARCH process.

Let the series conform to the expression of ARMA (p,q), then its form conforms to the following expression:

$$ARMA(p,q)\begin{cases} Y_t = c + \varepsilon_t + \sum_{i=1}^{p}\varphi_i Y_{t-i} + \sum_{j=1}^{q}\theta_j \varepsilon_{t-j} \\ \varphi_p \neq 0, \theta_q \neq 0 \\ E(\varepsilon_t) = 0, Var(\varepsilon_t) = \sigma_\varepsilon^2, E(\varepsilon_t \varepsilon_s) = 0, s \neq t \\ E(Y_s \varepsilon_t) = 0, \forall s < t \end{cases}$$

where in this paper $Y_t$ corresponds to the logarithmic return of index period t, $Y_{t-i}$ representing the return with lag i, and $\varepsilon_{t-j}$ is a perturbation term with lag j.

For the GARCH model, GARCH (1, 1) is generally used. The specific model representation is as follows:

$$GARCH(p,q)\begin{cases} \sigma_t^2 = \alpha_0 + \sum_{i=1}^{p}\alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{q}\beta_j \sigma_{t-j}^2 \\ \varepsilon_t = \sigma_t e_t, e_t \sim N(0,1) \end{cases}$$

(2)DCC-GARCH model

The multidimensional GARCH model focuses on setting the conditional covariance matrix $H_t$ of the current period perturbation term $\varepsilon_t$ to depend on the squared term of the previous period perturbation term $\varepsilon_{t-1}\varepsilon_{t-1}^{'}$ with the conditional covariance matrix $H_{t-1}$ of the previous period. The specific form of the elements in $H_t$ is $\sigma_{ij,t} = \rho_{ij,t}\sqrt{\sigma_{ii,t}\sigma_{jj,t}}$ ,obeying a one-dimensional GARCH process which is written in the form of the corresponding matrix : $H_t = D_t^{1/2} R_t D_t^{1/2}$. Engle (2002) proposes the DCC assumption that the coefficients are determined by the geometric weighted average of the normalized perturbation terms: $\rho_{ij,t} = \frac{\sum_{s=1}^{t-1}\lambda^s \tilde{\varepsilon}_{i,t-s}\tilde{\varepsilon}_{j,t-s}}{\sqrt{(\sum_{s=1}^{t-1}\lambda^s \tilde{\varepsilon}_{i,t-s}^2)(\sum_{s=1}^{t-1}\lambda^s \tilde{\varepsilon}_{j,t-s}^2)}}$ , so the model is specifically expressed as follows [10]:

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$$DCC-GARCH\begin{cases} H_t = D_t^{1/2} R_t D_t^{1/2}, \\ R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2} \\ Q_t = (1-\lambda_1-\lambda_2)R + \lambda_1 \tilde{\varepsilon}_{t-1} \tilde{\varepsilon}_{t-1}^{'} + \lambda_2 Q_{t-1} \\ \tilde{\varepsilon}_t = D_t^{-1/2} / \varepsilon_t, \lambda_1 \geq 0, \lambda_2 \geq 0, 0 \leq \lambda_1 + \lambda_2 < 1 \end{cases}$$

where $D_t$ is the conditional variance diagonal matrix, $R_t$ is the conditional correlation coefficient matrix.

## 4. Data

In this study, the China Green Bond Network Index was selected as a proxy for the Chinese green bond market, which includes publicly issued green financial bonds and policy bank bonds. As for the low carbon industry stock market, the index was selected from the CSI Mainland Low Carbon Economy Thematic Index, which includes companies in the fields of clean energy generation and energy conversion. The CSI 300 Index, on the other hand, was selected as a representative index for the general stock market, comprising the 300 most representative securities in the Shanghai and Shenzhen markets.

The time span of the sample is 15 April 2016, with data collected until 18 November 2022 at the latest, at a daily frequency, and using closing data. For the specific data treatment, data gaps arising from different market opening times need to be eliminated first due to the inconsistent trading hours of the bond and equity markets. The formula of Rt=100*(log(Pt)-log(Pt-1)) was used to log-differentiate the three indices, resulting in a total of 1645 valid samples.

The results of the descriptive statistics in Table 1 show that the extremes of the green bond market are all smaller than the other two equity markets; the low carbon industry market is more volatile; and both the green bond market and the common equity market show significant spikes and thick tails.

*Table 1: Descriptive statistics*

| | Greenbonds | Lowcarbon | CSI300 |
|---|---|---|---|
| Mean | -0.001 | 0.035 | 0.004 |
| Median | 0.004 | 0.061 | 0.036 |
| max | 0.810 | 6.922 | 5.777 |
| min | -0.847 | -8.385 | -8.209 |
| std_dev | 0.081 | 1.660 | 1.236 |
| Skewness | -0.744 | -0.333 | -0.650 |
| Kurtosis | 20.294 | 2.491 | 4.421 |
| Range | 1.657 | 15.307 | 13.986 |

## 5. Results and discussion

Before proceeding with the ARMA and GARCH modelling, the series data first needs to be subjected to a basis test to check whether the conditions for further modelling are met. The results of the return series tests for each market are given in Table 2. the ADF unit root test indicates that all series are smooth time series. the JB normality test similarly indicates that the returns for all markets do not obey a positive too distribution. In addition, the Ljung-Box test indicates that the three markets do not have white noise properties and that the series are autocorrelated. Finally, the ARCH test indicates that the return series of all markets have a significant ARCH effect.

*Table 2: Basic test results*

| | Greenbonds | Lowcarbon | CSI300 |
|---|---|---|---|
| ADF | -9.4938** | -10.306** | -11.627** |
| Jarque-Bera | 28442*** | 457.73*** | 1460.7*** |
| Ljung-Box | 42.506*** | 20.988* | 11.694* |
| ARCH | 166.6571*** | 154.1206*** | 77.21133*** |

After the above tests, the prerequisites for building a ARMA-GARCH model are met. The fitting results in Table 3 show that all coefficients are highly significant and the sum of $\alpha_1 + \beta_1$ are close to 1,

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which indicates that the characteristics of the market return series are sustainable.

*Table 3: ARMA-GARCH model estimation results and some test results*

| | Greenbonds | Lowcarbon | CSI300 |
|---|---|---|---|
| | ARMA(1,1) | ARMA(2,2) | ARMA(2,2) |
| $\varphi_1$ | 0.4455 (0.0255) | -1.9424 (0.0201) | -1.8732 (0.0768) |
| $\varphi_2$ | | -0.9638 (0.0205) | -0.8984 (0.0724) |
| $\theta_1$ | -0.9875 (0.0093) | 1.9317 (0.0218) | 1.8565 (0.0848) |
| $\theta_2$ | | 0.9500 (0.0222) | 0.8765 (0.0817) |
| Ljung-Box(residual) | 14.538 | 3.2199 | 8.7486 |
| Ljung-Box(residual^2) | 183.26*** | 145.93*** | 68.302*** |
| ARCH-LM | 183.7239*** | 146.3745*** | 68.49887*** |
| | GARCH(1,1) | | |
| $\alpha_0$ | 3.870e-04*** (1.641e-05) | 0.020356*** (0.004704) | 0.019787*** (0.004989) |
| $\alpha_1$ | 2.238e-01*** (2.225e-02) | 0.062336*** (0.006870) | 0.089747*** (0.005980) |
| $\beta_1$ | 7.386e-01*** (1.422e-02) | 0.931089*** (0.007452) | 0.901410*** (0.006688) |
| Log Likelihood | -3752.104 | 1490.43 | 1022.51 |

In Table 4, the three coefficients obtained $\alpha$ are significant and the coefficient between the green bond market and the low carbon industry stock market is greater than that between the and the traditional stock market, indicating that the new information from the low carbon industry stock market has a greater impact on the green bond market volatility correlation; all three coefficients $\alpha$ are small, indicating that the standardized residual product has a weaker effect on the dynamic correlation coefficient in the combination of stock and bond markets.

The coefficients $\beta$ have similar results.The coefficients between the green bond market and the low-carbon industry stock market are similarly larger than those between and the traditional stock market; the coefficients $\beta$ are all higher compared to the coefficients $\alpha$ , indicating a higher degree of persistence of the dynamic correlation coefficients between the two of the three markets, which are strongly influenced by the prior period.

Finally, a coefficient of $\alpha+\beta$ less than 1 indicates that the model is stable and the dynamic relationship is valid.

*Table 4: DCC-GARCH (1, 1) model estimation results*

| | $\alpha$ | $\beta$ | $\lambda=\alpha+\beta$ |
|---|---|---|---|
| Greenbonds-Lowcarbon | 0.015456* | 0.91226*** | 0.927716 |
| Greenbonds-CSI300 | 0.007664* | 0.89406*** | 0.901724 |
| Lowcarbon-CSI300 | 0.055446*** | 0.939991*** | 0.995437 |

Plotting the dynamic correlation coefficients between the market portfolios and comparing Figure 1(a) and Figure 1(b) reveals that the green bond market and the two equity markets move similarly with negative mean values, indicating that risk spills over between markets only when extreme events occur in the equity markets. However, in comparison, the magnitude and mean values of volatility between the green bond market and the low carbon industry equity market are greater than the corresponding magnitude and values with the equity market, indicating a higher risk spillover effect between the green bond market and the low carbon industry equity market. Compared to Figure 1(c), the two equity markets have a higher positive dependence on each other, and when one receives a market shock, it can greatly spill over to the other market.

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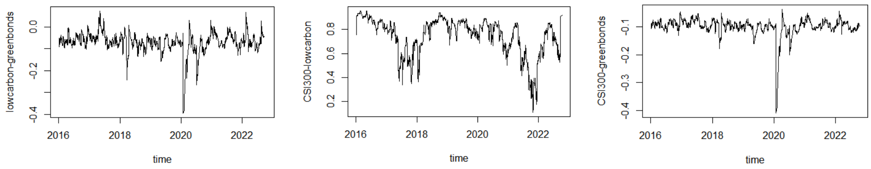


*Figure 1: Dynamic correlation coefficient between three markets.(a. green bond market and low carbon industry stock market;b. green bond market and stock market;c. stock market and low carbon industry stock market)*

## 6. Conclusion

This paper conducts a cross-sectional comparative study of the risk spillover effects between the Chinese green bond market and the low carbon industry stock market and traditional stock market, with the following findings:

(1) There are inherent differences in the risk structure between the Chinese green bond market and the equity market, resulting in weak risk spillover effects, with risks only transmitted between the markets in the event of extreme risk.

(2) The correlation between the Chinese green bond market and the low carbon industry stock market is higher than that between the Chinese green bond market and the traditional stock market. This is because the risk spillover effect is more pronounced between bond markets with similar composition and equity markets.

Therefore makes the following recommendations: strengthen the flow of information between green industries and establish a sound risk detection and early warning mechanism for the green bond market. The government should promote the implementation of supporting policies for the green bond market.

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