

Analysis of the Impact of the Financial Crisis on the Return Correlation Between Corporate Bonds and Enterprise Bonds: An Empirical Study Based on the Bivariate t-Copula Model

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Abstract: Corporate bonds and enterprise bonds are the most common financial products in the bond market. This paper takes the corporate bond and enterprise bond indices in the Shanghai and Shenzhen stock markets as research subjects, with the 2015 domestic financial crisis as the risk event. The sample of corporate and enterprise bonds is divided into two sub-samples: pre- and post-financial crisis. Using a binary Copula model, the study examines the impact of the risk event on the return correlation between corporate and enterprise bonds by comparing their correlations, particularly tail dependencies, before and after the crisis. A possible mechanism is also proposed. The study finds that the binary t-Copula model better fits the daily return series of corporate and enterprise bond indices both before and after the financial crisis. The estimated tail correlation coefficients indicate strong correlations and tail dependencies between corporate and enterprise bond returns both before and after the crisis. Moreover, these correlations and tail dependencies significantly strengthened in the post-crisis period.

Keywords: Corporate Bond Returns; Enterprise Bond Returns; Binary t-Copula Model; Financial Crisis

1. Introduction

As a vital component of the financial market, the bond market has garnered increasing attention from regulators and investors. During the development of the bond market, the continuous expansion of financial innovation has also exposed and revealed more risks. For instance, during the 2015 financial crisis, the bond market's role as a safe haven was reinforced. While the stock market experienced significant declines, the bond market became a primary venue for investors seeking to avoid risks or mitigate losses.

Following this crisis, the bond market attracted even greater attention. Within the bond market, enterprise bonds and corporate bonds occupy a substantial share and are highly representative. The onset of the financial crisis influenced investors' decision-making and the fluctuations in returns of enterprise and corporate bonds.

Nevertheless, numerous issues in the bond market warrant attention. Although the scale of China's bond market products continues to expand and the number of participating institutions continues to grow, it is undeniable that compared to developed Western countries, China's bond market remains relatively immature, with regulatory frameworks and supervision systems still lacking completeness. Moreover, Chinese investors are not sufficiently sensitive to risk indicators. Particularly in bond financing, yields are of paramount importance, and the correlations between different bond yields can influence the returns of financing portfolios. Under the impact of an economic crisis, these correlations may undergo changes.

In an era of increasingly sophisticated financial products, the corporate bond and enterprise bond markets, due to their distinct issuing entities, have become two closely interconnected yet relatively independent markets. As bond instruments, they share certain similarities but also exhibit non-negligible differences. As safe-haven assets, corporate and enterprise bonds may become the preferred choice for some investors seeking to avoid stock market risks. However, significant differences exist between corporate and enterprise bonds in terms of issuers, issuance mechanisms, and scale. Do they exhibit a same characteristic of "rising and falling together in the face of risks, or are there notable differences? Does the outbreak of a financial crisis alter investors' risk perceptions of these two types of bonds? In the long run, are there divergences in the trends of their returns?

Against this backdrop, this paper focuses on the enterprise and corporate bond markets issued and

traded in the Shanghai and Shenzhen stock exchanges. Based on Copula theory, a binary t-Copula model is constructed to explore changes in the correlation between enterprise and corporate bond returns before and after the financial crisis. Using the 2015 financial crisis as a dividing point, a comparative study is conducted between the commonly used binary normal Copula model and the binary t-Copula model. Using Kendall's rank correlation coefficient and squared Euclidean distance as discrimination criteria, it is found that the binary t-Copula model better fits the daily return series of enterprise and corporate bond indices both before and after the financial crisis. The results of the parameter ρ and tail correlation coefficients indicate strong correlations and tail dependencies between enterprise and corporate bond returns both before and after the crisis. Moreover, influenced by the financial crisis, these correlations and tail dependencies significantly strengthened in the post-crisis period. Under extreme scenarios in the bond market, there is a clear synchronization effect between enterprise and corporate bond returns. Based on the above research methods and conclusions, this paper offers potential theoretical explanations from the perspectives of market sentiment, investor behavior, and the complementary nature of stocks and bonds.

This paper studies the correlation between corporate and enterprise bond returns before and after the 2015 financial crisis, exploring the impact of risk events on their interdependence, which holds significant theoretical and practical implications.

From a theoretical perspective, compared to linear correlation, this paper employs a binary Copula model. On the one hand, this methodology is more reasonable as it describes the correlation between binary variables under assumptions that better align with the actual distribution of returns. On the other hand, existing scholarly research on financial market return correlations has primarily focused on the relationship between stock and bond markets or on the correlations among multiple representative stock indices, with relatively limited attention paid to the return correlations of specific bond indices. From a practical standpoint, this research provides a deeper understanding of the impact of financial crises on the bond market and the correlation between enterprise and corporate bond returns.

In the international market, Hoang & Farrukh employed a binary Copula model to analyze the

long-term and short-term dependencies between the S&P 500 Index and the 10-year Treasury bond index yields. Their findings indicate that during periods of poor economic conditions, investors tend to shift from equities to bonds to mitigate risks, resulting in a negative correlation between stock and bond returns.[1] Kim et al. applied a Gaussian Copula marginal regression approach to investigate the tail dependence between corporate bond yields and variables such as stock volatility, liquidity, and coupon rates. Their results reveal that stock volatility exerts a positive influence on corporate bond yields, with a stronger impact in the upper tail than in the lower tail [2]. Ito & Yoshida utilized t-Copula and CDCC models to examine asymmetric tail dependencies among government bonds, corporate bonds, and equities. Their study demonstrates that the t-Copula provides a superior fit for all paired samples compared to other Copula models. Moreover, during the COVID-19 crisis and high inflation periods, the lower tail correlation coefficients for different asset pairs were consistently higher than the upper tail coefficients, indicating a reduction in the benefits of asset diversification [3].

In addition to common financial products, the Copula model has also been used in the study of new markets, such as cryptocurrencies, to analyze the volatility of cryptocurrencies using a two-stage approach [4], or to analyze the risk coefficient of investment portfolios between crypt-ocurrencies and traditional assets based on the Markowitz framework [5] and prediction research [6].

Regarding research on the correlation between enterprise bond and corporate bond returns, Lin et al. applied a Copula-GARCH approach to study the liquidity risk and market risk of corporate bonds. Based on likelihood ratio tests, they identified the t-Copula as the optimal function for their analysis [7]. Komornik et al. used a multidimensional Copula model to investigate the correlations among three U.S. corporate bonds. Their results indicate high tail dependencies in both 3D and 2D models, suggesting that bond indices can serve as viable alternatives for quality asset allocation [8].

Green bonds have also been a research hotspot in recent years, and some scholars have attempted to apply complex Copula models to risk research in the green bond market [9,10] and contact with Clean Energy Market [11].

2. Copula Function Theoretical Basis

Copula theory was initially proposed by Sklar.

The Copula function primarily serves to connect the joint distribution of multidimensional random variables with their respective marginal distributions, thereby enabling the characterization of the correlation between random variables. This study focuses on the relationship between two-dimensional random variables; therefore, the core Copula theory involved is that of the bivariate Copula. Let the joint distribution function of continuous random variables X and Y be $H(X, Y)$, with marginal distribution functions $F(X)$ and $G(Y)$, respectively. Then, there necessarily exists a Copula function $C(U, V)$ satisfying: $H(X, Y) = C(F(X), G(Y))$.

Based on the theoretical foundation described above, the expression for the binary t-Copula model can be written as follows:

$$C^t(u, v; \rho, k) = \int_{-\infty}^{C^t(u)} \int_{-\infty}^{C^t(v)} \frac{1}{2\pi\sqrt{1-\rho^2}} \left[1 + \frac{s^2 - 2\rho st + t^2}{k(1-\rho^2)} \right]^{-(k+2)/2} ds dt \quad (1)$$

In financial risk analysis, the tail dependence between random variables is a key focus. The tail correlation coefficient measures the degree to which one variable is affected by another under extreme values. This study examines the extent to which the return of one bond index (enterprise bond or corporate bond) influences the other during sharp rises or falls. A higher tail correlation coefficient indicates a greater degree of influence. The expression for the tail correlation coefficient

λ of the binary t-Copula function is as follows:

$$\lambda = 2 - 2t_{k+1} \left(\frac{\sqrt{k+1}\sqrt{1-\rho}}{\sqrt{1+\rho}} \right) \quad (2)$$

3. Empirical Research

3.1 Data Processing and Analysis

Corporate bond indices and enterprise bond indices are the most commonly used proxy indicators in the bond market. Considering data symmetry and sample size, this study selects data on corporate bonds and enterprise bonds from China for the period from January 2009 to June 2024 for analysis. All data are sourced from the CSMAR database.

Against the backdrop of the Federal Reserve's interest rate hike in 2014 and the rise of the US dollar index, Chinese stock indices began to rise from June 2014, peaked in June 2015, and subsequently declined with multiple sharp drops. It was not until January 2016, with the intervention of national policies, that the stock index stabilized around 3000 points. Therefore, this study considers it reasonable to use the 2015

financial crisis as the segmentation point. The pre-crisis period spans from January 5, 2009, to December 31, 2015, comprising 1,700 trading days. The post-crisis period spans from January 4, 2016, to June 28, 2024, comprising 2,062 trading days.

The database provides daily closing prices of the bonds. Given that returns are often the subject of analysis in financial time series, this section outlines the calculation method for returns. The formula for calculating the daily return is:

$$ret = (P_t - P_{t-1}) / P_{t-1} \quad (3)$$

where ret is the return on day t , and P_t is the closing price on trading day t . For clarity in distinction, the daily returns and daily closing prices of the enterprise bond index between January 5, 2009, and December 31, 2015 (pre-financial crisis) are denoted as Qr and Qp , respectively, while the daily return series and daily closing price series of the corporate bond index for the same period are denoted as Gr and Gp . The daily return series and daily closing price series of the enterprise bond index between January 4, 2016, and June 28, 2024 (post-financial crisis) are denoted as qr and qp , respectively, and the daily returns and daily closing prices of the corporate bond index for this period are denoted as gr and gp . Analysis of the data distribution characteristics indicates that the stationarity of the closing prices for both indices is weaker than that of the returns. Therefore, the main analysis in the body of this paper focuses on the returns.

3.2 Descriptive Statistical Analysis

During the pre-financial crisis period (January 2009 to December 2015), the daily closing price of the corporate bond index (Gp) had a standard deviation of 15.69, with a minimum value of 115.07 and a maximum value of 171.30, indicating significant price volatility. Its skewness was 0.31, reflecting a right-skewed distribution, and its kurtosis was 2.06, suggesting that the distribution does not meet the characteristics of a normal distribution. In contrast, the corporate bond index returns (Gr) had a minimum value of -0.62, a maximum value of 0.78, and a standard deviation of 0.08, indicating significantly reduced volatility compared to the closing prices. The skewness of returns was 0.05, still showing a right-skewed trend, while the kurtosis was 16.22, indicating a more pronounced "leptokurtic and heavy-tailed" distribution compared to the closing prices. The daily closing price of the enterprise bond index (Qp) had a standard deviation of 18.58,

with a minimum value of 131.45 and a maximum value of 197.12, indicating substantial volatility in enterprise bond prices. Its skewness was 0.42, showing a right-skewed trend, and its kurtosis was 2.06, suggesting that its distribution also does not conform to the characteristics of a normal distribution. Meanwhile, the enterprise bond index returns (Qr) had a minimum value of -0.29, a maximum value of 0.37, and a standard deviation of 0.06, indicating significantly reduced volatility compared to the closing prices. The skewness of returns was -0.19, reflecting a left-skewed trend, and the kurtosis was 8.05, demonstrating a more pronounced "leptokurtic and heavy-tailed" distribution compared to the closing prices. Clearly, during the pre-financial crisis period, the returns of both corporate and enterprise bond indices exhibited significantly reduced volatility compared to their respective closing prices, and both displayed "leptokurtic and heavy-tailed" distribution characteristics.

During the post-financial crisis period (January 2016 to June 2024), the daily closing price of the corporate bond index (gp) exhibited a standard deviation of 20.31, with a minimum value of 171.39 and a maximum value of 241.27, indicating significant price volatility. Its skewness was 0.02, showing a slightly right-skewed distribution, and its kurtosis was 1.66, suggesting that the distribution does not meet the characteristics of a normal distribution. In contrast, the daily returns of the corporate bond index (gr) had a minimum value of -0.18, a maximum value of 0.16, and a standard deviation of 0.02, indicating significantly reduced volatility compared to the closing prices. The returns exhibited a skewness of 0.22, reflecting a right-skewed trend, and a kurtosis of 9.77, demonstrating a more pronounced "leptokurtic and heavy-tailed" distribution compared to the closing prices. The daily closing price of the enterprise bond index (qp) had a standard deviation of 25.88, with a minimum value of 197.29 and a maximum value of 287.67, indicating substantial volatility in enterprise bond prices. Its skewness was 0.04, showing a right-skewed trend, and its kurtosis was 1.70, suggesting that its distribution also does not conform to the characteristics of a normal distribution. Meanwhile, the enterprise bond index returns (qr) had a minimum value of -0.11, a maximum value of 0.15, and a standard deviation of 0.02, indicating significantly lower volatility compared to the closing prices. The returns

exhibited a skewness of 1.18, reflecting a right-skewed trend, and a kurtosis of 9.57, demonstrating a more pronounced "leptokurtic and heavy-tailed" distribution compared to the closing prices. In summary, during the post-financial crisis period, the returns of both corporate and enterprise bond indices exhibited significantly lower volatility compared to their respective closing prices, and both displayed distinct "leptokurtic and heavy-tailed" distribution characteristics.

3.3 Parameter Evaluation

Theoretically, both the bivariate normal Copula and the bivariate t-Copula exhibit symmetric tail dependence. However, the bivariate t-Copula generally possesses heavier tails compared to the normal Copula. This implies that the bivariate t-Copula is more capable of capturing the tail dependence between random variables, particularly under extreme return scenarios, where such dependence becomes more pronounced and the correlation between variables is more effectively reflected. When the absolute value of the parameter ρ is 0, it indicates no correlation between the returns of the enterprise bond index and the corporate bond index. As the absolute value of ρ approaches 1, the correlation between the two index returns strengthens, and when the absolute value of ρ reaches 1, the two index returns are perfectly correlated.

The estimated ρ is 0.79 in the pre-crisis sample and 0.92 in the post-crisis sample. The absolute values of ρ in both periods are relatively close to 1. This clearly indicates a strong correlation between the returns of the enterprise and corporate bond indices both before and after the financial crisis. Moreover, the correlation becomes highly pronounced in the post-crisis period, demonstrating a significant enhancement in the interdependence of the two indices. The fluctuations in enterprise bond returns are closely linked to those of corporate bond returns, reflecting a high degree of mutual influence.

The Kendall rank correlation coefficient is primarily applicable for studying the correlation between two ordinal categorical random variables and represents a nonparametric statistical method. Comparing the bivariate normal Copula rank correlation coefficient of 0.55 and the bivariate t-Copula rank correlation coefficient of 0.58 from the 2009.01–2015.12 sample with the Kendall rank correlation coefficient of 0.58, the results show that the bivariate t-Copula rank correlation

coefficient of 0.58 is closer to the Kendall rank correlation coefficient. Similarly, comparing the bivariate normal Copula rank correlation coefficient of 0.73 and the bivariate t-Copula rank correlation coefficient of 0.74 from the 2016.01–2024.06 sample with the Kendall rank correlation coefficient of 0.75, the bivariate t-Copula rank correlation coefficient of 0.74 is closer to 0.75.

In the comparison of rank correlation coefficients, the closer the Copula rank correlation coefficient is to the direct sample rank correlation coefficient, the better the model reflects the rank dependence between sample returns. From the comparison of rank correlation coefficients across the two sample periods, it is evident that both before and after the financial crisis, the bivariate t-Copula model—with a parameter ρ of 0.92—better captures the rank dependence between the enterprise bond index and corporate bond index returns, indicating a superior fit of the bivariate t-Copula model.

The smaller the squared Euclidean distance between a given Copula and the empirical Copula, the better the Copula model fits the sample data. According to the calculated squared Euclidean distance results, before the financial crisis, the squared Euclidean distance between the bivariate normal Copula and the empirical Copula is 0.07, which is greater than that between the bivariate t-Copula and the empirical Copula (0.02). Similarly, after the financial crisis, the squared Euclidean distance of the bivariate normal Copula (0.04) is also greater than that of the bivariate t-Copula (0.02). Therefore, based on the squared Euclidean distance criterion, this study concludes that the bivariate t-Copula model provides a better fit for the enterprise and corporate bond index returns data. The bivariate t-Copula model not only demonstrates superior goodness-of-fit with the observed data but also exhibits a higher degree of compatibility with the sample.

The tail correlation coefficient between enterprise bonds and corporate bonds was 0.51 before the financial crisis and increased by 0.17 to 0.68 after the crisis. This indicates a stronger dependence between the daily returns of enterprise and corporate bond indices in the post-crisis period. Under extreme market conditions, the impact of return fluctuations between the two types of bonds has become more pronounced. When the enterprise bond index experiences extremely high or low returns, the corporate bond index is more likely to exhibit similar extreme movements.

This clearly demonstrates a positive correlation between corporate and enterprise bond index

returns, meaning they tend to rise or fall together. To some extent, this co-movement may contribute to financial market instability. Investors holding both enterprise and corporate bonds may face the risk of simultaneous high profits or significant losses, reflecting a heightened level of risk contagion between the two bond markets.

3.4 Further Analysis

The 2015 financial crisis, as an extreme financial event, led to a strengthening of tail dependence between enterprise bonds and corporate bonds. The stock market's sharp rise followed by a steep decline resulted in financial market instability. To avoid or mitigate asset losses caused by this turmoil, a large number of investors often adopted identical or similar strategies, such as simultaneously purchasing enterprise bonds and corporate bonds in the bond market. This collective behavior subjected the prices of both enterprise and corporate bonds to concurrent shocks, driving up their yields and enhancing the tail dependence between them.

Market sentiment and investor behavior also serve as important factors influencing tail dependence between bond yields. When investors were extremely optimistic about the stock market and made substantial investments, they initially gained from stock investments. However, as stock returns rapidly declined or even hit lower limits, investor confidence waned and risk aversion increased. At this point, investors tended to favor financial assets with higher safety profiles. In China, bonds generally offer higher safety than stocks, with both enterprise and corporate bonds being perceived as relatively secure, thus meeting the demands of risk-averse investors. This shift in preference led to synchronized increases or decreases in the yields of enterprise and corporate bonds. Furthermore, when a large number of investors engaged in herd behavior, this exerted a strong influence on the tail dependence of returns in both the enterprise and corporate bond markets. The role of the bond market as a safe haven from the stock market may also contribute to the observed strengthening of tail dependence. Investors generally view the stock market as a high-risk, high-return environment, whereas the bond market offers more stable returns and lower risk, providing a certain degree of risk mitigation. When making investments, investors typically diversify their portfolios across both stocks and bonds to reduce potential losses. Thus, during periods of stock market turbulence or when

anticipating future losses in equities, investors tend to prioritize bond investments, concentrating their funds in familiar and stable bonds within the bond market. This drives up bond prices and may lead to a scenario where poorer stock market performance and greater financial instability coincide with better returns in the bond market, ultimately enhancing tail dependence among bonds.

The degree of similarity between enterprise bonds and corporate bonds also affects the tail dependence of their yields. When bonds are more closely related and similar, they become more substitutable and exhibit stronger risk contagion. Under extreme positive or negative bond yield scenarios, this results in a higher degree of tail dependence between the two. The correlation coefficient ρ and Kendall's rank correlation coefficient both indicate a high degree of interdependence between enterprise and corporate bonds. After the financial crisis, the correlation between their yields further intensified, ultimately leading to a stronger tail dependence in the post-crisis period.

4. Conclusions and Recommendations

4.1 Conclusions

This study employs Copula models to empirically analyze the correlation between enterprise bond and corporate bond returns before and after the financial crisis, utilizing the bivariate t-Copula model to characterize the non-linear dependence structure and tail distribution between these two bond indices. The main findings are as follows:

First, the empirical results indicate that both enterprise and corporate bond return series exhibit significant volatility clustering in both the pre- and post-crisis periods. The daily return series of both bond indices demonstrate typical "leptokurtic and heavy-tailed" distribution characteristics, with their marginal distributions significantly deviating from the traditional normal distribution assumption. Furthermore, the bivariate frequency distribution reveals symmetric tail characteristics in their joint distribution.

Regarding model fit, by comparing evaluation metrics such as Kendall's rank correlation coefficient and squared Euclidean distance, the bivariate t-Copula model is found to provide a better fit to the actual data in both sample periods. The estimated parameters ρ and tail correlation coefficients further confirm a strong positive dependence and tail dependence between

enterprise and corporate bond returns. Notably, this dependence strengthened significantly after the financial crisis, with the tail correlation coefficient increasing from 0.51 in the pre-crisis period to 0.68 in the post-crisis period.

Particularly noteworthy is the finding that under extreme market conditions, the returns of the two bond types exhibit a clear co-movement effect. When one bond index experiences substantial fluctuations, the other index tends to move synchronously in a similar direction. This linkage effect became more pronounced after the financial crisis.

4.2 Policy Recommendations

Based on the above conclusions, this study proposes the following recommendations for different stakeholders:

It is advisable to maintain a balanced allocation between stocks and bonds to fully utilize the hedging function of bond investments. Given the high degree of similarity and risk contagion between enterprise bonds and corporate bonds, it is recommended to selectively invest in one category rather than holding both simultaneously to avoid compounded risk exposure. Investors should make rational decisions, refrain from herd behavior, align investments with their personal risk tolerance, and enhance their awareness of financial risks. During periods of market exuberance, increased vigilance is essential to guard against the risks associated with asset price bubbles.

Strict adherence to regulatory requirements for bond issuance is paramount. Financing plans should be scientifically formulated considering macroeconomic conditions, market environment, and policy directions. Appropriate bond types should be selected based on actual corporate funding needs, ensuring both the fulfillment of financing requirements and the stability of the market financing environment. Furthermore, rigorous scrutiny of funding sources is necessary to ensure the safety and compliance of the financing process.

We recommend establishing a robust market risk monitoring mechanism to track fund flows in real-time, strictly supervise the inflow and outflow of market capital, and maintain order in the investment and financing markets. A financial market risk emergency response mechanism should be enhanced to improve the capacity for rapid reaction to significant market fluctuations. By refining the information disclosure system and

smoothing the transmission channels for risk information, market risks can be promptly identified and effectively mitigated. In response to the simultaneous rise and fall of both bond types under extreme conditions, particularly during abnormal market optimism, necessary capital control measures should be implemented to prevent systemic risks triggered by excessive capital concentration.

Furthermore, continuous reform of the bond credit rating system should be promoted, regulatory oversight of the bond market strengthened, and a balanced mechanism for managing gains and losses established. Encouraging collaborative supervision among various departments will collectively safeguard the stable development of the bond market.

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