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# Systemic Risk Spillover Effects in SSE Star Market and A-Share Market—Analysis based on the Copula-TGARCH-CoVaR Model

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***Abstract:***

The linkage effect and risk contagion between financial submarkets are the focus of systemic financial risk, especially the risk spillover effects of financial submarkets under extreme conditions. In the paper, we select the data from April 2019 to the end of April 2020, including the end of December 2019 when the COVID-19 epidemic broke out till the domestic epidemic situation tends to be eased. Firstly, using the SSE 50 Index calculation method, we calculate the SSE Star Market Index by the data of 57 stocks of the SSE Star Mrket. Then, the Copula function is used to construct the dependency structure between the SSE Star Market and the A-share market. Finally, the CoVaR method is used to analyze the extreme risk spillover effect between the SSE Star Market and the A-share market. The test results show that there is a bidirectional risk spillover effect and a positive correlation between the returns of the SSE Star market Index and the SSE 50 Index. There is a significant difference in the spillover effects of upside risks and downside risks between the SSE Star market and A-share market. The upside and downside risks of the two markets rose at the beginning of the COVID-19 epidemic. As the epidemic is effectively controlled, the risk is reduced and stabilized significantly.

***Keywords:*** *SSE Star market; risk spillover effect; Copula function; CoVaR method*

## I. INTRODUCTION AND LITERATURE REVIEW

Finance is the core of the real economy, especially systemic financial risks, which the relevant government departments are always active in preventing and resolving. Preventing financial risks is important because it is the first of three major battles. At the end of 2018, SSE Star Market was officially listed. Unlike the traditional boards in the stock market, the SSE Star market stick to the world's frontier technology, the main battlefield of the economy and the important needs of science and technology. It mainly serves high-tech enterprises, those who are in line with national strategies, have key core technologies and high market recognitions [1]. Nowadays, a large number of enterprises have emerged to be certified as high-tech enterprises in China and they can master the key core technology only with certain uniqueness and pioneering [2]. It is a significant reform of the capital market to establish the SSE Star

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market and pilot registration system. It cannot correctly reflect the overall operation of the SSE Star market since there is no official index before July 2020. We have selected 57 representative stocks in the SSE Star market to calculate the SSE Star index, based on the scientific calculation method of the SSE 50 index, which is used to correctly reflect the comprehensive status of high-quality companies in the SSE Star market. The SSE Star market is an experimental spot for capital market reform in China, and it is attractiveness and international competitiveness are increasing because of more than one year of operation and many institutional innovation initiatives [3]. Many scholars have made some research results on the operation mechanism of the board, as well as the significance of its opening and the test of market effectiveness. Some of them have analyzed in depth the system related to the SSE Star market and the impact on investors. For example, in order to achieve the protection of investors' interests, Ye Xueqing discusses the measures of risk prevention for investors in terms of investor management system, industry supervision system, Regulation of the China's Securities Regulatory Commission and securities dispute mechanism [4]. Wu Yingzhi studies the far-reaching impact brought by the SSE Star market through the perspective of listed companies, underwriters, and institutional investors [5]. Li Honghan,Wang Cunhua et al. analyze the current development status and importance of the SSE Star market for economic development, from the background of the establishment of the SSE Star market [6]. Chunzhi Tan, Jiaxin Huang et al. analyzed many possible risks of the SSE Star market and proposed preventive measures [7]. Cheng Junmin finds that the listing of the first SSE Star companies had a certain effect on the share prices of companies listed with correlations, which indicates that the main board market appeared to reach a semi-strong type of effective response, due to the listing of the first companies on the SSE Star market [8].

The A-share market, a transit point for stock issuance and circulation, and the main way for listed companies to raise capital. As an important part of China's financial market, the A-share market and the SSE Star market have high financial risk and are prone to financial crisis, and there is a certain linkage effect between the two markets. When extreme risks occur in one financial market, it will have a direct impact on the other financial market. It can effectively regulate and prevent and control financial risks by studying the risk spillover effects among financial submarkets, especially under the extreme conditions of the COVID-19 epidemic. There is a dynamic transmission effect of risk between the SSE Star market and the A-share market, and the return series generally sharp peaks and thick tails. Effective risk measures and models should be selected when capturing risk states, especially when financial markets are in extreme conditions where the tail dependence structure cannot be accurately described by linear relationships.

Conditional value-at-risk models based on Copula functions can be used to effectively measure systemic financial risk. Domestic and foreign studies using in combination with Copula function and GARCH models appeared since the application of CoVaR method in measuring the risk spillover effects of the financial system. The representative results of foreign studies, for example, Dong and Patton applied the Copula method to measure the systemic risk of credit default swaps [9]. Girardi and Ergin measured the systemic risk of four financial systems consisting of a large number of institutions, using multivariate GARCH models [10]. Bokusheva compared and analyzed the results of Copula and other risk measurement tools [11]. Annalisa measured risk in the European financial system, using Copula function and extreme value theory [12]. Lea Petrella assessed the contribution of major companies in European

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stock markets to systemic risk through the CoVaR method [13]. In domestic studies, for example, Gao Guohua and Pan Yingli measured and analyzed the CoVaR of 14 listed commercial banks in China through a GARCH model [14]. Based on the combination of Copula theory and CoVaR method, Xia Hai measured the size of risk spillover effect using nonparametric kernel density estimation method and compared the parameter estimation method with the measured risk spillover effect [15]. Ye Qiaobing and Wang Zhouwei measured the combined risk network contagion spillover effect of listed commercial banks in China based on CoVaR calculated by different GARCH models [16]. Cheng Bing conducted an empirical analysis of the systemic risk spillover effect of commercial banks in China, combining the Copula function and the ΔCoVaR method [17]. Ren Jian studied the systemic risk contagion of share price volatility of listed financial institutions in China's banking, securities and insurance industries using the CoVaR model [18]. Dai Lin performs systematic risk assessment by combining dynamic Copula-CoVaR model and financial system [19]. In this paper, we effectively measure the extreme risk spillover effect between the SSE Star market and the A-share market, mainly combining the TGARCH model to portray the marginal distribution of SSE Star index returns and SSE 50 index returns through the CoVaR method.

## II. INTRODUCTION TO METHODS AND MODELS

### 2.1 Copula function

Known as the link function, The Copula function relates the joint and marginal distributions [20]. First proposed by Sklar [21], it has the following advantages. First, it can capture both linear and nonlinear relationships between variables and can be applied in correlation and consistency measures. Second, it enables the analysis of extreme cases, due to the convenience of tail relations [22].

Exploring the linkage between the KSE market and the A-share market is based on the t-Copula function with the following distribution function expression.

$$C(u,v,\rho,\upsilon)=\int_{-\infty}^{T_\upsilon^{-1}(u)}\int_{-\infty}^{T_\upsilon^{-1}(v)}\frac{1}{2\pi\sqrt{1-\rho^2}}\exp(1+\frac{-(r^2+s^2-2\rho rs}{\upsilon(1-\rho^2)})^{\frac{\upsilon+2}{2}}drds \tag{1}$$

$\rho\in(-1,1)$ is the linear correlation coefficient and is the inverse of the t-distribution function $T_\upsilon^{-1}(.)$ with degrees of freedom $\upsilon$ .

### 2.2 GARCH model

The ARCH model cannot be widely used in the field of risk control because of the strong parameter constraints and high complexity of the model. Therefore, Bollerslev improved the conditional variance equation and proposed the GARCH model. The result is a more concise and convenient and widely used GARCH model, with less complex parameters and more flexible lag parameters [23].The GARCH(p,q) model is represented as follows.

$$y_t=x_t\beta+\varepsilon_t \tag{2}$$

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$$\varepsilon_t = \sigma_t z_t \tag{3}$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon^2{}_{t-i} + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \tag{4}$$

The mean equation of the model is Eq. (2). In Eq. (3), $z_t$ is an independent identically distributed random variable with mean 0 and variance 1. In Eq. (4), we require $\alpha_0 > 0$, $\alpha_i > 0$, $\beta_j > 0$; $p$, $q$ to be called the order of the ARCH and GARCH terms.

The RMA-GARCH family of models is an important tool used to capture the volatility characteristics of financial time series because of the ability to effectively characterize the conditional heteroskedasticity of financial asset returns. The model consists of two components, which are used to portray the log-return series $r_t$ (ARMA model) and the conditional variance of $r_t$ (GARCH model). The general form of ARMA (p,q) is as follows.

$$r_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i r_{t-i} + \varepsilon_t - \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} \tag{5}$$

$\varphi_i$ and $\theta_j$ are the model coefficients. $\varepsilon_t$ is a white noise series with independent identical distribution.

In the standard GARCH model, the conditional variance is assumed to be largely unaffected by positive and negative fluctuations. In fact, when the positive and negative residuals are equal in absolute value, the negative residuals are larger than the positive residuals in terms of their impact on return volatility. The TGARCH model can effectively represent the asymmetric impact of stock price fluctuations in different directions on its own volatility. It is a GARCH model that estimates the conditional standard deviation through a linear combination of the error term and standard deviation of the historical data, as defined below.

$$\sigma_t{}^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon^2{}_{t-i} + \sum_{k=i}^{k} \gamma_k d_{t-k} \varepsilon_{t-k} + \sum_{j=1}^{q} \beta_j \sigma^2{}_{t-j} \tag{6}$$

Parameters $\alpha_0, \alpha_1, \ldots, \alpha_q$, $\beta_1, \beta_2, \ldots, \beta_p$ satisfy $\alpha_0, \alpha_1, \ldots, \alpha_q \geq 0$, $\beta_1, \beta_2, \ldots, \beta_p \geq 0$. $\gamma_k d_{t-k} \varepsilon_{t-k}$ is the asymmetric effect term. $d_{t-k}$ is the explanatory variable. It takes the value of 1 when $\varepsilon_t < 0$, and 0 otherwise.

2.3 CoVaR method

In the 1990s, JP Morgan first proposed the definition of VaR, which is the value at risk, used to determine the probability of risk occurrence. The VaR method has the following advantages. Firstly, it is a uniform standard for risk measurement and facilitates investors' understanding of risk. Second, it can be

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calculated beforehand to reduce market risk. Third, it provides a regulatory basis for relevant authorities. The VaR method is mainly used to calculate the value-at-risk of financial assets in general. The VaR value, which represents the magnitude of risk, loses its meaning if there are extreme conditions in the market. Its mathematical formula is as follows.

$$P(\Delta p_{\Delta t} > VaR) = 1 - \alpha \tag{7}$$

In Eq. (7), $VaR$ is the value at risk at confidence level $\alpha$. $\Delta p_{\Delta t}$ is the loss of the asset during the holding period $\Delta t$.

The conditional value-at-risk (CoVaR) method originated in 2007 as an improvement of the traditional VaR method by American scholars to effectively measure the losses caused by the subprime mortgage crisis. The CoVaR approach not only compensates for the shortcomings of VaR which can only estimate the risk of a single economy, but also quantifies the risk spillover effects of extreme risks in other markets on this market [24]. CoVaR calculates another market's extreme value at risk when a market is at extreme risk. The CoVaR model was proposed by Adrian and Brunnermeier [25], and the expression of the CoVaR model is given below.

$$P(X_j \le -CoVaR_q^{j|i} \mid X_i = -VaR_q^i) = 1 - q \tag{8}$$

$X_i$, $X_j$ are the returns of the two financial markets or institutions. $CoVaR$ denotes the $q$ quantile of the conditional loss distribution function of the financial market or institution $X_j$ when the $CoVaR_q^{j|i}$ of the financial market or institution $X_i$ to the financial market or institution $X_j$ is equal to the extreme loss $VaR_q^i$ of the financial market or institution $X_i$ at the confidence level $q$.

## III. SSE STAR MARKET INDEX CALCULATION AND DESCRIPTIVE STATISTICS

### 3.1 Index calculation method

The SSE 50 Index is weighted by the number of adjusted share capital of the constituent stocks, and its calculation formula is as follows. Reporting period index = (Adjusted market value of sample stocks in the reporting period / base period) * 1000. In the case of a stock, the base period is the closing price of the stock on the previous day. Adjusted market capitalization = Σ(share price * number of adjusted share capital). The number of adjusted share capital is adjusted using a graded approach to component share capital.

### 3.2 Data selection principles

The SSE Star market has already occupied an important position in China's capital market, from the first 25 listed companies to 92 listed companies today. In this paper, a total of 57 stocks of the leading stocks of the SSE Star market and another high-quality listed stocks of the SSE Star market traded in Shenzhen Stock Exchange（SZSE）are selected as sample stocks.

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### 3.3 Calculation of SSE Star Market Index

The calculation of the SSE Star Market index was carried out according to the calculation method of the SSE 50 index, through the daily opening price, closing price, volume, total number of shares and outstanding shares data of 57 SSE Star Market stocks for the period from April 1, 2019 to April 30, 2020 .Some of the data of the SSE Star Market index are shown in Table 1.

**Table 1 Partial Data Table of SSE Star Market Index**

| Date | SSE Star Market Index |
|---|---|
| 2019.4.1 | 1033.772 |
| 2019.4.2 | 999.937 |
| 2019.4.3 | 999.797 |
| 2019.4.4 | 999.974 |
| 2019.4.5 | 982.788 |
| … | … |
| 2020.4.27 | 986.695 |
| 2020.4.28 | 992.233 |
| 2020.4.29 | 985.210 |
| 2020.4.30 | 1013.283 |

### 3.4 Data processing

The SSE 50 Index is a symbol of A-shares, reflecting the status of the most liquid and influential companies in the Shanghai stock market. The SSE Star Market index yield rate and SSE 50 index yield rate are log-differentiated from the SSE Star Market index and SSE 50 index, and some of the data are shown in Table 2. All data were selected from April 1, 2019 to April 30, 2020.

**Table 2 Selected Data of SSE Star Market Index and SSE 50 Index Yield Rate**

| Date | SSE Star Market Index Yield Rate | SSE 50 Index Yield Rate |
|---|---|---|
| 2019.4.1 | -0.0334 | 0.0191 |
| 2019.4.2 | 0.0001 | -0.0014 |
| 2019.4.3 | -0.0171 | 0.0109 |
| 2019.4.4 | 0.0105 | 0.011 |
| 2019.4.5 | 0.0108 | 0.0035 |
| … | … | … |
| 2020.4.27 | -0.0015 | -0.0125 |
| 2020.4.28 | 0.0209 | 0.0071 |
| 2020.4.29 | 0.0171 | 0.007 |
| 2020.4.30 | 0.0036 | 0.006 |

### 3.5 Descriptive statistics

Descriptive statistical analysis was performed on the SSE Star market index yield rate and the SSE 50

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index yield rate, and the results are shown in Table 3.

**Table 3 Descriptive Statistics of SSE Star Market Index Yield Rate and SSE 50 Index Yield Rate**

| Variables | Mean Value | Standard Deviation | Maximum Value | Minimum Value | Skewness | Kurtosis | JB statistic and probability | | ARCH-LM and probability | |
|---|---|---|---|---|---|---|---|---|---|---|
| SSE Star | 0 | 0.017 | 0.07 | -0.06 | 0.25 | 4.25 | 20.08 | 0.00 | 45.3 | 0.00 |
| SSE 50 | 0 | 0.012 | 0.35 | -0.07 | -0.72 | 7.21 | 218.13 | 0.00 | 89.26 | 0.00 |

As shown in Table 3, the mean values of both the SSE Star market index yield rate and the SSE 50 index yield rate tend to be zero. The standard deviation of the SSE Star market index yield rate is greater than the standard deviation of the SSE 50 index yield rate and is more volatile. The skewness of the SSE Star market index yield rate is greater than 0, showing a right skewed distribution. The skewness of the SSE 50 index yield rate is less than 0, showing a left-skewed distribution. They all have kurtosis greater than 3, so they are spiky and thick-tailed. Their statistical probability P-value is 0, rejecting the original hypothesis. Both of them do not obey the normal distribution, which is obtained by the JB statistic. The Ljung-Box statistic and ARCH model are applied to test the heteroskedasticity between the SSE Star market index yield rate and the SSE 50 index yield rate, and the statistical probability p-values of both are zero, indicating that there is an ARCH effect for both of them.

## Ⅳ. EMPIRICAL ANALYSIS

### 4.1 Establishing the marginal distribution

The ARMA model can remove autocorrelation. The GARCH model can portray the volatility of time series. The model is constructed for the SSE Star market index yield rate and the SSE 50 index yield rate by ARMA(p,q)-TGARCH(m,n) model. The parameter estimation results are shown in Table 4.

**Table 4 Parameter Estimation of Marginal Model of SSE Star Market Index Yield Rate**

| $\phi 0$ | $\gamma$ | $\phi 1$ | $\alpha 0$ | $\alpha 1$ | $\beta 1$ | $\lambda$ | ARCH | KS Test | LB | Tail test | Skewness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.0007 | 0.08 | -0.81 | 0.009 | 0.11 | 0.81 | 0.0 | 0.88 (0.84) | 0.07 (0.16) | 7.2 (0.053) | 3.19 | 0.16 |

As shown in Table 4, the marginal model of SSE Star market index yield rate is not autocorrelated and adequately captures the ARCH effect. The SSE Star market is characterized by asymmetry and thick-tailedness. The KS test is conducted to compare the standard residual model of marginal distribution with the standard normal distribution, and the result shows that the standard residual model conform to the

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normal distribution at 95% confidence level. It is reasonable to use the ARMA(1,1)-TGARCH(1,1) model. As shown in Table 4, the ARMA(1,1)-TGARCH(1,1) model formula can be calculated for the SSE Star market index yield rate.

$$r_t = -0.0007 - 0.81 r_{t-1} + \varepsilon_t + 0.81 \varepsilon_{t-j} \tag{9}$$

$$\sigma_t^2 = 0.0009 + 0.11 \varepsilon_{t-1}^2 + 0.08 d_{t-1} \varepsilon_{t-1} + 0.81 \sigma_{t-1}^2 \tag{10}$$

**Table 5 Parameter Estimation of Marginal Model of SSE 50 Index Yield Rate**

| φ0 | γ | φ1 | α0 | α1 | β1 | λ | ARCH | KS Test | LB | Tail test | Skewness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0002 | -0.03 | 0.40 | 0.0006 | 0.04 | 0.70 | 0.0 | 0.68 (0.70) | 0.03 (0.7) | 7.17 (0.123) | 2.71 | 0.7 |

From Table 5, it can be seen that the marginal model of the SSE 50 index yield rate is not autocorrelated and there is an ARCH effect. The estimation of degrees of freedom proves that the model error term for the A-share market is non-normal and thick-tailed. The KS test shows that the marginal model is normally distributed at the confidence level of 95%. In conclusion, it is reasonable to apply the ARMA(1,1)-TGARCH(1,1) model for modeling.From Table 5, the formula of ARMA(1,1)-TGARCH(1,1) model of SSE 50 index yield rate can be obtained.

$$r_t = 0.0002 + 0.4 r_{t-1} + \varepsilon_t - 0.4 \varepsilon_{t-j} \tag{11}$$

$$\sigma_t^2 = 0.0006 + 0.04 \varepsilon_{t-1}^2 - 0.03 d_{t-1} \varepsilon_{t-1} + 0.7 \sigma_{t-1}^2 \tag{12}$$

4.2 Copula test for A-share market and SSE Star market

The correlation between financial submarkets will show dynamic Copula function relationship over time [24]. A binary Copula function model is developed for the SSE Star market index yield rate and the SSE 50 index yield rate. The best Copula function model is selected by the AIC minimum criterion. The parameter estimation results are shown in Table 6.

**Table 6 Results of Parameter Estimation of Copula Function**

| | Correlation coefficient | AIC |
|---|---|---|
| Gaussian Copula | 0.221 | -529.961 |
| t-Copula | 0.244 | -530.002 |

From Table 6, the t-Copula function is better able to fit the distribution model of the SSE Star market index yield rate and the SSE 50 index yield rate than the Gaussian Copula. Therefore, the t-Copula function is chosen to construct a model to fit the correlation structure between them. From the results in Table 6, it can be seen that there is a positive correlation between the SSE Star market index yield rate and the SSE 50 index yield rate.

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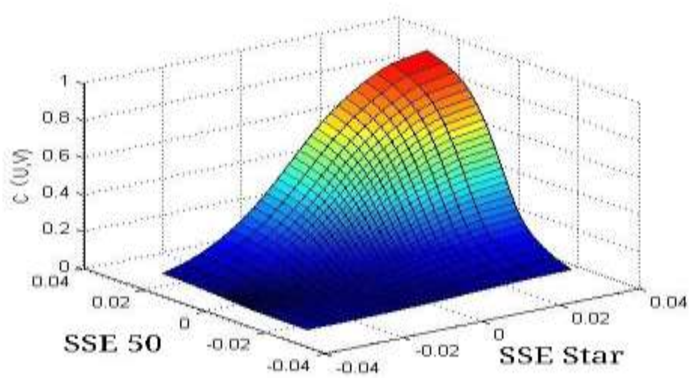


Figure 1 Binary t-Copula distribution function plot

The binary t-Copula distribution function plot of the SSE Star market index yield rate and the SSE 50 index yield rate is shown in Figure 1. From Figure 1, it can be seen that the binary t-Copula function has a thick-tail feature, which indicates that there is a strong tail correlation between them. Under the squared Euclidean distance criterion, the SSE Star market index yield rate and the SSE 50 index yield rate can be well fitted by the binary t-Copula model.

4.3 Extreme risk spillover effects of A-share market on SSE Star market

By calculating the CoVaR of the SSE Star market, the risk profile of it can be portrayed in the case of the A-share market risk based on the VaR measure. The conditional value-at-risk (CoVaR) of the SSE Star market index yield rate under the confidence level of 95% of the SSE50 index yield rate is derived by the t-Copula function and ARMA-TGARCH model. Figure 2 shows the upward and downward CoVaR trends of the SSE Star market index yield rate, clearly demonstrating how the SSE Star market is affected in the event of extreme risk losses in the A-share market.

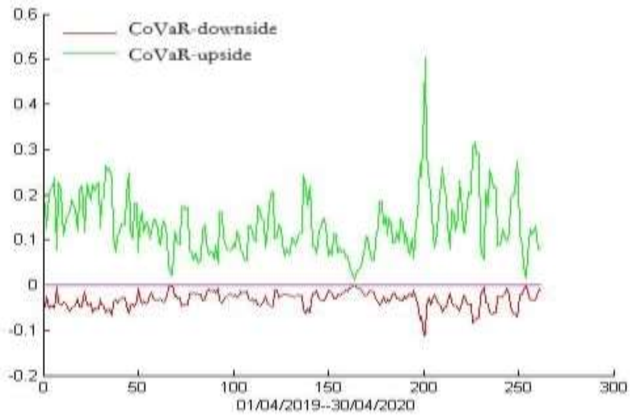


Figure 2 Upside and Downside CoVaR of the SSE Star Market

As shown in Figure 2, the upside and downside CoVaR of the SSE Star market index yield rate show an asymmetric structure. The spillover effects of upside and downside risks in the SSE Star CSCI market are different when the A-share market changes. The upside and downside CoVaR curves fluctuate significantly in the time period around December 2019, which is the first outbreak of the COVID-19. As

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the COVID-19 is effectively controlled, the upside downside risk decreases and gradually smoothes out. Table 7 shows the statistics of downside and upside VaR and CoVaR of the SSE Star market index yield rate and the results of hypothesis testing in the presence of value-at-risk VaR for the SSE 50 index yield rate.

**Table 7 Downside and upside VaR and CoVaR of SSE Star Market Index Yield Rate and Hypothesis Testing Results**

| Downside | | | Upside | | |
|---|---|---|---|---|---|
| VaR | CoVaR | H0 : CoVaR=VaR H1 : CoVaR>VaR | VaR | CoVaR | H0 : CoVaR=VaR H1 : CoVaR<VaR |
| -0.09123 | -0.1133 | 0.125 (0.000) | 0.02445 | 0.5024 | 0.142 (0.000) |

Table 7 shows the value-at-risk (VaR) and conditional value-at-risk (CoVaR) of the SSE Star market index yield rate at a quantile of 0.05. The large value of downside VaR indicates that the downside risk potential of the SSE Star market is high. The small value of upside VaR indicates that the upside risk of the SSE Star market shows better stability. The conditional value-at-risk of the downside risk of the SSE Star market index yield rate is less than the value-at-risk. There will be a risk spillover effect on the SSE Star market when there is an extreme downward change in the A-share market, for example, a significant decrease in common stock prices or a sudden increase in gold prices, as shown by the KS test. The CoVaR for the upside risk of the SSE Star market index yield rate is greater than the VaR. It indicates that the stock market environment represented by A-shares directly affects the market conditions of SSE Star. The spillover effects of upside risk and downside risk in the A-share market show asymmetry, and the magnitude of the impact of upside risk is significantly greater than that of downside risk. The volatility of A-share stock prices was dramatic and had a huge impact on the SSE Star market, and the risk was significantly higher during the outbreak. With the COVID-19 effectively under control and positive investor sentiment towards the stock market, the SSE Star market has stabilized although slightly high risk.

## 4.4 Extreme risk spillover effects of the SSE Star market on the A-share market

The impact on the A-share market in the event of extreme risk in the SSE Star market is shown in Figure 3, which portrays the upward and downward CoVaR trends of the SSE 50 index yield rate.

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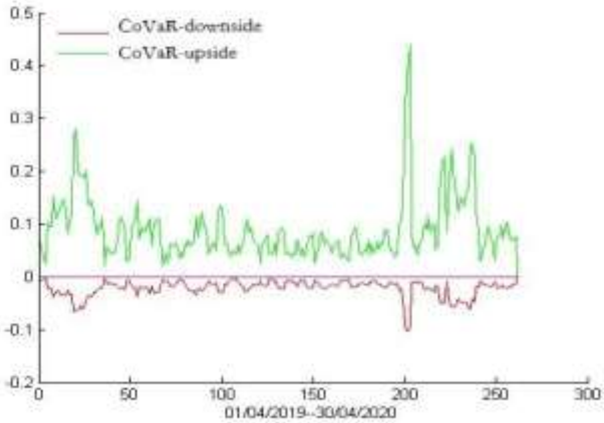


Figure 3 Upside and Downside CoVaR of the A-share Market

As can be seen in Figure 3, the upward and downward CoVaR of the SSE 50 index yield rate show an asymmetric structure under the conditions of extreme risk in the SSE Star market. During the COVID-19 period, the trend of the upward and downward CoVaR curves changes significantly until March 2020 when they smooth out again. The statistics and hypothesis testing results of the downside and upside VaR and CoVaR of the SSE 50 index yield rate are shown in Table 8.

**Table 8 Downside and upside VaR and CoVaR of SSE 50 Index returns and hypothesis testing results**

| Downside | | | Upside | | |
|---|---|---|---|---|---|
| VaR | CoVaR | H0:CoVaR = VaR H1:CoVaR < VaR | VaR | CoVaR | H0:CoVaR = VaR H1:CoVaR > VaR |
| -0.08547 | -0.1024 | 0.962 (0.000) | 0.02838 | 0.4403 | 0.819 (0.000) |

As can be seen in Table 8, the downside CoVaR of the SSE 50 returns is smaller than the downside VaR, which implies that the SSE Star market stock prices have a systematic impact on the A-share market. For upside risk, CoVaR is greater than VaR, indicating that the policies implemented by the state in the SSE Star market have a significant impact on the A-share market. During the COVID-19, the stock price fluctuations of the SSE Star market were dramatic, which had an impact on the A-share market and significantly increased the risk. With China's implementation of appropriate incentives for the SSE Star market and the effective control of the COVID-19, the market for the SSE Star has returned to stability. This led to a significant reduction in the upside downside risk of the A-share market, even below normal levels. This also indicates that in the future, the SSE Star market will rise to an increasingly important position in the Chinese stock market, and its risks will have a far greater impact on A-shares than A-shares have on themselves. The risk spillover effect of the SSE Star market on the A-share market is large. When there is a change in the SSE Star market, the risk spillover of the SSE Star to the A-share market reaches 96.2% for the downside risk impact and 81.9% for the upside risk impact when the quantile is 0.05. Although the current capital of China's science and technology innovation board market is not as strong as

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the A-share market. In the future, if the SSE Star market faces extreme risk situations, it is likely to have a significant impact on the A-share market or even the whole national economy.

## Ⅴ. CONCLUSIONS AND RECOMMENDATIONS

The extreme risk spillover effects of the SSE Star market and the A-share market are asymmetric, and the upside risks are greater than the downside risks. At present, the A-share market has a more obvious impact on the situation of the SSE Star market. But through the above empirical analysis, we can find that in the long run, the extreme risk spillover effect of the SSE Star market on the A-share market will be stronger.

Although the SSE Star market will have an impact on the stock capital of A-shares, the movement of A-share market is a microcosm of the change of China's stock market. Most investors will continue to invest their major capital in the A-share market and adopt a wait-and-see or small capital testing attitude towards the SSE Star board, so the impact of A-shares on the board will be more significant when the stock market becomes volatile. During the COVID-19, there were massive fluctuations in A-share stock prices, and the stock market entered a low period with a sharp increase in risk. The A-share stock market directly responds to the changes in China's social economy, and the development and continuation of the epidemic has had a significant impact on China's social economy. The main manifestations were lower business returns, weakened social consumption power, serious impact on the performance of most listed companies and panic in the investment sentiment of the majority of investors. After a brief period of downturn in the SSE Star market, under the active guidance of policies, biomedical companies developed at a high speed and their stocks rose the most, and the demand for telecommuting and online live streaming directly drove the development of related product forms. In addition, the strong demand for key materials for epidemic prevention and control directly affected the stock prices of related high-tech companies. The A-share market receives capital support during the COVID-19 to speed up the economic recovery of the market and to gradually reduce the risk under the positive impact of the SSE Star market. Until March 2020, the upward and downward risks of the SSE Star market and the A-share market are significantly smoothed and the market operates normally.

The upside risks to the A-share market are as follows, firstly due to the easing of trade frictions between the US and China, prompting market investors to renew their earnings forecasts. Secondly, policy easing efforts thus bringing stronger short-term economic growth for the A-share market. Its downside risks are as follows, firstly, global economic growth is slow, affecting our economic development. The real estate sector is slowing down, which has a broad impact on the economy. Secondly, the external demand for manufacturing is decreasing. Thirdly, it puts pressure on investment. The upside risks to the SSE Star market are primarily driven by government policies and market demand for new technologies. Upside risks during the COVID-19 period also include the development of vaccines to boost recovery. Its downside risks include uncertainty about equity profitability, uncertainty about the development of innovative technology companies and the second wave hitting to delay the recovery of the COVID-19.

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Based on the above analysis, it is recommended that the government should fully understand the market situation and actively develop programs to promote market development. When the market is strongly turbulent, it will promptly identify problems and introduce corresponding policies to help the market restore stability as soon as possible. As an emerging segment, the SSE Star market is supported by relevant policies to formulate rules and systems as well as develop relevant technical systems to promote the development of it. For investors, they should achieve rational investment by fully understanding the status of enterprises, accumulating investment experience and improving risk tolerance.

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