Skewed-t-TGARCH Algorithmic Modeling for Risk Measures in Emerging Markets: A Study on Chilean and South African Boards

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Abstract: Whether the opening of international boards in emerging markets will lead to a significant increase in market risk is a topic of common concern in the industry. In this paper, we take Chile and South Africa, which are emerging markets that have successfully opened international boards, as examples to explore the risk impacts of opening international boards on their stock markets, aiming to provide a reference basis for the establishment of international boards in China's A-share market. First, we use the GARCH model under different hypothetical distributions to capture the volatility information of the series, and use VaR for backtesting. Further, the asymmetric characteristics of the volatility of the Chilean and South African stock markets are explored by constructing Skewed-t-TGARCH and Skewed-t-EGARCH models. And the stock market risk is measured by the indicators of stock market trading competitiveness, stock return volatility, and stock price volatility, so as to analyze and quantify in detail the market risk of the Chilean and South African markets, which have successfully opened the international board. We found that (1) the Skewed-t-TGARCH algorithm can more accurately characterize the at-risk value of the stock index series. (2) The market risk of opening an international board increases significantly in the short term and does not change significantly in the long term. (3) The degree of impact, speed of shock response ,and durability of opening international boards on market risk are affected by the heterogeneity of their market characteristics.
Design and analysis of algorithms • Professional topics

Keywords : Emerging market, International boards, Market risk, Financial stability

1 INTRODUCTION

The international board refers to the market segment formed by listing the shares of foreign companies on domestic stock exchanges and trading them in local currency [1]. Over the past two decades, the United States and Hong Kong have promoted stable economic growth by opening up their markets and encouraging the listing of foreign companies. However, Japan's experience shows that although the International Board promoted initial economic growth, market risks also increased as offshore companies exited the Tokyo Stock Exchange, leading to long-term economic stagnation. Therefore, the establishment of the International Board seems to be like a double-edged sword, which can promote economic growth but may equally increase stock market risks, thus hindering economic development.

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Since the 1970s, the degree of financial openness of emerging market economies, as measured by de facto indicators of financial liberalization, has gradually increased, with the gradual deregulation of financial controls to open up financial markets and the establishment of international boards one after another. China first introduced the concept of an international board in 2007, aiming to enhance market liquidity and efficiency. However, the lack of in-depth theoretical research results on the effects and risks of international boards has put the process of opening international boards in China's stock market on hold. However, with the establishment of Shanghai-Hong Kong Stock Connect, Shenzhen-Hong Kong Stock Connect ,and Shanghai-Lunan Stock Connect, as well as the internationalization of RMB, the conditions for the construction of international boards are becoming more mature .The construction of international boards has been revived . The meeting of the Political Bureau of the Central Committee of the Communist Party of China (CPC) in 2020 has further emphasized the importance of promoting the construction of the basic system of the capital market. In this context, the establishment of the international board is regarded as an essential step to supplement the short board of the capital market system, which is of great significance to China's economic development and the construction of an international financial center.

The positive market effects of the opening of international boards on the stock market and macroeconomy have been fully confirmed by Yu Ying [2], Zhang Xiaowan [3], Luo Xiaoyun [4] and others in recent years, while the impact risk impact of the opening of international boards on the stock market of the emerging markets and how it affects China's capital market and its possible risk problems have not yet formed a unified view in the academic and financial circles. Therefore, it is of great theoretical and practical significance to study the impact risk impact of the opening of China's international board. Therefore, it is necessary and feasible to examine the impact of market shock risk of opening international boards based on the market data of emerging countries, such as Chile and South Africa, with the aim of providing important decision-making reference value for the establishment of international boards in China's A-share market.

2 LITERATURE REVIEW

2.1 Opening of international boards in emerging markets

There are fewer studies on the opening of international boards in emerging markets, but there is a large body of literature on the effects of financial liberalization and capital market opening on stock market risk in emerging markets, but the empirical results vary. Some scholars find that capital market opening is beneficial to stock market stability. For example, Bekaert et al.'s findings on stock market opening in emerging countries show that opening reduces consumption volatility relative to output volatility through risk sharing, leading to more efficient capital allocation and higher risk diversification benefits[5]. Umutlu et al.[6] show that financial liberalization in emerging countries has led to the participation of more investors , improving the accuracy of information and reducing market volatility to a large extent. Some other scholars believe that capital market liberalization will increase stock market volatility[6]. For example, Nyamomgo and Misati, by tracking the financial liberalization reform process in 34 emerging countries, find that financial liberalization may lead to financial system turbulence, especially for low-income countries, where the adverse effects of financial liberalization outweigh the positive ones[7]. Roy and Shijin reveal that the degree of economic development of the country largely determines the relationship between financial liberalization reforms and stock market return volatility. During the period when many emerging economies started financial liberalization reforms, the volatility of their stock markets increased dramatically[8]. Meanwhile, other scholars have also pointed out that the impact of capital market liberalization on stock market risk varies from place to place. For example, Dan concludes by analyzing nine emerging market economies that the impact of financial liberalization on stock market volatility in emerging market economies varies from country to country: in Thailand, financial liberalization led to a decrease in stock market volatility; however, in Colombia and Mexico, financial liberalization instead increased stock market volatility, and there was no significant change in the other six emerging market economies[9].McLean et al. further investigate the volatility of stock returns for two types of firms, including those that can introduce foreign capital and those that cannot. After disaggregating into base and excess volatility, they find that in emerging market economies, firms with foreign capitalization have lower base volatility but higher excess volatility than firms without foreign capitalization[10].

2.2 Use of GARCH models

Numerous scholars have conducted in-depth studies on risk assessment among stock markets using various empirical methods. International finance literature with various styles of empirical methods, such as cointegration tests, error correction models, univariate and multivariate ARCH/GARCH models, and Copula functions, have played an important role in elaborating stock market linkages and risk assessment. Shijun Li et al. found that applying the VaR derived from the ARMA-GARCH-biased t model to the study of risk dependence better reflects the risk dependence when applying the GARCH-like model to the study of risk measurement and dependence of different industry sector indices in China[11]. When Yao Ping et al. studied the spike fat tail, offset and asymmetry characteristics of crude oil yields, they found that the TGARCH model with the introduction of the leverage effect was significantly better than the general GARCH-type model in predicting downside risk[12]. Donghai Zhou et al. use GARCH models under different hypothetical distributions to capture the volatility information in the series and find that the TGARCH and EGARCH models are able to more accurately characterize the VAR values of stock index series[13].

A review of the existing literature shows that the existing literature mainly studies the impact of capital market opening or financial liberalization in emerging markets on the shock risk of the stock market. There is little empirical research literature on the impact risk of listing foreign companies at the highest level of capital market liberalization, and the academic and financial communities have not yet formed a unified view on how the opening of international boards affects China's capital market and its possible risks, so the lack of in-depth theoretical research on the risk of international boards has led to the shelving of the process of opening international boards in China's stock market. Therefore, analyzing the impact risk of the opening of the international board on the stock market from the perspectives of stock market trading competitiveness, stock return volatility and stock price volatility is the basis of this paper.

3 RESEARCH DESIGN

In order to adequately measure the at-risk value of the stock index return series of the emerging markets of Chile and South Africa, which have opened international boards, to compare the speed and persistence of the two emerging markets' response to the risk of shocks arising from the opening of international boards, and to further investigate whether there is a difference between the two emerging markets when they are subjected to favorable and unfavorable news. First, this paper uses a GARCH model under different hypothetical distributions to capture the volatility information of the series and employs VaR for backtesting tests. Then, the asymmetric nature of the volatility of the Chilean and South African stock markets is further explored by constructing Skewed-t-TGARCH and Skewed-t-EGARCH models. Finally, the event study method is utilized to examine the stock market performance before and after the opening of the international board. Finally, the event study method is utilized to determine whether the opening of the international board makes a significant difference to the market performance of their stock markets in the short term, i.e., whether the opening of the international board causes a significant change in the stock prices and increases stock market volatility in the short term.

3.1 GARCH model.

Bollerslev proposed the GARCH model as an optimization of the RiskMetrics model, and the general GARCH(p, q) model can be expressed as

$$\begin{cases} r_t = u_t + \varepsilon_t; \\ \varepsilon_t = \sigma_t \eta_t; \\ \sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j}^2 \end{cases} \tag{1}$$

Where: u_t denotes the deterministic information fitting model of r_t ; the general assumption $\eta_t \overset{i.i.d.}{\sim} N(0, \sigma^2)$. The GARCH model not only profoundly reveals the volatility aggregation property in the financial time series, but also provides some explanatory theories for its sharp peaks and thick tails property.

3.2 Asymmetric GARCH models.

In the threshold GARCH model, the improved conditional heteroskedasticity is

$$\begin{cases} \sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 d_{t-i} + \sum_{i=1}^{q} \gamma_i \varepsilon_{t-i}^2 d_{t-i} + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2; \\ \varepsilon_{t-i} \geq 0, d_{t-i} = 0; \\ \varepsilon_{t-i} < 0, d_{t-i} = 1 \end{cases} \tag{2}$$

Indeed, the core idea of a threshold GARCH model is to incorporate a dummy variable d_{t-i} into a standard GARCH model that contains the asymmetric factor γ_i. In the event of a loss, the expected volatility may exceed the value of volatility predicted by the general profitability scenario.

In the EGARCH model, the conditional variance equation is

$$\begin{cases} \ln(\sigma_t^2) = \alpha_0 + \sum_{i=1}^{q} (\alpha_i v_{t-i} + \gamma_i (|v_{t-i}| - E|v_{t-i}|)) + \sum_{i=1}^{p} \beta_j \ln(\sigma_{t-j}^2), \\ v_{t-i} = \varepsilon_{t-i} / \sigma_{t-i} \end{cases} \quad (3)$$

The EGARCH model has two major advantages:

1. The parameters α_i, β_i, γ_i can be taken as non-positive numbers;
2. When the parameter γ_i, which is used to represent the "leverage effect", is negative, the model can be identified as asymmetric. When $v_{t-i} \geq 0$, the oscillatory contribution from v_{t-i} is $(\gamma_i + \alpha_i)|v_{t-i}|$; when $v_{t-i} \leq 0$, the oscillatory contribution from v_{t-i} is $(\gamma_i - \alpha_i)|v_{t-i}|$.

3.3 Skewed-t distribution

The standardized t-distribution proposed by Bollerslev (1987), which is used in this paper, takes the form:

$$f(z) = \frac{\Gamma(\frac{v+1}{2})}{\sqrt{(v-2)\pi}\Gamma(\frac{v}{2})}(1+\frac{z^2}{v-2})^{-\frac{v+1}{2}} \quad (4)$$

In order to fully reflect the correlation properties of the stock index series distribution, this paper uses the Skewed-t form proposed by Hansen (1994):

$$f(z|v,\xi) = \begin{cases} bc[1+\frac{1}{v-2}(\frac{bz+a}{1-\varepsilon})^2]^{-\frac{v+1}{2}}, Z < -\frac{a}{b} \\ bc[1+\frac{1}{v-2}(\frac{bz+a}{1+\varepsilon})^2]^{-\frac{v+1}{2}}, Z \geq -\frac{a}{b} \end{cases} \quad (5)$$

$$a = \frac{4\lambda c(\eta-2)}{\eta-1}, b = \sqrt{1+3\lambda^2-a^2}, c = \frac{\Gamma(\frac{\eta+1}{2})}{\sqrt{\pi(\eta-2)}\Gamma(\frac{\eta}{2})}$$

where v is the degree of freedom and ε embodies the skewness of the distribution function, when $\varepsilon > 0$ the distribution is right-skewed, when $\varepsilon < 0$ the distribution is left-skewed, and when $\varepsilon = 0$ the whole distribution degenerates into a standardized t-distribution.

4 EMPIRICAL ANALYSIS BASED ON THE GARCH MODEL

4.1 Data description

In this paper, the daily closing price data of the Chilean IPSA40 Index (SSE) and the South African Johannesburg All-Share Index (JSE) from the beginning of January 1996 to the end of December 2022 are selected for the study, and the time span covers the period of the opening of the Chilean international board in February 2000, the opening of the South African international board in December 2004, the financial crisis of 2008, and the period of the new Crown Pneumonia in 2021. Where the yield is calculated using the formula $r_t = \ln P_t - \ln P_{t-1}$.

Table 1: Descriptive statistics of the return data of the three major stock indices

	Chile	South Africa
sample size	6730	6749
maximum values	0.152	0.409
minimum value	-0.153	-0.410
average value	0.000	0.000
standard deviation	0.012	0.014
skewness	-0.435	-0.366
kurtosis	21.767	209.693
J-B statistic	132804 (0.000***)	12341719 (0.000***)
ADF	-18.876 (0.000***)	-19.337 (0.000***)
Ljung-Box	110.72 (0.000***)	72.535 (0.000***)
ARCH-LM	797.33 (0.000***)	2743 (0.000***)

As can be seen from Table 1, the standard deviation of the South African market is larger, indicating that the overall risk of the South African market is more volatile; the skewness of both emerging market index returns is negative, indicating that the market has a longer left tail and a greater likelihood of the existence of negative returns; the kurtosis values are all in excess of the kurtosis value of 3 for a normal distribution, indicating that each return is characterized by a sharp peak and thick tail. From the JB statistic, both returns do not obey the normal distribution. p-value of ADF statistic is less than 0.01, so the original hypothesis of the existence of unit root is rejected and the two emerging market return series are considered to be smooth. The result of Ljung-Box test shows that all the returns lagged by 12th order, at 1% significant level, the original hypothesis is rejected and autocorrelation exists.ARCH effect test shows that the return series of all the four markets reject the original hypothesis and heteroskedasticity exists.

4.2 Statistical analysis

Analyzing Figure 1 shows volatility aggregation in the return series of the stock markets, especially during the Asian financial crisis of 1998, the global financial crisis of 2008, and the New Crown Pneumonia of 2021. Among them, the overall return volatility of the Chilean stock market is more similar to that of the emerging markets, while the South African stock market shows excellent resistance to volatility spillover risk and less overall return volatility. In addition, neither the Chilean stock market nor the South African stock market found significant volatility in returns after the opening of the international board, and the log stock index series chart (see Figure 2) does not show significant volatility and is also less volatile in terms of long-term trends.

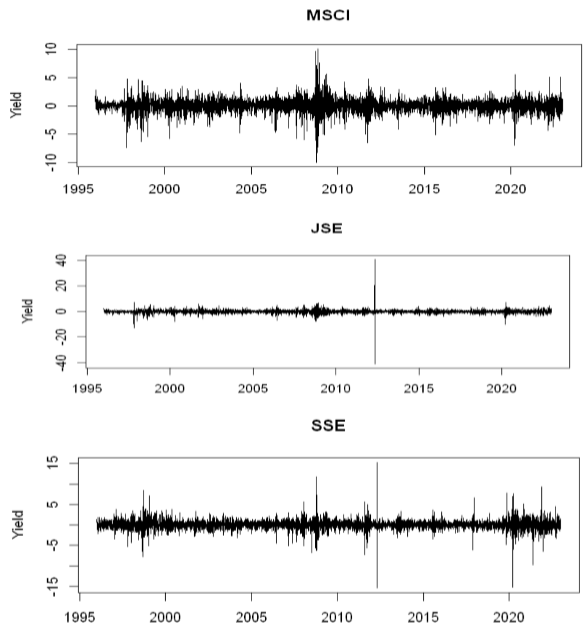


Figure 1:Yield series plot

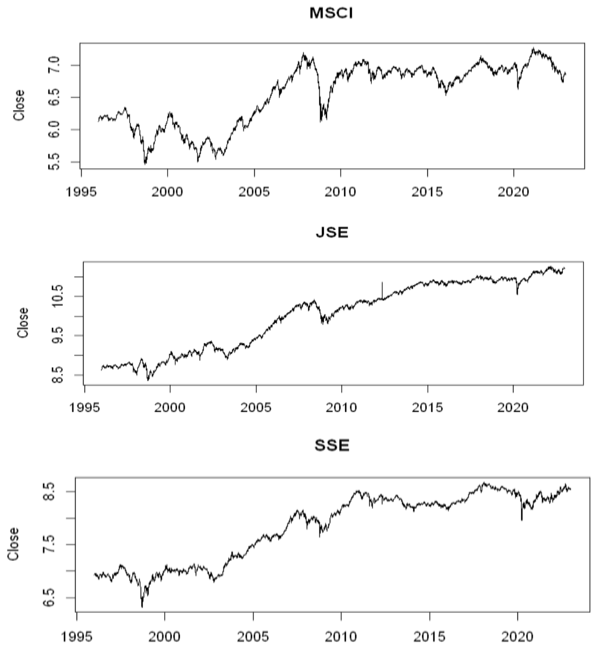


Figure 2: Logarithmic stock index series chart

Figure 3 shows that compared to the Chilean stock market, the South African stock market has a more significant trading size, higher trading activity, and greater market depth and liquidity.

In the short-term period between the opening of international boards in Chile and South Africa, in the short-term period, the Chilean stock market's total stock market as a percentage of GDP and stock trading turnover rate show a downward trend, and the competitiveness of stock market trading has weakened. While South Africa's stock market total stock market ratio of GDP and stock trading turnover rate showed an upward trend, in which the stock market total stock market ratio of GDP increased significantly, showing better market liquidity, stock market trading competitiveness has improved. From the perspective of long-term change trends, the trading scale and trading activity degree of the two markets have been favorable for a long time and have been developed rapidly since 2014, in which the South African market has made a significant breakthrough.

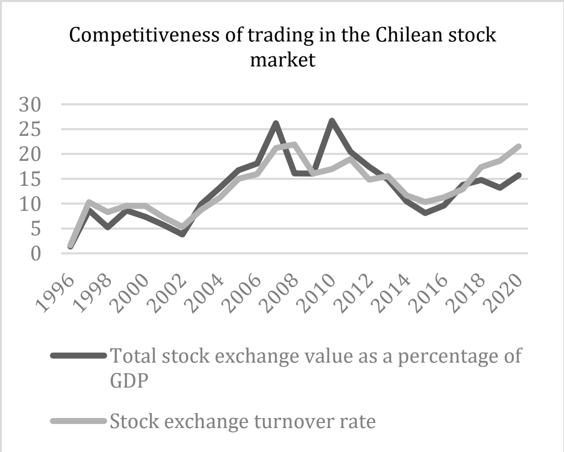


Figure 3: Competitiveness of stock market trading in Chile and South Africa

In addition, by means of Figure 4, it can be seen that the opening of international boards in Chile and South Africa also did not have a significant impact on total domestic GDP in the short term and maintained a rapid growth in the longer term. Analyzing Figure 5, It can be seen that the size of foreign exchange reserves of the two countries in the same period did not occur more substantial fluctuations. Therefore, it can be shown that the opening of the international board, to a certain extent promotes the development of the stock market and the process of financial liberalization, the impact on the macro-economy is positive, and the risk impact is controllable under the appropriate regulatory policies.

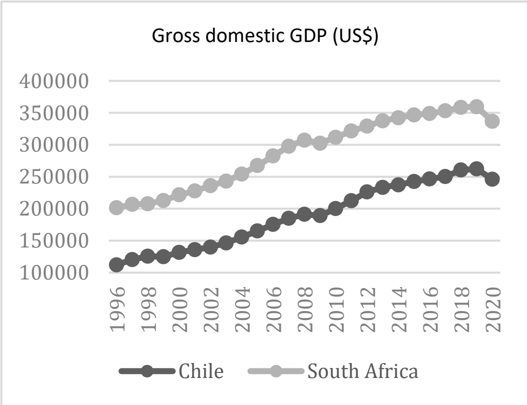


Figure 4: Gross domestic GDP of Chile, South Africa (US$)

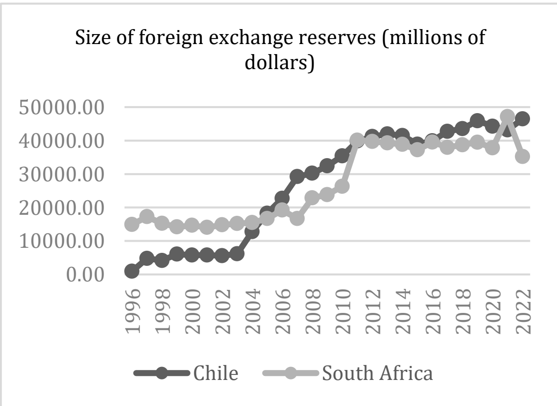


Figure 5:Size of foreign exchange reserves of Chile and South Africa (millions of dollars)

4.3 Characterization of spikes and thick tails

Different hypothetical distributions are made for the distribution types of SSE and JSE stock index series and the better model is selected by combining the AIC, BIC, SIC, HQIC information criterion , and the great likelihood estimator. According to the results of the comparison test of the possible distribution types of SSE and JSE stock index series (see Table 2 and Table 3), the Skewed-t distribution of SSE, JSE index return series has the smallest AIC value, BIC, SIC, HQIC value , and the largest great likelihood estimator, so Skewed-t is selected for modeling analysis. However, after comparative analysis it can be found that the AIC, BIC, SIC, HQIC and maximum likelihood estimates are basically similar in all the hypothetical cases, so Norm-GARCH with Skewed-t-GARCH model is selected for modeling and analysis of stock index return series.

Table 2: Information Criteria for Fitting GARCH Models to SSE Stock Indexes

Model Type	AIC	BIC	SIC	HQIC	Logarithmic great likelihood estimate
Norm-GARCH(1,1)	-6.4069	-6.4028	-6.4069	-6.4055	21560.01
t-GARCH(1,1)	-6.5010	-6.4959	-6.5010	-6.4992	21877.58
St-GARCH(1,1)	-6.5010	-6.4949	-6.5010	-6.4989	21878.68
Ged-GARCH(1,1)	-6.4837	-6.4787	-6.4837	-6.4820	21819.56
Sged-GARCH(1,1)	-6.4842	-6.4781	-6.4842	-6.4821	21822
Norm-EGARCH(1,1)	-6.4184	-6.4133	-6.4184	-6.4166	21599.55
t-EGARCH(1,1)	-6.5100	-6.5040	-6.5100	-6.5079	21908.98
St-EGARCH(1,1)	-6.5098	-6.5027	-6.5098	-6.5074	21909.27
Ged-EGARCH(1,1)	-6.4923	-6.4862	-6.4923	-6.4902	21849.38
Sged-EGARCH(1,1)	-6.4929	-6.4852	-6.4923	-6.4899	21850.44
Norm-gjrGARCH(1,1)	-6.4166	-6.4115	-6.4166	-6.4148	21593.52
t-gjrGARCH(1,1)	-6.5090	-6.5029	-6.5090	-6.5069	21905.53
St-gjrGARCH(1,1)	-6.5088	-6.5017	-6.5088	-6.5064	21905.88
Ged-gjrGARCH(1,1)	-6.4912	-6.4851	-6.4912	-6.4891	21845.53
Sged-gjrGARCH(1,1)	-6.4912	-6.4841	-6.4912	-6.4888	21846.76

Table 3: Information criterion for fitting GARCH model to JSE stock indexes

Model Type	AIC	BIC	SIC	HQIC	Logarithmic great likelihood estimate
Norm-GARCH(1,1)	-6.2125	-6.2085	-6.2125	-6.2111	20965.1
t-GARCH(1,1)	-6.2508	-6.2458	-6.2508	-6.2491	21095.35
St-GARCH(1,1)	-6.2554	-6.2493	-6.2554	-6.2533	21111.67
Ged-GARCH(1,1)	-4.5606	-4.5556	-4.5606	-4.5589	15392.58
Sged-GARCH(1,1)	-4.5603	-4.5543	-4.5603	-4.5582	15392.58
Norm-EGARCH(1,1)	-6.2397	-6.2346	-6.2397	-6.2379	21057.68
t-EGARCH(1,1)	-6.2716	-6.2656	-6.2716	-6.2695	21166.5
St-EGARCH(1,1)	-6.2767	-6.2697	-6.2767	-6.2743	21184.68
Ged-EGARCH(1,1)	-6.2224	-6.2164	-6.2224	-6.2203	21000.52
Sged-EGARCH(1,1)	-6.2243	-6.2173	-6.2243	-6.2219	21007.92
Norm-gjrGARCH(1,1)	-6.2291	-6.2240	-6.2291	-6.2273	21021.96
t-gjrGARCH(1,1)	-6.2615	-6.2555	-6.2615	-6.2594	21132.43
St-gjrGARCH(1,1)	-6.2662	-6.2591	-6.2662	-6.2637	21149.02
Ged-gjrGARCH(1,1)	-4.2727	-4.2667	-4.2727	-4.2706	14422.16
Sged-gjrGARCH(1,1)	-4.2724	-4.2654	-4.2724	-4.2700	14422.16

4.4 Model parameter estimation

From Table 4 of the parameter estimation results can be seen, under the Norm distribution and Skewed-t distribution, the sum of α and β coefficients of SSE, JSE index return series are less than 1 and close to 1, indicating that the model is smooth, the return series fluctuations are all obvious aggregation effect, persistence characteristics are obvious; for the parameter α estimation, JSE is the largest, SSE is the second largest, which indicates that the South African stock market JSE index return volatility is more responsive to shocks; while the ordering of β values is reversed, with SSE being larger and JSE being the second largest, indicating that the SSE index return of the Chilean stock market is the most persistent to shocks. Overall, the speed of response to shocks is opposite to the persistence of the JSE and SSE stock indices. Meanwhile, the skewness coefficients of both are less than one, indicating that the daily return series of the stock markets of Chile and South Africa are characterized by left skewness.

Table 4:GARCH parameter estimation of return series of SSE and JSE stock indices

Type	Distribution	μ	ω	α	β	skewness
SSE	Norm	4.86×10^{-4} (0.048)	5.00×10^{-6} (0.957)	1.96×10^{-1} (0.648)	7.85×10^{-1} (0.143)	NA
	Skewed-t	4.37×10^{-4} (0.001***)	3×10^{-6} (0.266)	1.36×10^{-1} (0.000***)	8.41×10^{-1} (0.000***)	9.75×10^{-1} (0.000***)
JSE	Norm	7.00×10^{-4} (0.000***)	4.00×10^{-6} (0.000***)	1.27×10^{-1} (0.000***)	8.48×10^{-1} (0.000***)	NA
	Skewed-t	5.69×10^{-4} (0.000***)	4×10^{-6} (0.287***)	1.20×10^{-1} (0.000***)	8.57×10^{-1} (0.000***)	9.04×10^{-1} (0.000***)

4.5 Comparative analysis of VaR value backtesting

By Table 5 Comparative analysis of the VaR value backtesting shows that at the α=5% confidence level, SSE with Skewed-t distribution overestimates the value at risk than Norm distribution, and the failure rate increases from 6.3% to 6.7%; comparing the success rate of JSE with Norm and Skewed-t distributions, the failure rate decreases from 6.7% to 6.3%. At the α=1% confidence level, the failure rates of SSE and JSE stock indices are significantly reduced, which confirms the existence of "sharp peaks and thick tails" characteristics of SSE and JSE.

Table 5: Comparison of VAR backtesting of SSE and JSE stock indices

Type of index	Distribution type	α/%	Number of days of failure	Failure rate/%
SSE	Norm	5	63	6.3
		1	26	2.6
	Skewed-t	5	67	6.7
		1	19	1.9
JSE	Norm	5	67	6.7
		1	17	1.7
	Skewed-t	5	63	6.3
		1	11	1.1

In this paper, Kupiec's Unconditional Coverage Test and Christoffersen's Conditional Coverage Test (UC and CC for short) are utilized according to Donghai Zhou's (2021) backtesting approach. At 5% and 1% significance levels, if the p-value exceeds the corresponding significance level, respectively, then the test is considered to be passed. From the Table 6, it can be seen that under Norm distribution, SSE fails the UC & CC test at 1% significance level and JSE fails the UC & CC test at 5% significance level; In contrast,under Skewed-t distribution, both SSE and JSE index returns pass the UC & CC test at 1% significance level, which once again verifies that SSE and JSE index returns have The SSE and JSE index returns are characterized by "sharp peaks and thick tails".

Table 6:VAR value return test results for SSE and JSE stock indices

Type of index	Distribution type	significance level	UC			CC		
			statistic	threshold value	p-value	statistic	threshold value	p-value
SSE	Norm	5	3.299	3.841	0.069	3.592	5.991	0.166
		1	17.947	3.841	0	18.089	5.991	0
	Skewed-t	5	5.524	3.841	0.019	5.588	5.991	0.061
		1	6.473	3.841	0.011	7.276	5.991	0.026
JSE	Norm	5	5.524	3.841	0.019	6.928	5.991	0.031
		1	4.091	3.841	0.043	4.68	5.991	0.096
	Skewed-t	5	3.299	3.841	0.069	5.501	5.991	0.064
		1	0.098	3.841	0.754	0.343	5.991	0.842

5 EMPIRICAL STUDY BASED ON EGARCH AND TGARCH MODELS

5.1 Model parameter estimation

From Table 7 it can be seen that SSE has a parameter γ value of 0.1 in the Skewed-t-TGARCH model, with a p-value less than the 1% significance level, so the parameter value is significant; the γ coefficient of the response asymmetry factor in the Skewed-t-EGARCH model is also significant, which is considered to be a significant leverage effect of SSE.

The asymmetric coefficient γ of the SSE in the fitted SGED-TGARCH model is 0.1 and significant at the 1% level, with a positive sign, which usually implies the presence of a "negative leverage effect", whereby a negative error term or "bad news" triggers greater volatility. Volatility, which indicates that the market usually becomes more volatile in the face of unfavorable information, suggests that the SSE stock index returns of the Chilean stock market may be more responsive to bad news than to good news. This is a common phenomenon in financial markets as markets tend to react more strongly to negative information. According to the above analysis, volatility will increase by a factor of 0.0747 when a positive shock is encountered, whereas in the case of a negative shock, the increase in volatility will be up to a factor of 0.1747, which will make the impact of a negative shock 2.339 times that of a positive shock. This asymmetric effect amplifies the range of volatility changes following a shock.

The coefficient of SSE reflecting the asymmetric effect in the Skewed-t-EGARCH model is 0.214. If νt-1 is positive, it represents the effect of a positive shock, and its overall impact amount reaches 0.1604. If νt-1 is negative, it represents the effect of a negative shock, and its overall impact amount is calculated to be 0.2676. Thus, it can be seen that the effect of a negative shock is 1.668 times greater than that of a positive shock. 1.668 times, and negative news of the same magnitude produces a larger impact effect than good news, and this result is consistent with the estimation results of the Skewed-t-TGARCH model.

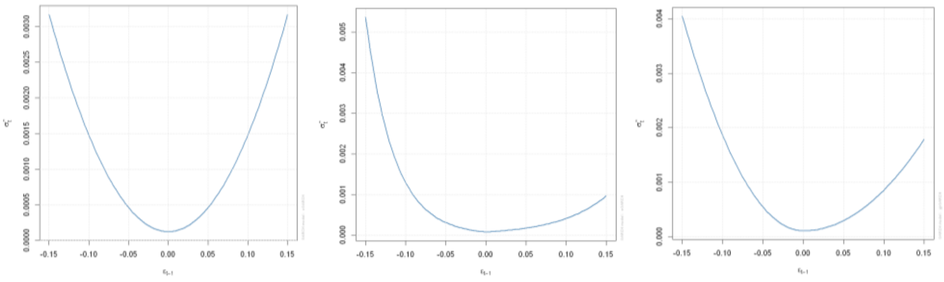
The JSE has α = 0.0517 and γ = 0.117 in the Skewed-t-TGARCH model and is significant at the 1% level, which represents the fact that the JSE stock index returns in the South African stock market are likely to be more responsive to bad news than to good news. Based on the above analysis, volatility will increase by a factor of 0.0517 when a positive shock is encountered, whereas in the case of a negative shock, the increase in volatility will be up to a factor of 0.1687, which will make the impact of a negative shock to be 3.263 times that of a positive shock. This asymmetric effect amplifies the range of volatility changes following a shock.

JSE in the Skewed-t-EGARCH model α = -0.0841, γ = 0.178. If νt-1 is positive, it represents the effect of a positive shock, and its overall impact amount reaches -0.0841+0.178=0.0939. If νt-1 is negative, it represents the effect of a negative shock, and its overall impact amount is calculated to be 0.0841+0.178 = 0.2621. 0.2621. It can be seen that the effect of negative shocks is 2.791 times that of positive shocks, and negative news of the same magnitude produces a greater shock effect than good news, a result that is consistent with the estimation results of the Skewed-t-TGARCH model.

Table 7:TGARCH and EGARCH parameter estimates for the return series of SSE and JSE stock indices

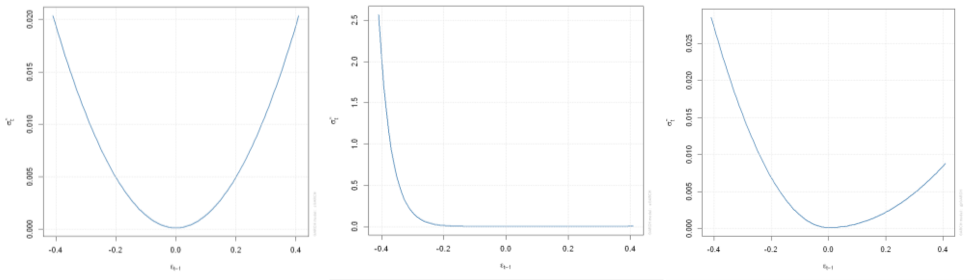
Type of index	Distribution type	μ	ω	α	β	γ	skewness
SSE	Skewed-t TGARCH	3.50×10^{-4} (0.008)***	3.00×10^{-6} (0.239)	7.47×10^{-2} (0.000)***	8.51×10^{-1} (0.000)***	1.00×10^{-1} (0.000)***	9.85×10^{-1} (0.000)***
	Skewed-t EGARCH	3.49×10^{-4} (0.020)**	-2.78×10^{-1} (0.000)***	-5.36×10^{-2} (0.000)***	9.70×10^{-1} (0.000)***	2.14×10^{-1} (0.000)***	9.87×10^{-1} (0.000)***
JSE	Skewed-t TGARCH	3.92×10^{-4} (0.005)***	4.00×10^{-6} (0.367)	5.17×10^{-2} (0.000)***	8.64×10^{-1} (0.000)***	1.17×10^{-1} (0.000)***	9.03×10^{-1} (0.000)***
	Skewed-t EGARCH	3.29×10^{-4} (0.037)**	-2.36×10^{-1} (0.000)***	-8.41×10^{-2} (0.000)***	9.74×10^{-1} (0.000)***	1.78×10^{-1} (0.000)***	8.97×10^{-1} (0.000)***

Figure 6 and Figure 7 show the new interest impact curves of Skewed-t-GARCH(1,1), Skewed-t-TGARCH(1,1), Skewed-t-EGARCH(1,1) models for SSE and JSE, where the new interest impact curves of Skewed-t-GARCH(1,1) for SSE and JSE stock index returns show symmetry, and the new interest impact curves of Skewed-t-TGARCH(1,1), Skewed-t-TGARCH(1,1) models of new interest impact curves are asymmetric, in which SSE reacts more sensitively to positive news than good news, and JSE reacts very strongly to negative news.



(a) Skewed-t-GARCH(1,1) (b) Skewed-t-EGARCH(1,1) (c) Skewed-t-TGARCH(1,1)

Figure 6: New interest curve for the SSE stock index



(a) Skewed-t-GARCH(1,1) (b) Skewed-t-EGARCH(1,1) (c) Skewed-t-TGARCH(1,1)

Figure1 New interest curve for the JSE stock index

5.2 Comparative analysis of VaR value backtesting

SSE's backtest of the VaR value of Skewed-t-TGARCH at the α=1% confidence level is improved compared to the Skewed-t-GARCH model (seeTable), the failure rate is reduced from 1.9% to 1.7%, indicating that the Skewed-t-TGARCH model is most capable of portraying its risk, and the accuracy of portraying the SSE tail risk is significantly improved.JSE's backtesting of the VaR values of both the Skewed-t-EGARCH and the Skewed-t-TGARCH at α = 5% confidence level is significantly improved compared to that of the Skewed-t- GARCH models are both significantly improved compared to the Skewed-t-EGARCH model. Further, the VaR value backtesting is improved byTable of the VaR return test results, it is seen that SSE passes the UC and CC tests at the α=1% confidence level, while JSE passes the UC and CC tests at different distributions and significance levels.

Table 8:Comparison of VAR backtesting for SSE and JSE stock indices

Type of index	Distribution type	α/%	Number of days of failure	Failure rate/%
SSE	EGARCH	5	72	7.2
		1	21	2.1
	TGARCH	5	75	7.5
		1	17	1.7
JSE	EGARCH	5	58	5.8
		1	11	1.1
	TGARCH	5	59	5.9
		1	11	1.1

Table 9:VAR value return test results for SSE and JSE stock indices

Type of index	Distribution type	significance level	statistic	UC threshold value	p-value	statistic	CC threshold value	p-value
SSE	EGARCH	5	9.022	3.841	0.003	9.03	5.991	0.011
		1	9.284	3.841	0.002	9.833	5.991	0.007
	TGARCH	5	11.484	3.841	0.001	11.511	5.991	0.003
		1	4.091	3.841	0.043	4.68	5.991	0.096
JSE	EGARCH	5	1.284	3.841	0.257	2.074	5.991	0.355
		1	0.38	3.841	0.538	0.672	5.991	0.715
	TGARCH	5	1.616	3.841	0.204	2.282	5.991	0.319
		1	0.098	3.841	0.754	0.343	5.991	0.842

6 CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 Conclusion

The characterization of the daily return volatility of the Chilean and South African stock indices over a long time span from the beginning of January 1996 to the end of December 2022 reveals that the Skewed-t-TGARCH algorithm is able to more accurately characterize the at-risk value of the stock index series, and that this study is able to draw the following conclusions:

First, in the short term, the opening of the International Board has led to a weakening of the trading competitiveness of the Chilean stock market, while the South African market has increased its trading competitiveness, and both market trading competitiveness and macroeconomics have been positive in the long term. The opening of the stock market has led to an increase in trading competitiveness due to the introduction of more traders and capital, which should improve market liquidity, while the weakening of the trading competitiveness of the Chilean stock market has been analyzed for the following two reasons: Firstly, the opening of the international board has led to the inability of the local market's laws, regulations and trading rules to effectively adapt to the new market environment, as the Chilean "Foreigners' Securities Exchange Stock Exchange Handbook" issued at that time was mainly aimed at combating money laundering and terrorist activities. which was issued at the time with the main purpose of combating money laundering and terrorist financial transactions. Secondly, long-term investors lost confidence in the market and shifted to more stable investment channels, thereby reducing stock market liquidity and further affecting market competitiveness.

Second, the opening of international boards in the Chilean and South African markets led to a significant increase in market risk. Among them, the South African stock market can quickly absorb and smooth out the shock risk caused by the opening of the international board, summarizing the reason for this is that the South African market may have the world's first-class regulation, trading and clearing system, settlement and risk management in emerging markets, which makes it able to respond quickly and adequately to the market risk after the opening of the international board, and indicates that the market has a certain degree of policy efficiency. In addition, loose foreign exchange controls, a robust prudential regulatory system, a sound financial legal system and financial accounting standards contributed to the relatively successful opening of South Africa's international board. The insensitivity and persistence of the Chilean stock market in responding to shock risk may be related to the fact that it does not have better listing rules and does not have sufficient market depth. This is because if the market is deep enough and liquid, then even temporary large shocks can be quickly absorbed by the market and the impact will be relatively small and more likely to be short-term.

Thirdly, there is a convergence between the Chilean and South African stock markets, with both reacting similarly to new interest rate shocks, and the Chilean and South African stock markets reacting significantly more strongly to negative news than to good news, with a very pronounced leverage effect, which is attributable to investors' risk appetite and loss aversion. Therefore, due consideration should be given to the impact of risk shocks faced by investors in China's financial markets and their ability to withstand them, so as to avoid a significant increase in stock market risk due to investor panic over the opening of the international board.

Fourth, while the AR of the Chilean and South African markets always fluctuated around the value of 0, the CAR increased significantly after the opening of the International Board, indicating that the market's share prices changed significantly and that the opening of the International Board exacerbated stock market volatility in the short term. The reason for this is attributed to the fact that both Chile and South Africa chose to list companies originating from mature markets with consumer market ties to their countries, and South Africa also chose to list African companies that are geographically proximate and have high economic ties, which have the advantage of being stable, contributing to the local economy, and having low foreign exchange shocks. This also led to the opening of South Africa's international board of risk impact is relatively small, the opening of the international board is more successful. At the same time, it can also show that the opening of the international board has to a certain extent promoted the development of the stock market and the process of financial liberalization, and the impact on the macroeconomy is positive, and the risk impact is controllable under the appropriate regulatory policy and institutional system.

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