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Financial Crisis: Introduction of Kurtosis Index

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Abstract

Due to increased globalization, significant volatility has been observed in international equities markets from financial shocks such as the 2009 Lehman Crisis, 2020 COVID-19 pandemic, and the 2022 Russian invasion of Ukraine. We review the changes in indices such as the S&P 500, VIX, SKEW, Kurtosis, and EPU. Specifically, we design a Tail-Risk Index (TRI) that models kurtosis and identifies the features of a financial crisis more clearly than other indices.

Keywords: *fat-tailed risk, financial crisis, kurtosis index*

1. INTRODUCTION

"Fat-tailed risk" with the least occurrence has long worried financial institutions. It occurred during the aftermath of crises such as the collapse of the Lehman Brothers, coronavirus disease 2019 (COVID-19), and Russia's invasion of Ukraine. Its occurrence inflicts enormous damage on the entire financial institution system. The sense of crisis is diminished by the Goldilocks market price effect among parties such as pension funds and financial institutions. The economic and social turmoil on a global scale caused by the COVID-19 pandemic and the Russian invasion of Ukraine emphasizes the importance of operations prepared for managing the tail risk. During the financial crisis period, risk-averse investors attempted to sell their risk assets and sought "flight to quality," or "flee to safety" assets such as equities. However, they could not find buyers.

Any investor who flees to safety assets must persuade another investor to accept the other side of this deal and opt for increased risk assets. Thus, only some investors can flee to safety assets. In this paper, we focus on the change in indices such as the S&P 500, VIX, SKEW, Kurtosis, and EPU to analyze the effect of three different financial crisis-inducing shocks. Specifically, we design a Kurtosis Index that indicates the features of the financial crisis more clearly than other indices.

2. DATA

Our sample data of the S&P 500, VIX, SKEW and EPU daily/monthly returns are collected from the CBOE, MSCI. In the analyses, the returns are based on U.S. dollar and historical record periods are from January 1, 1990 to March 31, 2022.

CBOE provides S&P 500, VIX, and SKEW Indexes. MSCI provides the database of MSCI ESG related Indexes. We create Kurtosis Indexes to check the fat-tail risk.

Namely, we introduce to reinforce SKEW Indexes by using higher order moments.

Table 1: Basic statistics (Jan. 1990–Mar. 2022)

	S&P 500	VIX	SKEW	Kurtosis	EPU
Mean	2495.006	19.52302	120.8758	8.40752	109.0383
Median	1851.325	17.62	118.84	0.070005	88.365
Maximum	10050.41	82.69	170.55	2491.605	861.1
Minimum	326.08	9.14	101.23	1.90E-21	3.32
Std. Dev.	2059.732	8.011184	9.326475	76.59054	80.37782
Skewness	1.580185	2.190288	1.238221	19.42885	2.40704
Kurtosis	5.193821	11.37388	4.746682	466.4742	12.80484
Jarque-Bera	5013.766	30224.44	3103.697	73007395	58551.55

3. METHODOLOGY

Mean is the average value of the series, obtained by summing up the series and dividing by the number of observations. Standard Deviation is a measure of dispersion or spread in the series. The standard deviation is given by $s=\sqrt{\frac{\left(\sum_{t=1}^{N}(y_t-y)^2\right)}{(N-1)}}$, where N is the number of observations in the current sample. And $\bar{y}$ is the mean of the series. Skewness is a measure of asymmetry of the distribution of the series around its mean. $S=\frac{1}{N}\sum_{t=1}^{N}\left(\frac{y_t-\bar{y}}{\hat{\sigma}}\right)^3$, where $\hat{\sigma}$ is an estimator for the standard deviation that is based on the biased estimator for the variance.

Kurtosis measures the peakedness or flatness of the distribution of the series.

Kurtosis is computed as $K=\frac{1}{N}\sum_{t=1}^{N}\left(\frac{y_t-\bar{y}}{\hat{\sigma}}\right)^4$, where $\hat{\sigma}$ is again based on the biased estimator for the variance. In addition, Jarque-Bera is a test statistic for testing whether the series is normally distributed. The test statistic measures the difference of the skewness and kurtosis of the series with those from the normal distribution. The statistic is computed as $Jarque-Bera=\frac{N}{6}\sum_{t=1}^{N}\left(S^2+\frac{(K-3)^2}{4}\right)$, where S is the skewness, and K is the kurtosis. Table 1 shows each index's statistic.

The Jarque-Bera test statistic follows a chi-squared distribution with 2 degrees of freedom under the null hypothesis of normality. Judging from Table 1, the Jarque-Bera test statistic for each index is very large, leading to a rejection of normality.

We explain the tail risk using Figures 1 and 2. Figure 1 indicates that if the skewness is negative, the return shifts to the negative region and the probability of tail risk increases. Figure 2 suggests that if kurtosis becomes larger, the base of distribution expands and the probability of fat tail risk increases. Namely, as kurtosis increases, the tails of the distribution become heavier, making tail risks more likely to occur from Figure 2. The kurtosis index was developed to quickly capture this tail risk.

4. EMPIRICAL RESULTS

Figure 3 suggests that the S&P 500 index faced drawdowns in September 2008, February 2020, and February 2022 following the Lehman shock, COVID-19 pandemic, and Ukraine crisis, respectively. The VIX scores high during each shock, and when the scores are low, the risk of investment also seems to be low. However, whether this is true or not entails considering not only volatility but also tail risk. Figure 4 confirms that the SKEW index shows relatively high values in the past twenty years, implying that the equity volatility is low, although the possibility of drawdown is large enough. Concerning the return on financial assets such as equity, drawdown with tail risk has been indicated to occur with the least probability. The tail risk seems to become larger by the year in

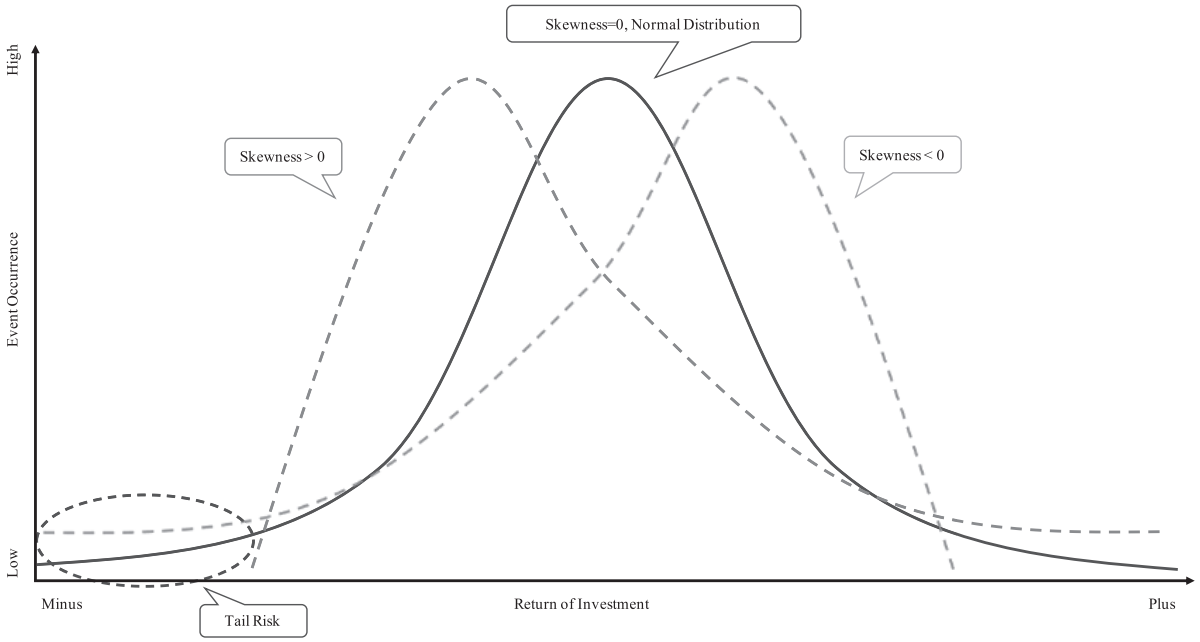

Figure 1: Features of skewness

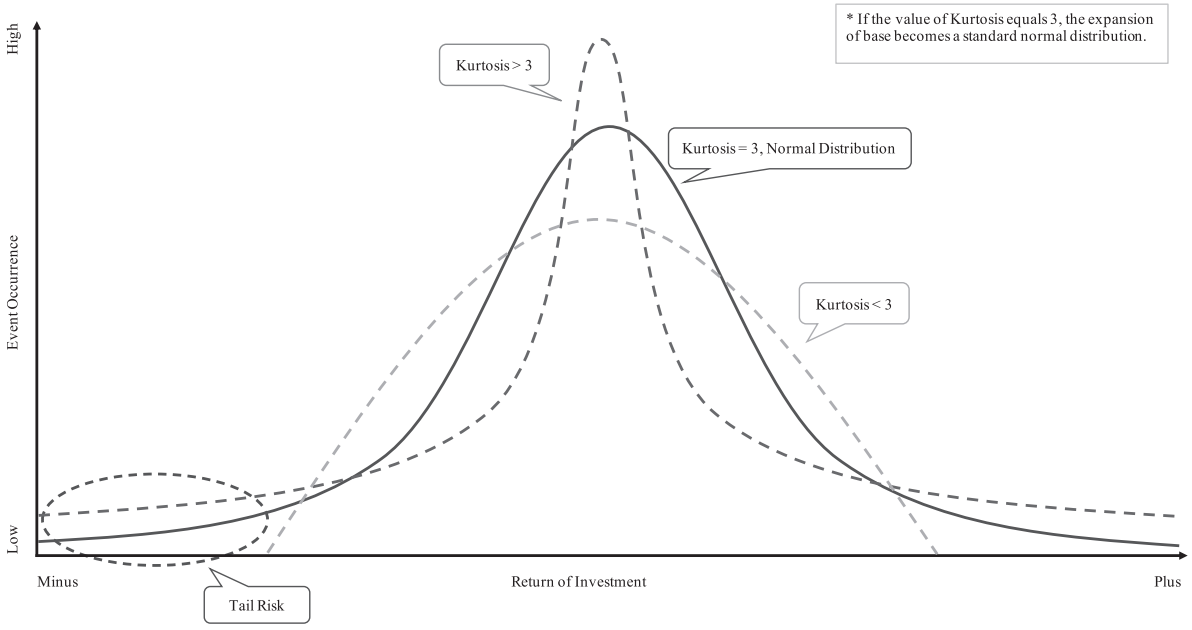

Figure 2: Features of kurtosis

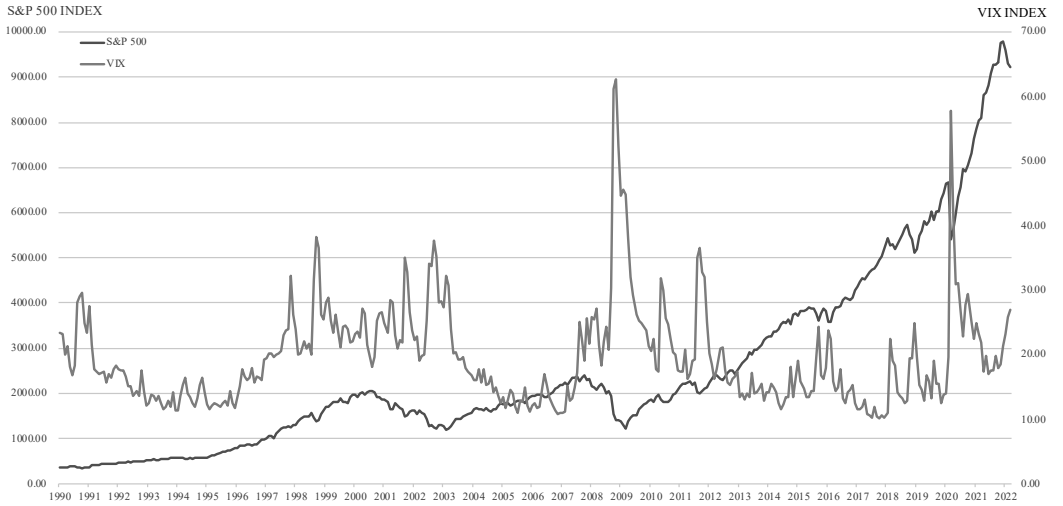

Figure 3: Changes in S&P 500 index and VIX

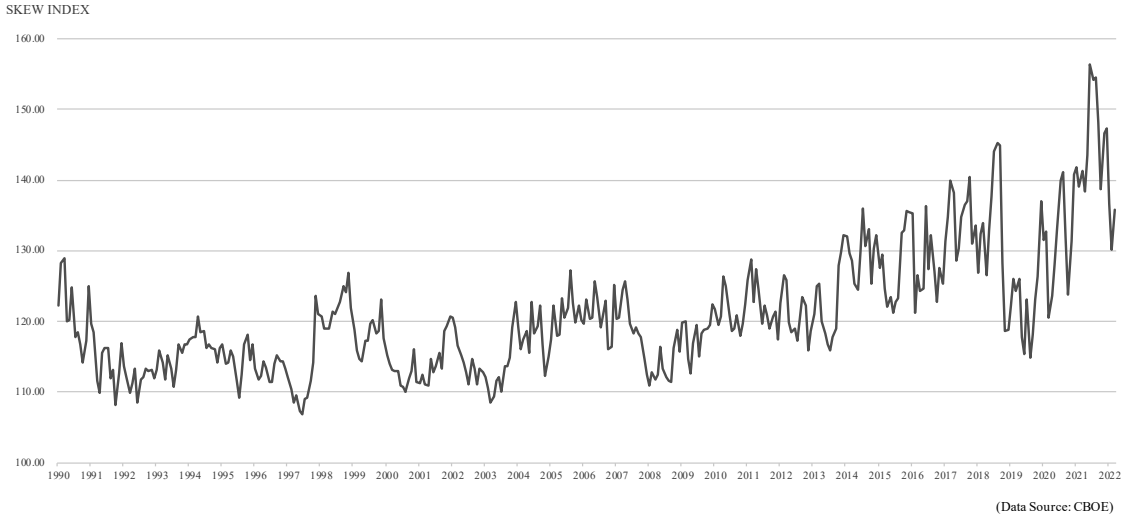

Figure 4: Changes in SKEW index

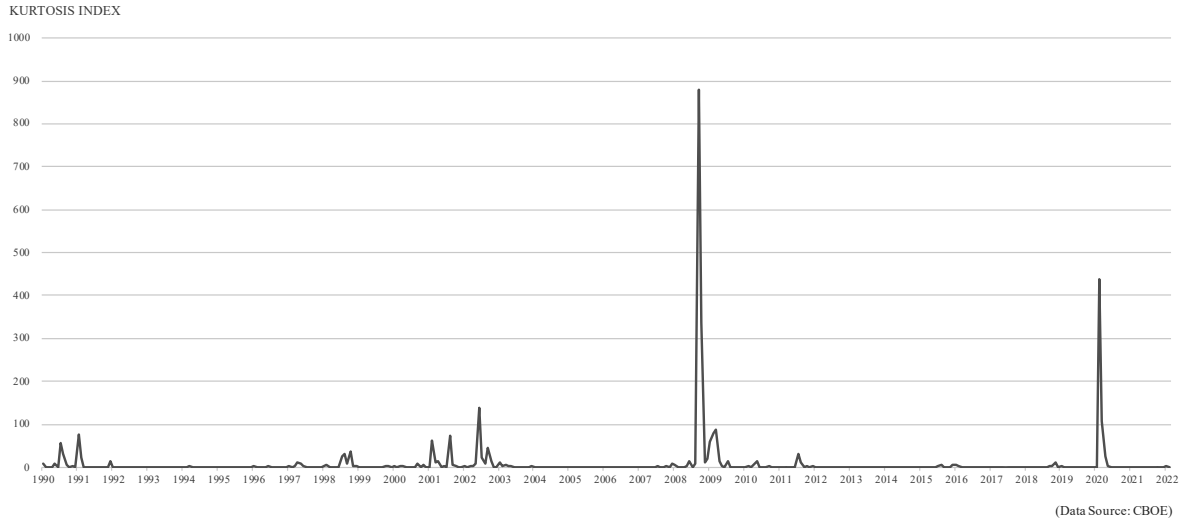

Figure 5: Changes in kurtosis index

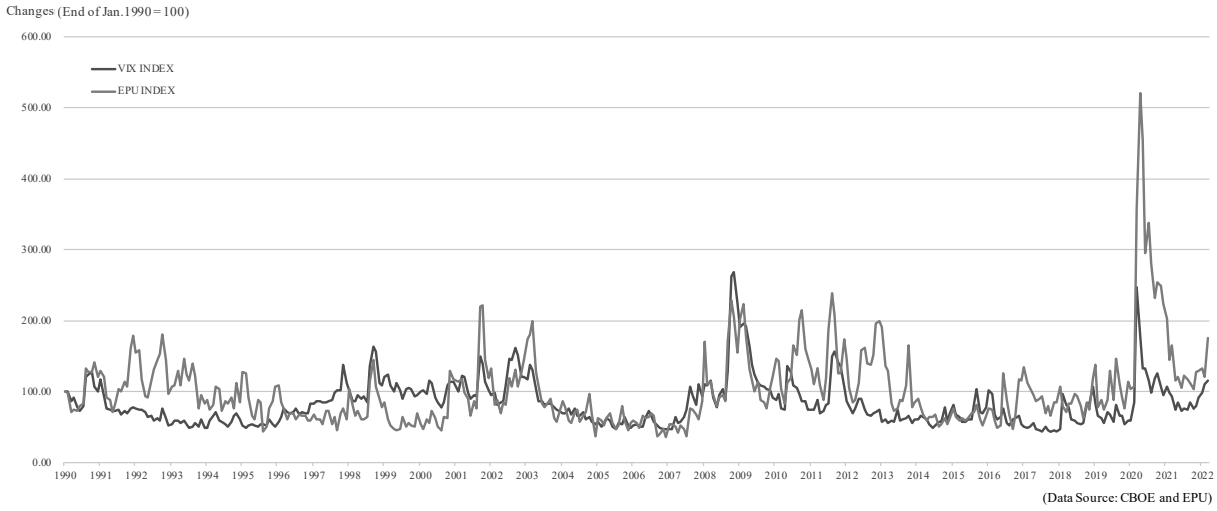

Figure 6: Changes in VIX and EPU index (End of Jan. 1990=100)

recent times.

Tail risk in equity returns has been identified in the literature (Marsh and Pfleiderer, 2010; Rodriguez-Nieto and Mollick, 2021), and we use the statistical measure of kurtosis to identify the phenomenon of fat-tail risk in equity returns by developing a kurtosis index. We propose that the kurtosis index is a measure that allows us to the magnitude of financial crises over time. Figure 5 suggests that financial crisis symptoms emerge more clearly in Kurtosis than in the VIX and SKEW index. Therefore, we propose that the Kurtosis index should be adopted as one of the indicators of financial risks henceforth.

The most important fact is that News of Russia's invasion of Ukraine was leaked through social media and television reporting. As the impact of the Ukraine shock on the S&P 500 was so limited, I intentionally include it for reference in comparison with the Lehman Shock and the Corona Shock.

Here, we investigate the impact of the Lehman shock, COVID-19 pandemic, and Ukraine's invasion on indices such as the S&P 500, VIX, SKEW, Kurtosis, and EPU by using the daily dataset for these indices. We check the movements around August 15, September 15, and November 17, 2008, in the case of the Lehman shock, around February 17, March 9, and March 16, 2020, for the COVID-19 pandemic, and around February 16, February 24, and March 14, 2022, for Ukraine's invasion. Figure 7-a illustrates that the S&P 500 index declined sharply from September 15 to around November 17 because of Lehman Brothers' bankruptcy, although the tendency of decline appeared around August 15, suggesting that the concerned parties could predict the market crash.

Figure 7-b shows that the S&P 500 index declined sharply from March 9 to around March 16, after which it increased sharply, indicating that the effect of the shock was limited.

As evident from Figure 7-c, the S&P 500 index declined sharply from February 16 to around February 23 in anticipation of Russia's invasion of Ukraine. The market appeared to have already factored in Russia's invasion as the S&P 500 index increased on the day of the invasion. After March 14, the index increased sharply, indicating that the shock's effect was also limited.

Figure 8-a illustrates that the VIX increased sharply from September 15 to around November 17, triggered by the bankruptcy of Lehman Brothers. However, the tendency of an increasing VIX appeared around August 15, suggesting that the concerned parties could predict the market volatility.

Figure 8-b shows that the VIX increased sharply from February 17 to around March 16 as the COVID-19 pandemic intensified, after which it decreased sharply, indicating that the shock's effect was limited.

Figure 8-c illustrates that the VIX increased in the expectation of the Ukraine shock, from February 16 to around February 23. However, the market appeared to have already factored in this aspect as the index declined on the day of Russia's invasion of Ukraine on February 24. After March 14, the VIX decreased sharply, implying that the shock's effect was limited.

Figure 9-a shows that the SKEW index declined from September 15, with the announcement of Lehman's bankruptcy, to around October 6. Thereafter, the SKEW index increased till November 10, although the tendency to increase appeared around September 8, suggesting that the concerned parties could predict the market crash.

As evident from Figure 9-b, the SKEW index declined sharply from February 17 to around March 16, with the widespread increase in COVID-19 infections. Thereafter, the index increased sharply, indicating that the shock's effect may lead to the next drawdown.

Figure 9-c shows that the SKEW index increased sharply from February 23 to around February 28, following the Ukraine shock. The market appears to have already factored in the Russian invasion as the index increased on the day of the invasion. After March 14, the SKEW index again increased sharply, suggesting that the shock's effect may lead to the next drawdown.

Figure 10-a demonstrates that the Kurtosis index increased sharply from September 15 to around October 20, following the bankruptcy of Lehman Brothers. However, a declining tendency appeared thereafter, implying that the shock's effect was limited.

As evident in Figure 10-b, the Kurtosis index

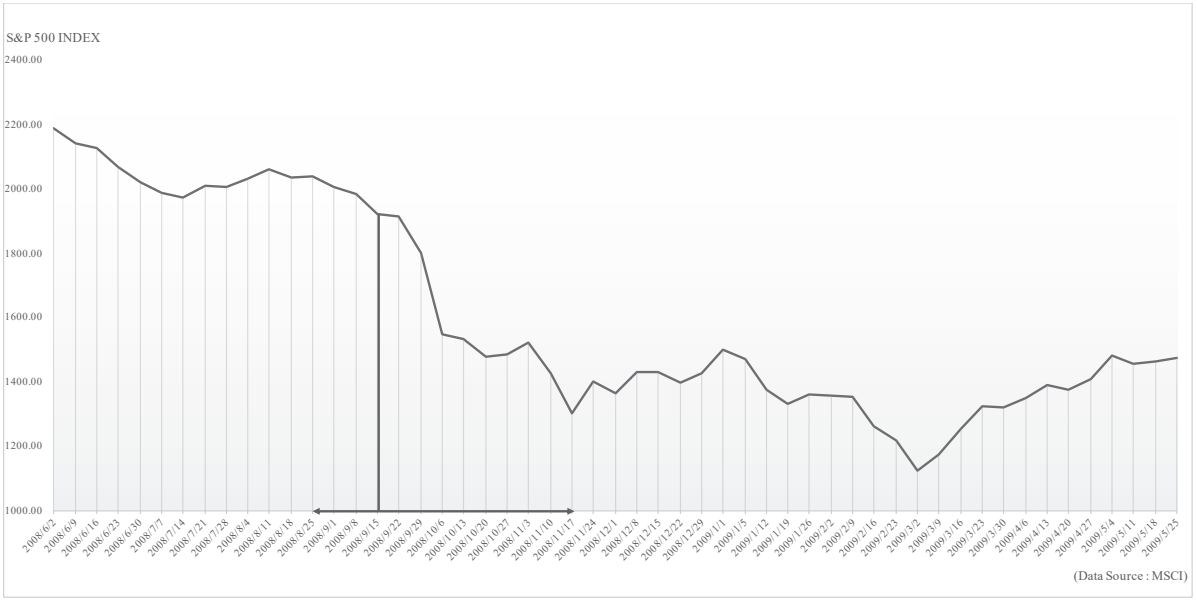

Figure 7-a: Changes in S&P 500 index—Lehman shock period

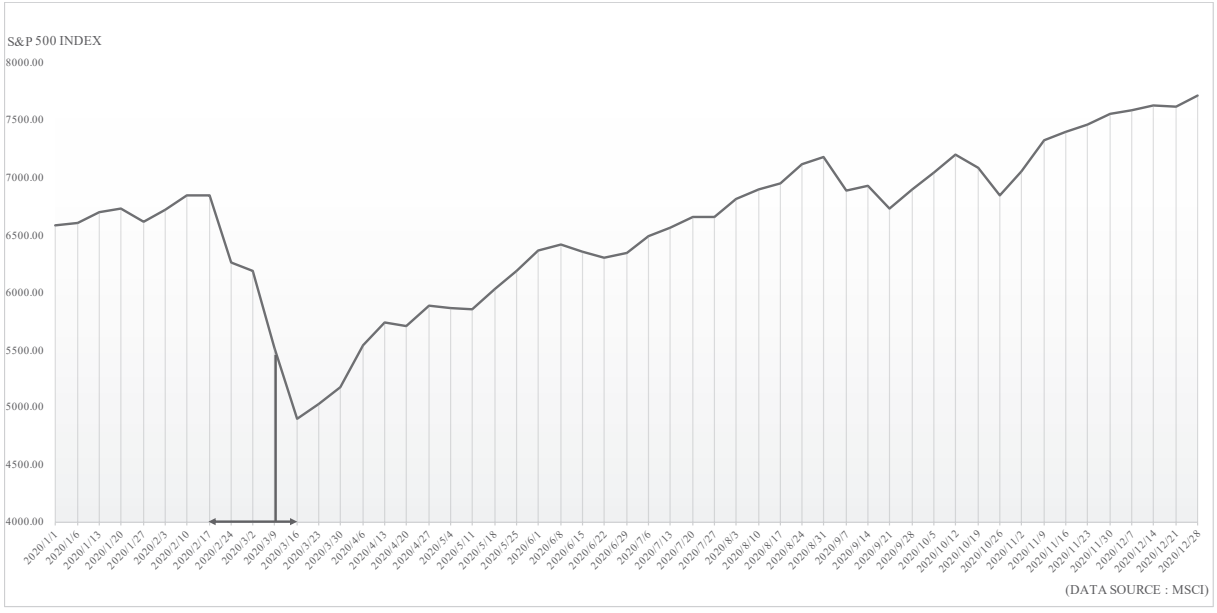

Figure 7-b: Changes in S&P 500 index—COVID-19 shock period

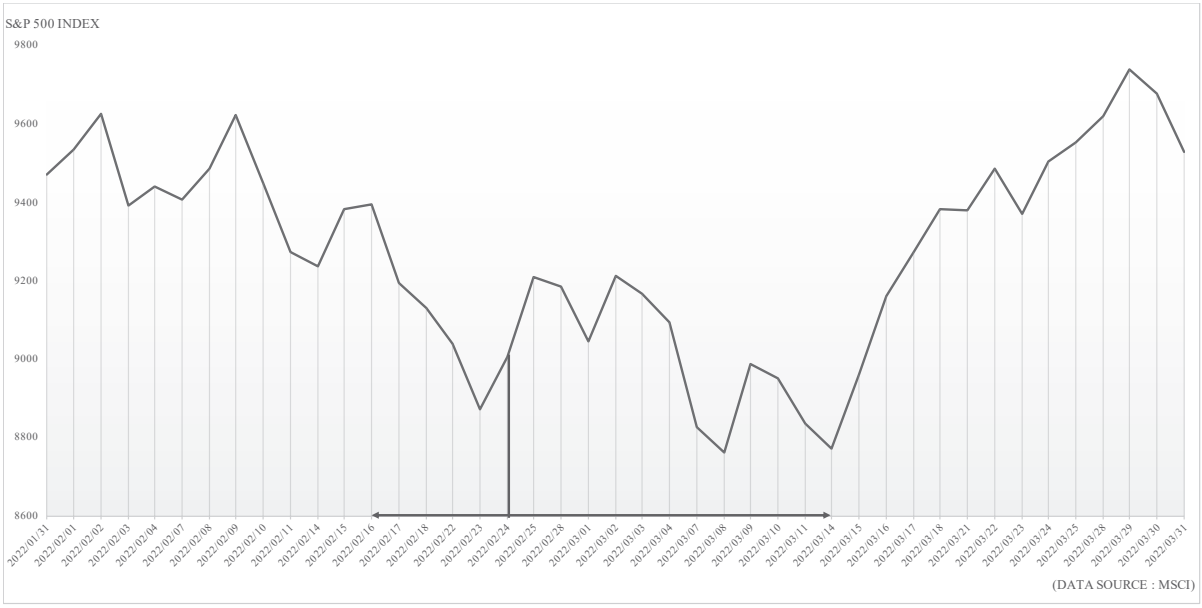

Figure 7-c: Changes in S&P 500 index—Ukraine invasion shock period

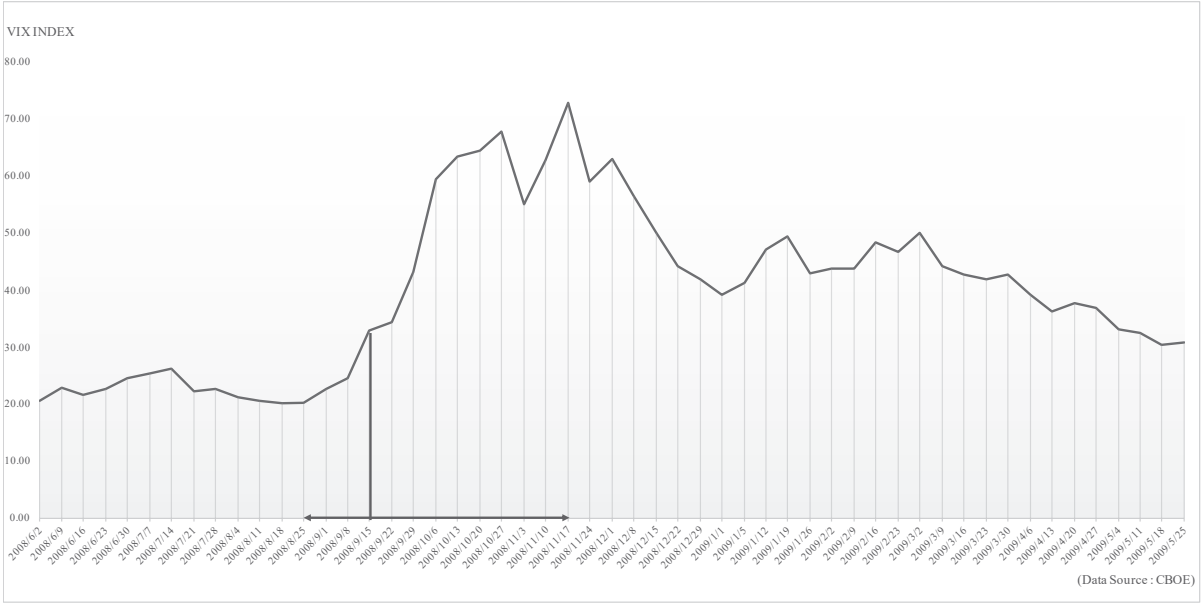

Figure 8-a: Changes in VIX—Lehman shock period

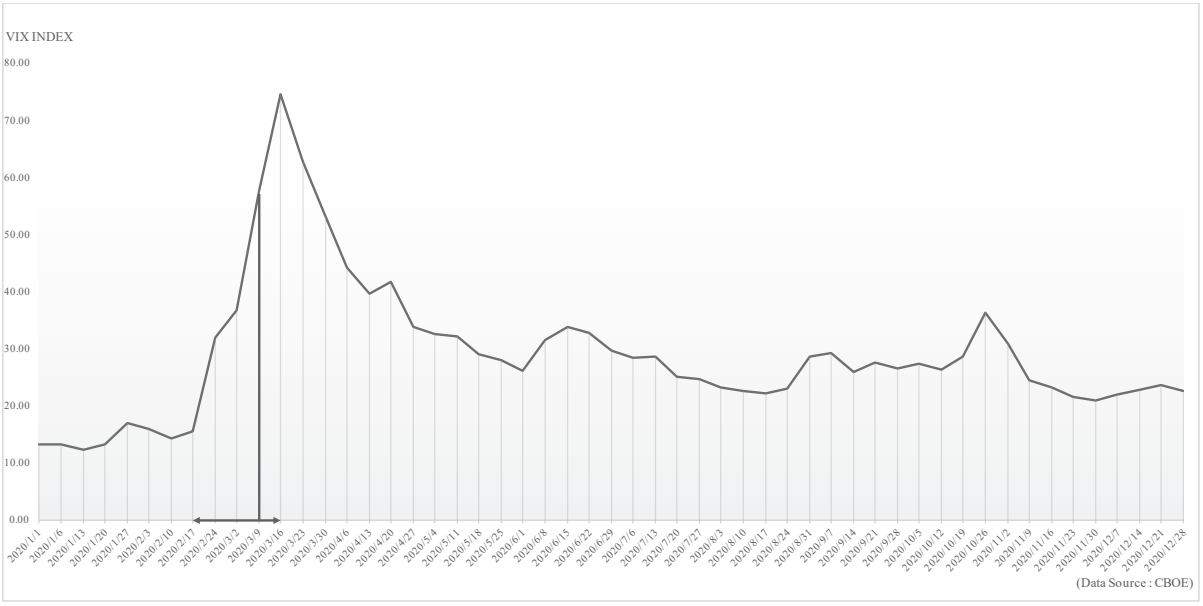

Figure 8-b: Changes in VIX—COVID-19 shock period

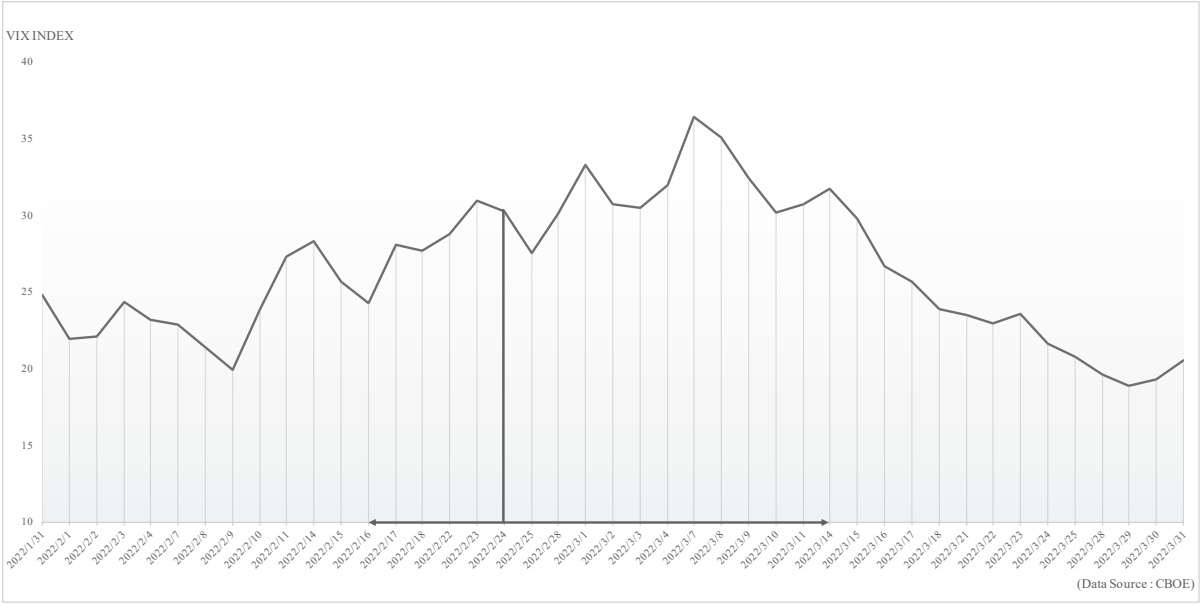

Figure 8-c: Changes in VIX—Ukraine invasion shock period

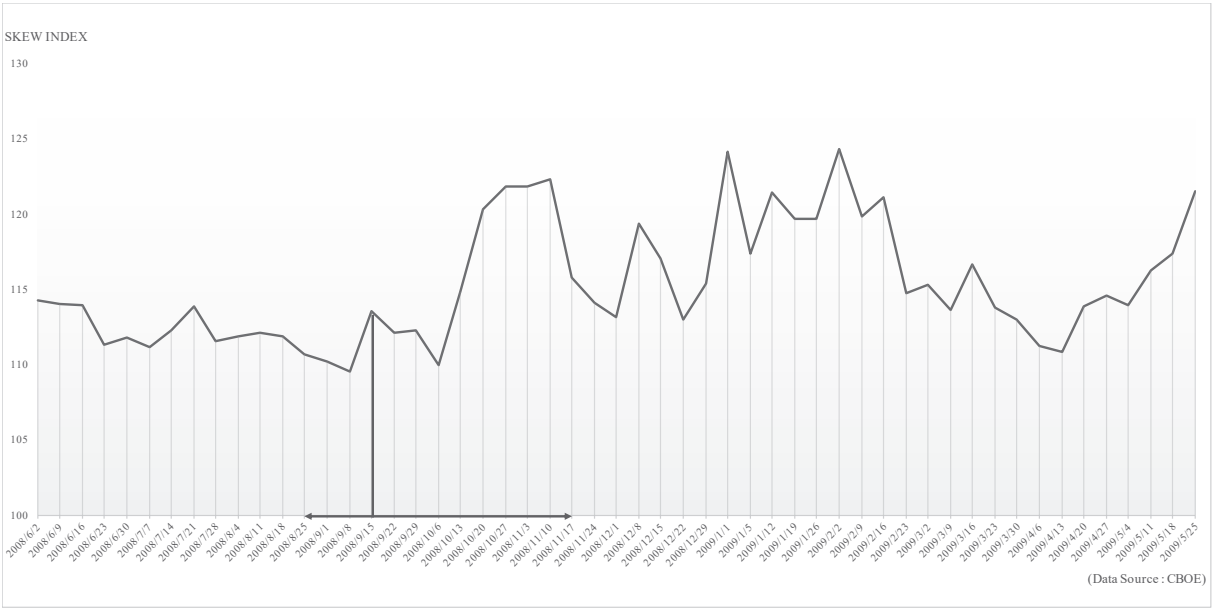

Figure 9-a: Changes in SKEW index—Lehman shock period

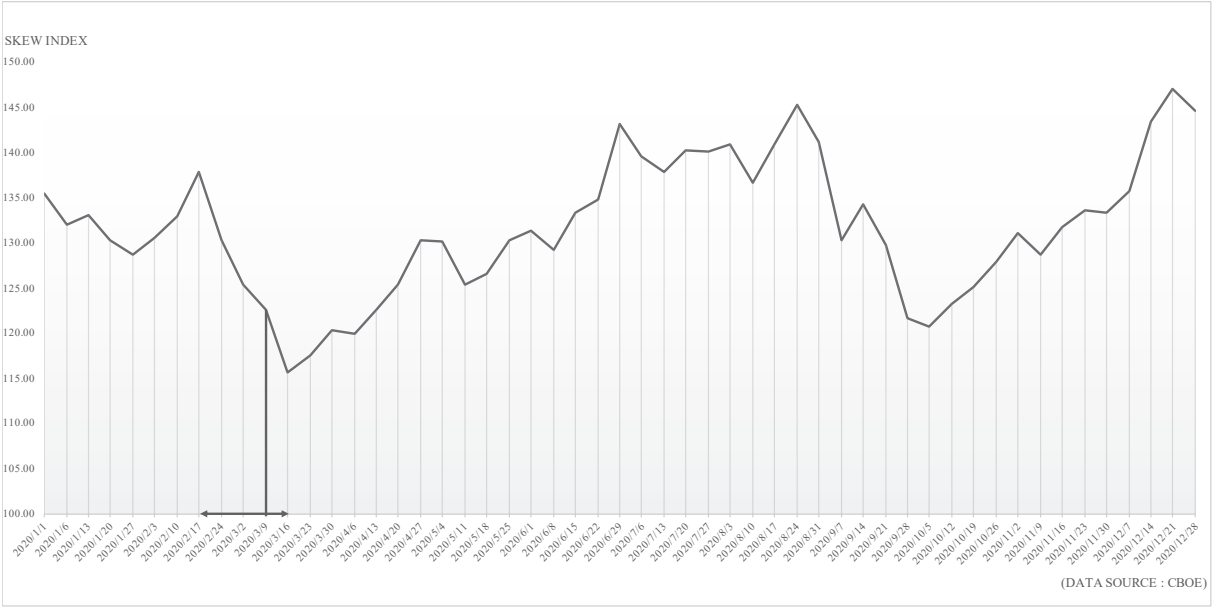

Figure 9-b: Changes in SKEW index—COVID-19 shock period

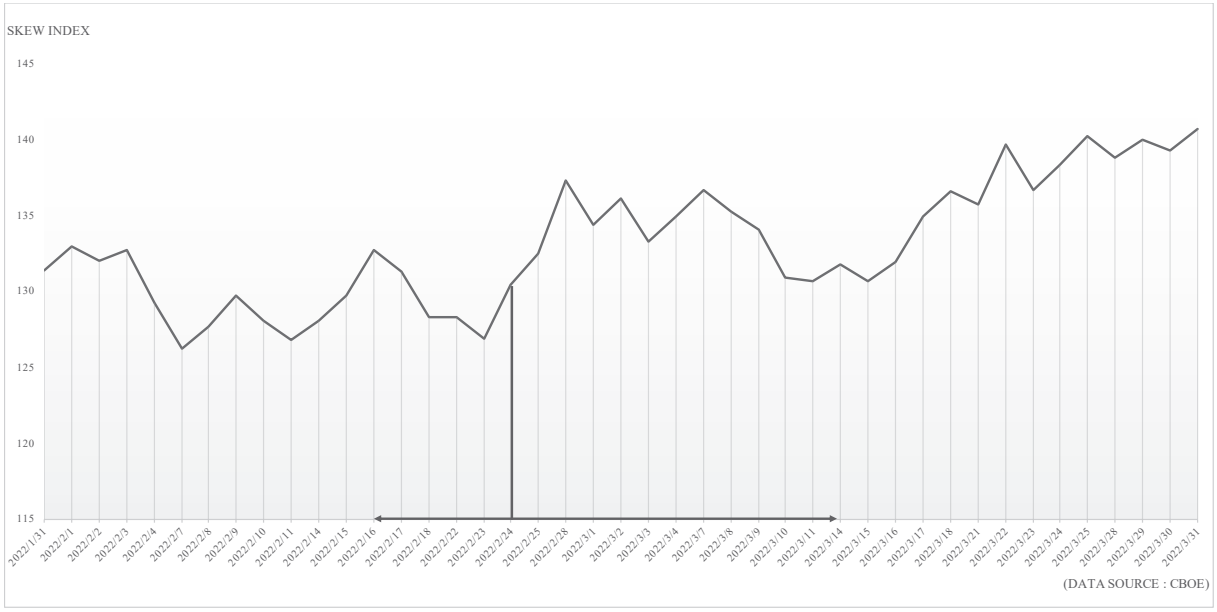

Figure 9-c: Changes in SKEW index—Ukraine invasion shock period

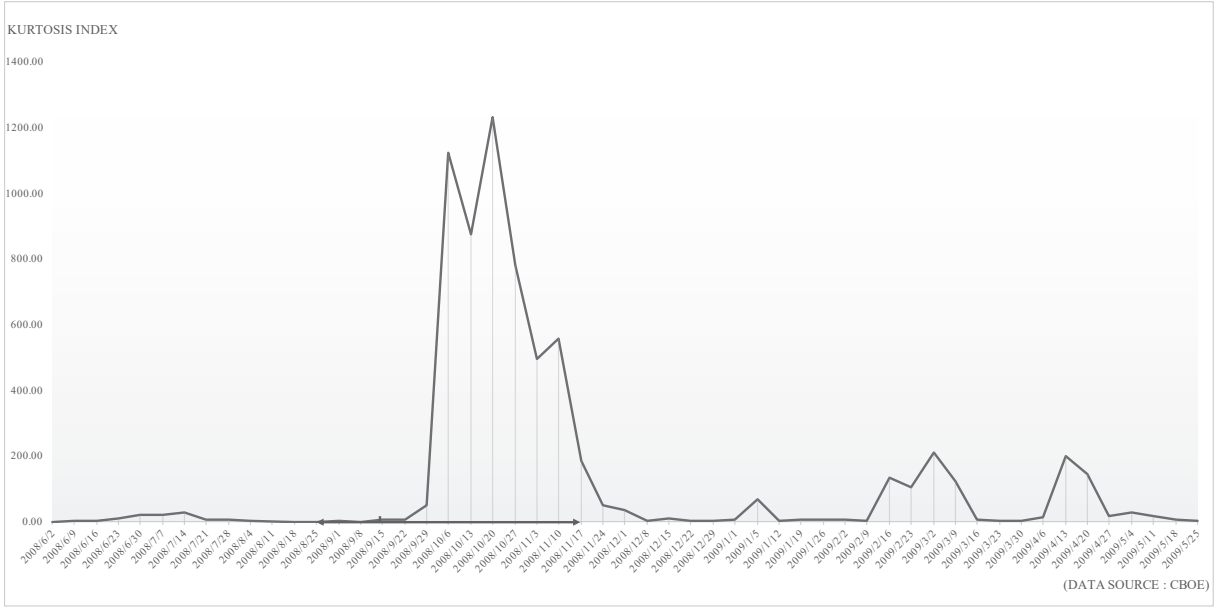

Figure 10-a: Changes in Kurtosis index—Lehman shock period

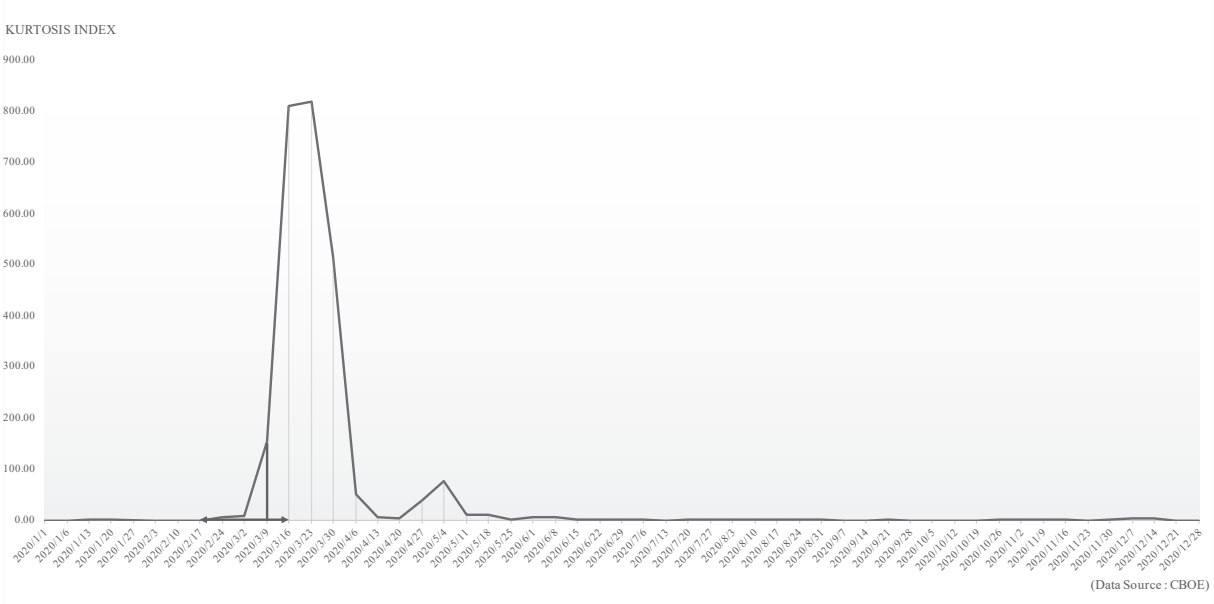

Figure 10-b: Changes in Kurtosis index—COVID-19 shock period

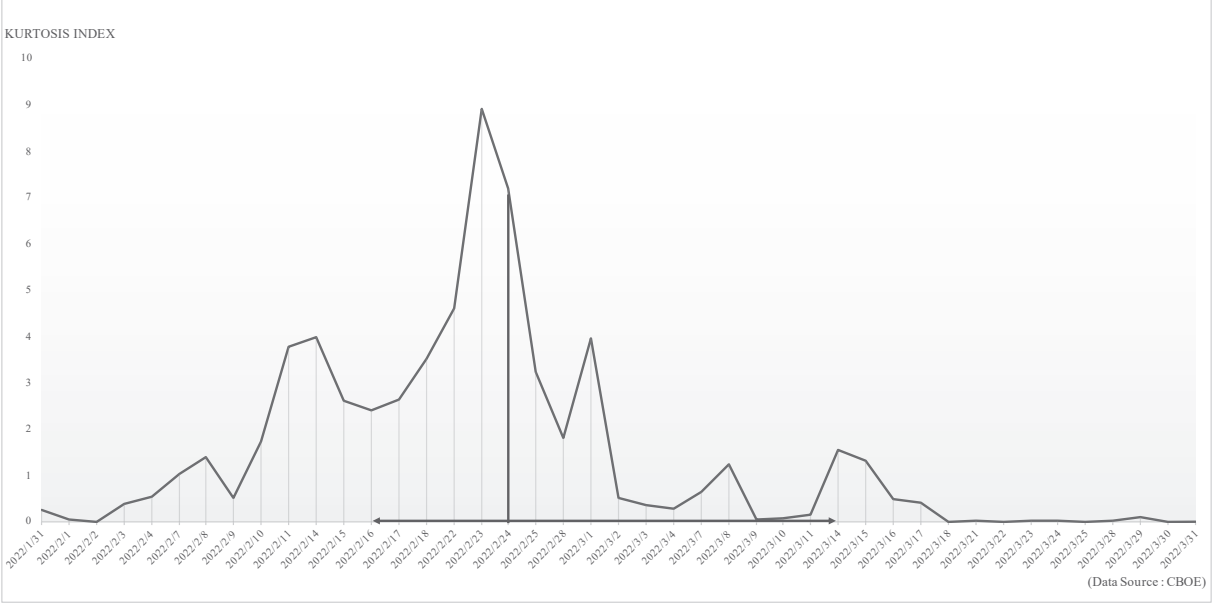

Figure 10-c: Changes in Kurtosis index—Ukraine invasion shock period

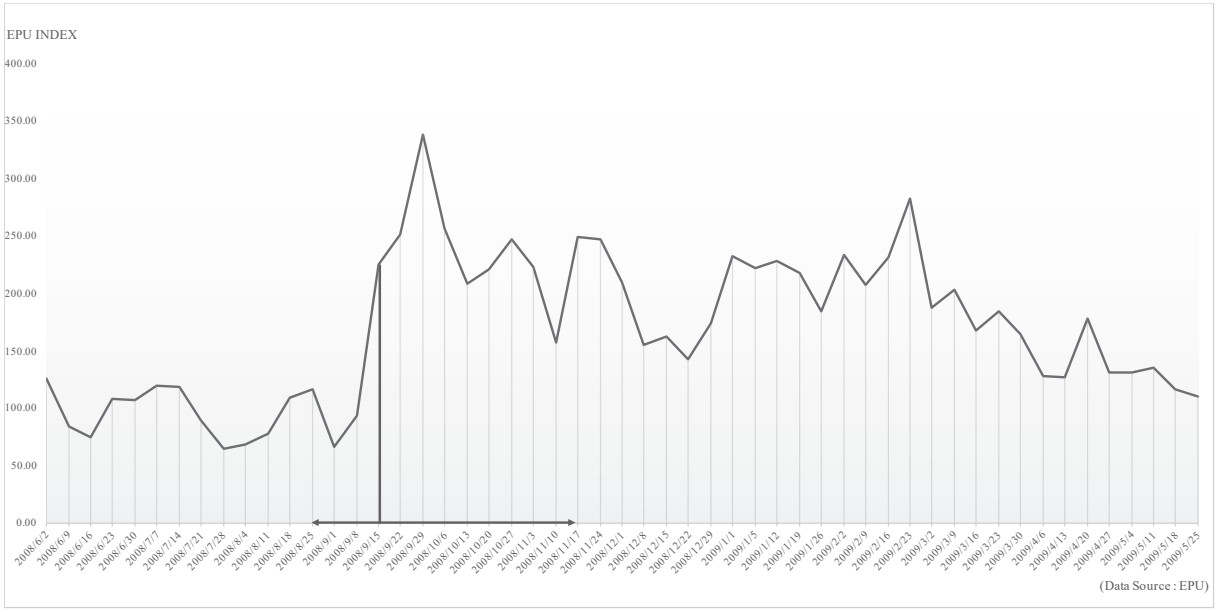

Figure 11-a: Changes in EPU index—Lehman shock period

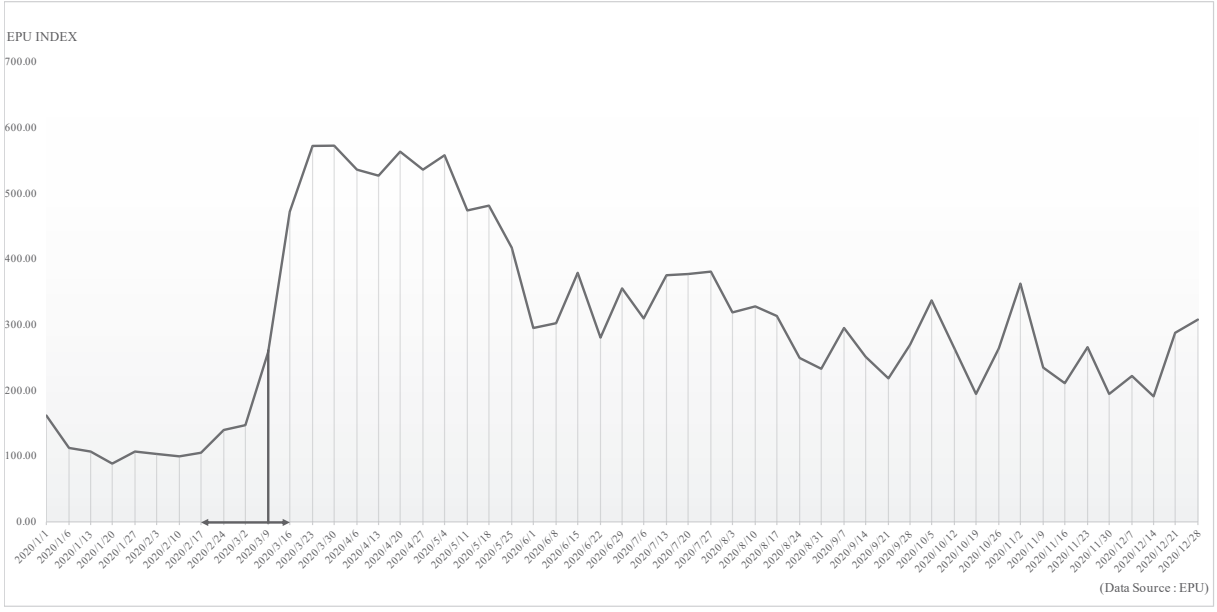

Figure 11-b: Changes in EPU index—COVID-19 shock period

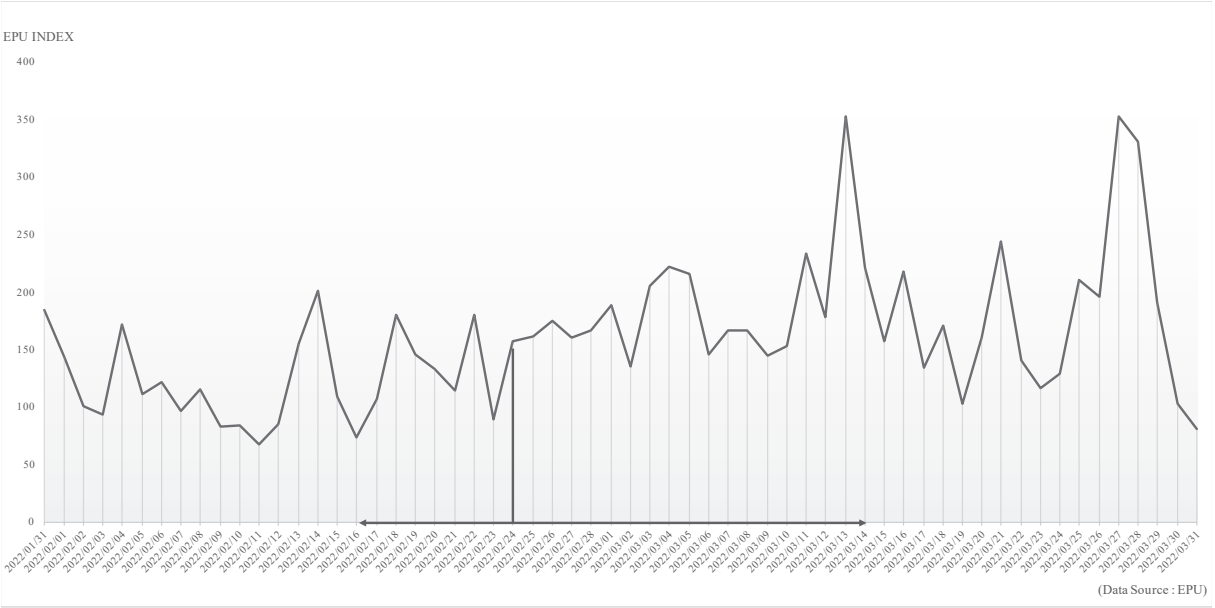

Figure 11-c: Changes in EPU index—Ukraine shock period

increased sharply from March 2 to around March 23, with the rapid spread of the COVID-19 pandemic. However, the index decreased sharply thereafter, indicating that the shock's effect was limited.

Figure 10-c illustrates that the Kurtosis index increased sharply from February 16 to around February 23, in anticipation of Russia's invasion of Ukraine. However, the market seems to have already allowed for the Russian invasion as the index decreased on the day of the invasion. The index recorded a sharp decrease thereafter, suggesting that the shock's effect was limited.

The EPU index, developed by Nick Bloom et.al. at Stanford University, indicates the uncertainty of economic policy and is calculated based on the number of references to the uncertainty of economic policy in major newspapers. Figure 11-a illustrates that the EPU index increased sharply from September 1 to around September 29, following the collapse of Lehman Brothers. However, a declining tendency appeared after September 29, suggesting that the parties concerned could predict the market crash.

As shown in Figure 11-b, the EPU index increased sharply from February 17 to around March 30, with increasing COVID-19 infections. However, the index decreased thereafter, indicating that the shock's effect was limited.

Figure 11-c illustrates that the EPU index fluctuated sharply from February 16 to around February 23, in anticipation of Ukraine's invasion. However, the market appears to have already factored in Russia's invasion as the index increased on the day of the invasion. The EPU index increased smoothly thereafter, suggesting that the shock's effect was limited.

5. CONCLUSION

In this study, we analyzed the changes in indices such as the S&P 500, VIX, SKEW, Kurtosis, and EPU during three different crisis periods. In particular, we developed a Kurtosis index that reflects the financial crisis features more clearly than other indices.

We hope the diffusion of Kurtosis index to the financial institutions for financial crisis in the foreseeable future.

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