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Article

Investigating the impact of Sino-US trade conflict on the co-movement of stock market between China, US and other East Asian Economies in the perspective of biomechanics and bioinformatics

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Abstract: The Sino-U.S. trade conflict on 22 March 2018 the global system of trade and also the international stock market. This paper introduces the theories of biomechanics and bioinformatics to construct a dynamic analytical model based on Vector Auto-Regression (VAR) to investigate the impact of Sino-U.S. trade conflict on the stock markets of China, U.S. and other Asian economies. By employing concepts from biomechanics, the key variables in the co-movement of stock markets in China, the United States, and East Asia are analogized. The co-movement of stock is treated as a "state variable" and the "stress and strain" experienced by each country's stock market under the influence of other markets are analyzed. This approach reveals the patterns of variation within these stock markets and provides a quantitative basis for understanding their dynamics. The granger causality and co-integration analysis are conducted on the empirical daily stock price data from 21 September 2016 to 22 September 2019. Benchmarking on Sino-US trade conflict on 22 March 2018, the data is divided into two phases, including 21 September 2016 to 21 March 2018, and 22 March 2018 to 22 September 2019. The results of this study show that the Asian stock markets seem to be more independent with the U.S. stock market after the Sino-U.S. trade conflict. And the results of the dynamic analysis model based on VAR also suggest that the tariff and the trade barriers not only hurt the relationship between China's stock market and U.S.'s stock market, but also hurt the relationships of stock markets among U.S.'s and other Asian economies. The results of this empirical study can provide information for both investors and policy-makers to have a sound understanding of the stock market.

Keywords: Sino-U.S. trade conflict; stock markets; co-integration analysis; granger causality; co-movement; biomechanics; bioinformatics

1. Introduction

With the acceleration of economic globalization, the cooperation between economies and the flow of production factors strengthens the economic influence among various economies [1,2]. Stock markets, as an important component of international equity market, show co-movements among different economies in extensive literature [3–8]. With significance and great interests, many scholars have explored the transmission mechanism of stock market movements across international equity market and found that the macroeconomic factors and the contagion effects among stock markets can impact the co-movement of the stock market [9–16].

As one of the most important economies in the world, China enhances the openness of the equity market and China's stock market, and other counties' stock markets are gradually connected. However, on 22 March 2018, the Office of the U.S. Trade Representative ("USTR") released an extensive report detailing the results of its "Investigation Into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974." and stated that $60 billion in Chinese imports could be affected by the tariffs, raised the intellectual property rights infringement of Chinese goods and restricted Chinese investment in the United States. At the same day, China also announced that it will impose tariffs on some goods imported from the United States. These tariffs policy changing impacts the bilateral trade with each other and also the global system of trade [17]. And some researchers have identified the impact of Sino-US trade conflict on the bilateral trade of China, US and other countries [18–20]. These studies suggested that the tariff affects the barrier-free trade on the part of the US and China are certain to inflict pain upon both countries, but it might come as a benefit for other countries. Therefore, the linkages between the trade of China, US and other countries will change after the Sino-US trade conflict. And as the indicator of economic, the stock price in China, US, and other counties are also affected. On 22 March 2018, China stock price fell 3.39%, and US stock price fell 2.52%. With the continues of the Sino-US trade conflict, both the international stock markets are volatile, and the global capital market has also undergone drastic changes. How to understand the changing of the co-movement of Stock Market between China, US and other East Asian economies pre- and post- the Sino-US trade conflict becomes important for both investors and policy makers.

However, most previous studies focus on the transmission mechanisms of stock price movements across international equity markets and how these mechanisms change over time. Few studies have addressed the impact of typical event, especially policy changes in the analysis of stock market co-movement. Although there are some studies that analysing the impacts of financial crisis events on the co-movement, these studies are mainly driving form the market contagion effect without the consideration of changes in real economy. Distinguished with the financial crisis, the Sino-US trade conflict mainly impacts the tariff and the bilateral trade, which may affect the stock market co-movement from economic fundamentals.

The theories and related research of biomechanics and bioinformatics have been widely applied in fields such as healthcare, sports and rehabilitation, and they also hold promising potential for applications in other areas [21–23]. In biomechanics, stress and strain describe the internal reactions of an object under external forces. In trade and stock markets, factors such as policy changes, economic data fluctuations, and unexpected events can exert pressure on markets, leading to reactions analogous to stress and strain. By constructing corresponding models, these market pressures and risks can be quantified, providing a scientific basis for risk management. Data mining techniques commonly employed in bioinformatics can be applied to analyze trade and stock market data. By mining extensive trade and transaction datasets, valuable feature information can be extracted, such as price trends, variations in trading volume, and market sentiment indicators. These features can serve as a foundation for subsequent analysis and prediction, contributing to informed decision-making in market analysis.

Against this background, this research empirically examines the changes of the co-movement of stock market between China, US and other East Asian Economics pre- and post- the Sino-US trade conflict and explore the driver of the changes of stock market's co-movement pre- and post- the Sino-US trade conflict from the macroeconomic and biomechanical perspective, representing by the trade.

To investigate the above questions, the Vector Auto-Regressive (VAR) method is employed in this research. To address the relationships of stock market among countries and the causal linkages among the stock markets and the trade, the granger causality and co-integration analysis are conducted. With the empirical daily stock price data, the impact of Sino-US trade conflict on the co-movement of stock market between China, US and other East Asian economies is examined. To avoid the noise of COVID-19 and the shock of stock market in 2015, this research collects the data from 21 September 2016 to 22 September 2019. Benchmarking on Sino-US trade conflict on 22 March 2018, the data is divided into two phases, including 21 September 2016 to 21 March 2018, and 22 March 2018 to 22 September 2019. Our results show that there are strong relationships between China's stock market and U.S. stock market and among other eight Asian economies and U.S. stock market before trade conflict. But the general relationships become weak after the trade conflict. And the results of VAR also suggest that the tariff and the trade barriers not only hurt the relationship between China's stock market and U.S.'s stock market, but also hurt the relationships of stock markets among U.S.'s and other Asian economies.

The rest of this paper is organized as follows. Section 2 reviews the literatures from the transmission mechanism and the empirically research on the co-movement of stock market. Section 3 describes the data and method used in this paper. Section 4 reports the empirical results. And the main findings and the conclusion are summarized in the Section 5.

2. Related work

Extensive literature has been conducted to analyze the co-movement of stock price across different international equity markets. These literature on the co-movement of stock market can be divided into two categories. The first category is the research that explores the transmission mechanism of stock prices across different international markets so as to explain why stock markets are interdependent. The second category is study that empirically investigates how the co-movement of a specific group's stock markets are. In this category, some studies attempted to examine the changes of the co-movement of stock market before and after an event, such as the financial crisis in 2008, stock market crash in 1987, etc. The analysis of trade and stock market based on biomechanical theory or bioinformatics methods is an interdisciplinary research attempt, which is still in the developmental stage, but has great potential and application prospects. To have a sound understanding of the co-movement of stock market, this research reviews the literature from the transmission mechanism, the empirically research on the co-movement of stock market and stock markets analysis from the perspective of biomechanical and bioinformatics methods.

2.1. The transmission mechanism

Based on the characteristics of transmission mechanism, the co-movement of stock market can be explained by economic fundamentals hypothesis or market contagion hypothesis.

The economic fundamentals hypothesis is developed based on Efficient Market Hypothesis and Arbitrage Pricing Theory. Efficient Market Hypothesis was proposed by [24], which promulgates that all relevant information about the changes in macroeconomic factors are fully reflected in current stock prices in the efficiency market. And Arbitrage Pricing Theory (APT) was championed by [25] and [26], which stated that there is linkage between stock prices and macroeconomic fundamentals. Based on these two theories, the information about the fundamental economic factors, such as real output, inflation, money supply, interest rate, trade, industries, etc., may influence the stock price or stock returns.

Some scholars also provided empirical support for the economic fundamentals hypothesis. For example, Nelson [27] found that macroeconomic variables can influence the stock returns by affecting stock prices. Geweke [28] examined the macroeconomic variables' impacts on the extent of stock market interdependence. The results of Geweke's study show that imports, the size differential, and the physical distance between markets can influence the interdependence of stock market significantly. Roll [29] found that the stocks from different countries, but from the same industry, are correlated. Chen [30] calculated the correlations between the emerging stock markets of 25 counties in four regions and found that the interdependence of stock market can be explained by the extent of bilateral trade between the country and the region. Subsequently, more and more scholars have conducted the research on the relationship between stock prices and macroeconomic factors for different international equity markets [10,12,16,31–34].

But as the economic fundamentals hypothesis is developed based on efficient market hypothesis, it cannot explain the co-movement of stock market among different international equity market when excluding macroeconomic indicators or considering the individual investment impacts on the stock markets. With this concern, Granger [35] argued that the linkages among stock markets may results from a market contagion effect. King [36] also analyzed why the stock markets fell together despite widely differing economic environment in 1987 by a model in which contagion between markets occurs as a result of attempts by rational agents to infer information from price changes in other markets. Later, Karolyi [37] explored the factors that affect cross-country stock return correlations and found that the macroeconomic factors have no measurable influence on U.S and Japanese return correlations, but large shocks to broad-based market indices impact both the magnitude and persistence of the return correlations significantly. Connolly [38] also found that the bulk of the observed co-movement in the intraday and overnight returns of the international equity markets cannot be attributed to public information about economic fundamentals. In contrast, their study indicates that future inquiry on market co-movement may focus on the distinction between contagion and trading on private information, rather than public information. Recently, more scholars analyzed the co-movement of stock market under the financial crises and provided sound empirical evidence for this hypothesis [9,11,13,15,39,40]. These researches provide a solid theoretical basis for the research on the co-movement of stock market.

2.2. Empirical research on the co-movement of a specific group's stock markets

The empirical research on analyzing the co-movement of a specific group's stock markets is mainly conducted on regional category or emerging and developed counties' category.

The empirical studies on co-movement of regional market have been conducted in Asia [3,41], Eruope [7], Latin Amercia [3,4], or cross regions, such as the Asia-Pacific [6,8]. The emerging counties also attracts lots of interests from scholars. For instance, Graham [42] examined the co-movement of 22 emerging stock markets with the U.S. market and found that the strength of co-movement differs by country. De Jong [43] document the time-variation in the level of integration among 30 emerging markets, covering Latin America (7 countries), Asia and the Far East (10), Europe (7), and the Mideast and Africa (6). From previous studies, it can be found that most studies related the stock market of different countries with that of U.S. due to the leading role of U.S. equity market. And as the capital markets are not totally integrated, the segmentation of stock market is an important issue for the research of co-movement.

Furthermore, the changes of the co-movement of a specific groups' stock markets before and after an event, especially pre- and post- financial crisis, also attracts lot of interests from scholars. For example, scholars examined the impacts of Asian financial crisis on the co-movement of stock markets and found long-run relationships and short-term dynamic causal linkages in Asian stock markets [39,41,44,45]. The finical crisis in 2008 has also been proved that can significantly affects the co-movement of stock markets in some studies [15,46–49]. Iwanicz-Drozdowska et al. [50] examined the contagion effects on stock markets in 16 major developed and emerging economies in response to a series of economic and non-economic events during the period from 2000 to 2020. In [51], the DCC-MGARCH model is utilized to investigate contagion effects in financial markets during the financial crisis and the COVID-19 pandemic. Bayona [52] investigated the conditions under which market co-movement occurs through experimental analysis.

2.3. Stock markets analysis from the perspective of biomechanical and bioinformatics methods

Biomechanical theories and bioinformatics methodologies provide novel perspectives and approaches for analyzing stock market-related research.

In biomechanics, an object's equilibrium state is the result of various interacting forces. Similarly, in trade and stock markets, the supply-demand relationship mirrors this equilibrium state. When the supply and demand for goods or stocks in the market reach a relatively stable balance, market prices tend to stabilize as well. Existing studies have constructed models analogous to mechanical equilibrium to analyze how shifts in supply and demand forces influence market price fluctuations [53].

Widely used machine learning algorithms in bioinformatics, such as neural networks, support vector machines, and decision trees, have already been applied for stock market prediction and classification [54,55]. Furthermore, the complex network theory from bioinformatics can be leveraged to analyze various relationships within trade and stock markets, providing deeper insights into their structural dynamics and interactions [56].

From previous studies, it can be found that economic fundamentals hypothesis and market contagion hypothesis are not opposite and can be used to find out the drivers of the co-movement of stock markets. However, it should be noticed that most previous studies focus on the transmission mechanisms of stock price movements across international equity markets and how these mechanisms change over time. Few studies have addressed the impact of typical event, especially policy changes in the analysis of stock market co-movement. Besides, the analysis on the impacts of financial crisis events on the co-movement are mainly driving form the market contagion effect. But the Sino-US trade conflict may drive the stock market co-movement from macroeconomic factors. The research of event impact on the co-movement of stock market is still in silence.

As the Sino-US Trade Conflict have significant impacts on the bilateral trade, this study hypothesis that the co-movement of stock market between China, US and other East Asian Economics are changing pre and post the trade conflict. And as the trade can be considered as an important indicator of macroeconomic factors, based on the economic fundamentals hypothesis, this research proposes a further hypothesis that the changes of co-movement of Stock Market between China, US and other East Asian Economics are mainly results from changes in trade. The hypothesis of this research can be summarized as follows.

- Hypothesis 1: The co-movement of stock market between China, US and other East Asian Economics are changing pre and post the trade conflict.
- Hypothesis 2: The changes of co-movement of stock market between China, US and other East Asian Economics are caused by the changes on bilateral trade.

3. Data and method

The data used in this study were draw from the database of Datastream and is composited of daily stock market index closing prices from China, America, and other eight Asian stock markets, including the Shanghai SE Composite (SH), the Shenzhen Component Index (SZ), the US S&P 500 Composite index (US), the Hong Kong Hang Seng (HK), the Japanese Nikkei 225 Stock Average (JP), the South Korean SE Composite (KR), the Taiwanese SE Weighted (TW), the Jakarta Composite Index (IDN), FTSE Malaysia index (MYS), FTSE Singapore Straits Times Index (SG), The Thailand SET Index (TH). All market indices are collected in both local currency and US dollar terms. And all these daily closing values are transformed to the natural log and the returns are calculated as the first difference of each log-transformed series to avoid the inconstant of absolute changes over time. The calculation of returns can be stated as Equation (1),

$$RPI_t = ln\frac{pi_t}{pi_{(t-1)}} \tag{1}$$

where the is the return of the stock index at time.

Focusing on the impact of Sino-US trade conflict, the dataset is collected from 21 September 2016 to 22 September 2019 to avoid the noise of COVID-19 and the shock of stock market in 2015. Therefore, the timeline can be divided as pre-Sino-US trade conflict (from 21 September 2016 to 21 March 2018) and post-Sino-US trade conflict (from 22 March 2018 to 22 September 2019), for each contains one and a half year. And the data is computed separately by these two periods.

The primary purpose of excluding data from the pandemic period is to ensure the generalizability and stability of the experimental results. The abnormal market conditions caused by the pandemic may distort the findings and fail to reflect market patterns during normal periods. Using data from before or after the pandemic, when market conditions were more stable, better captures the intrinsic characteristics and long-term trends of the market.

During the pandemic, markets were disrupted by extreme events, such as sudden economic lockdowns, large-scale fiscal stimulus, and unconventional policies, resulting in abnormal data. These anomalies do not accurately represent the normal functioning of markets. Furthermore, differences in policy responses across countries made market performance challenging to compare. Extreme data from the pandemic period may distort the assessment of long-term trends and obscure the influence of other factors, hindering the experiment's ability to uncover regularities under normal circumstances.

Table 1. Descriptive Statistics for the observations (both indexes and returns).

Variables	**Mean**	**Median**	**Std. Dev**	**Skewness**	**Kurtosis**
Entire sampling period					
HK_{entire}	4.4204	4.4174	0.0488	0.1260	1.8077
IDN_{entire}	3.7644	3.7664	0.0301	−0.0791	1.9339
JP_{entire}	4.3149	4.3299	0.0413	−0.6108	2.3709
KR_{entire}	3.3397	3.3291	0.0332	0.4277	1.9289
MYS_{entire}	3.2371	3.2326	0.0192	0.3561	1.9950
SG_{entire}	3.5016	3.5008	0.0297	0.0018	2.2677
SH_{entire}	3.4764	3.4901	0.0366	−0.5055	2.1094
SZ_{entire}	3.9839	4.0085	0.0554	−0.7702	2.3176
TH_{entire}	3.2118	3.2124	0.0254	0.0032	2.0836
TW_{entire}	4.0060	3.9988	0.0293	−0.1365	1.5763
US_{entire}	3.4093	3.4268	0.0461	−0.3752	1.7308
RHK_{entire}	0.0002	0.0005	0.0045	0.1025	3.7449
$RIDN_{entire}$	0.0003	0.0003	0.0041	−0.6142	5.4877
RJP_{entire}	0.0001	0.0002	0.0050	−0.1112	10.8298
RKR_{entire}	0.0002	0.0002	0.0033	−0.0988	6.1034
$RMYS_{entire}$	0.0001	3.74×10^{-5}	0.0024	0.0645	3.4603
RSG_{entire}	0.0001	-2.31×10^{-5}	0.0032	−0.0979	3.6667
RSH_{entire}	0.0003	0.0003	0.0042	0.3980	4.7553
RSZ_{entire}	0.0003	0.0002	0.0052	0.4527	4.7527
RTH_{entire}	0.0005	0.0004	0.0051	2.4196	27.4801
RTW_{entire}	0.0002	0.0001	0.0034	−0.0382	5.0691
RUS_{entire}	1.24×10^{-6}	9.30×10^{-5}	0.0037	−0.5734	5.3695

Table 1. (*Continued*).

Variables	**Mean**	**Median**	**Std. Dev**	**Skewness**	**Kurtosis**
Pre-trade conflict subsampling period					
HK_{pre}	4.3910	4.3742	0.0508	1.4661	3.7242
IDN_{pre}	3.7455	3.7331	0.0318	1.2635	3.4070
JP_{pre}	4.2829	4.2841	0.0387	0.6783	3.4488
KR_{pre}	3.3311	3.3182	0.0331	1.0508	2.8662
MYS_{pre}	3.2341	3.2316	0.0184	0.5694	2.1905
SG_{pre}	3.4892	3.4905	0.0326	0.5384	2.3028
SH_{pre}	3.5047	3.5047	0.0144	0.7595	4.1152
SZ_{pre}	4.0245	4.0246	0.0169	0.1252	2.5184
TH_{pre}	3.1938	3.1940	0.0228	1.5025	5.4217
TW_{pre}	3.9876	3.9841	0.0269	0.9510	2.9022
US_{pre}	3.3704	3.3689	0.0362	0.9887	3.0597
RHK_{pre}	-3.16×10^{-5}	0.0002	0.0038	−0.1563	3.1278
$RIDN_{pre}$	3.37×10^{-7}	−0.0005	0.0037	−0.5037	6.9595
RJP_{pre}	9.46×10^{-5}	-6.93×10^{-5}	0.0051	0.6933	15.2246
RKR_{pre}	0.0002	0.0001	0.0028	0.0722	4.9954
$RMYS_{pre}$	6.08×10^{-5}	2.86×10^{-5}	0.0019	1.1058	3.6394
RSG_{pre}	6.61×10^{-5}	−0.0001	0.0025	−0.0283	3.2378
RSH_{pre}	0.0001	0.0003	0.0025	−0.1679	3.2174
RSZ_{pre}	-6.82×10^{-5}	5.56×10^{-5}	0.0030	−0.0199	3.2916
RTH_{pre}	0.0007	0.0003	0.0049	5.5681	46.2298
RTW_{pre}	1.16×10^{-5}	-6.56×10^{-5}	0.0030	−0.6669	6.7102
RUS_{pre}	0.0002	1.87×10^{-5}	0.0025	0.3110	5.6725

Table 1. (*Continued*).

Variables	Mean	Median	Std. Dev	Skewness	Kurtosis
Post-trade conflict subsampling period					
HK_{post}	4.4459	4.4489	0.0286	0.0796	1.9151
IDN_{post}	3.7808	3.7790	0.0152	0.2299	1.9664
JP_{post}	4.3427	4.3460	0.01499	−0.3756	3.2727
KR_{post}	3.3471	3.3549	0.0315	−0.0398	1.8527
MYS_{post}	3.2397	3.2341	0.0196	0.1747	1.9367
SG_{post}	3.5123	3.5108	0.0218	0.3160	2.1408
SH_{post}	3.4520	3.4455	0.0321	0.2161	1.8105
SZ_{post}	3.9488	3.9501	0.0531	0.0494	1.8054
TH_{post}	3.2273	3.2274	0.0151	−0.1247	2.3708
TW_{post}	4.0220	4.0314	0.0206	−0.7665	2.0267
US_{post}	3.4430	3.4421	0.0194	−0.2410	2.8535
RHK_{post}	0.0005	0.0009	0.0052	0.1287	3.4824
$RIDN_{post}$	0.0007	0.0009	0.0045	−0.7421	4.7012
RJP_{post}	0.0001	0.0004	0.0049	−1.0009	5.7989
RKR_{post}	0.0001	0.0003	0.0037	−0.1684	5.9568
$RMYS_{post}$	0.0002	0.0001	0.0027	0.0044	2.9383
RSG_{post}	0.0001	0.0002	0.0038	−0.1280	3.1423
RSH_{post}	0.0006	-5.33×10^{-5}	0.0054	0.2886	3.2847
RSZ_{post}	0.0006	0.0002	0.0067	0.3073	3.2664
RTH_{post}	0.0004	0.0005	0.0054	0.0154	13.3681
RTW_{post}	0.0004	0.0002	0.0038	0.2159	3.9660
RUS_{post}	−0.0002	0.0001	0.0045	−0.5382	3.8950

Besides, since there are different opening dates in countries, we removed the data with missing values. The log-transformed indexes and returns used in this research are summarized in **Table 1**. The Mean and Median reflect the trend of stock market returns, with co-movement strengthening when the trends align. The standard deviation (Std. Dev) amplifies market synchronization during periods of high volatility, thereby increasing co-movement. Skewness and Kurtosis significantly influence market co-movement during crises or extreme events, with negative skewness and high kurtosis often leading to synchronized extreme returns. These statistical properties capture the distribution and risk characteristics of the market, driving inter-market co-movement through investor behavior, global economic interconnections, and systemic events.

And to examine the relationship of stock market price index among different counties, this study employed the VAR model with time-series data. The analysis is conducted based on the Equation (2).

$$\Delta Y_t = \phi_1 Y_{t-1} + \ldots + \Phi_p Y_{t-p} + \mathrm{H} x_t + \varepsilon_t \quad (2)$$

4. Empirical results

4.1. The co-movement among different stock markets

4.1.1. Unit root test results

Sequence alignment is a commonly used method and technique in bioinformatics that involves comparing two or more biological sequences to identify their similarities, differences, and evolutionary relationships. Building on this concept, the analysis will proceed to examine stock market return sequences.In the first step, this study implements the unit root test to examine whether the series of the 11 log-transformed stock market returns are stationary. The most common method used with this purpose is the Augmented Dickey-Fuller (ADF) test. The test is based on Equation (3).

$$\Delta Y_t = \mu + \beta Y_{t-1} + \alpha_l Y_{t-l} + \ldots + \alpha_p Y_{t-p} + \mu_t \quad (3)$$

Table 2 reports the results of the unite root tests. As this research sampling period covers the Sino-US trade conflict, the data series is divided into two periods for the data point on 22 March 2018 when conducting the unit root test.

Table 2. Unit root test based on ADF test and phillips-perron test.

Variables	**ADF Test**		**Phillips-Perron Test**	
	***t*−statistic**	**Prob.**	**Adj. *t*−statistic**	**Prob.**
Entire sampling period				
HK_{entire}	−1.5664	0.4986	−1.6294	0.4663
IDN_{entire}	−1.6450	0.4583	−1.6138	0.4743
JP_{entire}	−2.2650	0.1842	−2.2650	0.1842
KR_{entire}	−1.4916	0.5368	−1.4916	0.5368
MYS_{entire}	−1.1331	0.7035	−1.1665	0.6897
SG_{entire}	−1.8220	0.3695	−1.8503	0.3558
SH_{entire}	−1.8570	0.3526	−1.8928	0.3356
SZ_{entire}	−1.8959	0.3341	−1.6795	0.4407
TH_{entire}	−2.1897	0.2106	−2.0965	0.2463
TW_{entire}	−1.6623	0.4495	−1.7336	0.4133
US_{entire}	−1.1778	0.6849	−1.2360	0.6596
RHK_{entire}	−14.3193	0.0000	−14.4692	0.0000
$RIDN_{entire}$	−13.7207	0.0000	−13.7207	0.0000
RJP_{entire}	−16.8597	0.0000	−16.8142	0.0000
RKR_{entire}	−16.7616	0.0000	−17.7448	0.0000
$RMYS_{entire}$	−15.1587	0.0000	−15.4631	0.0000
RSG_{entire}	−15.6704	0.0000	−16.1269	0.0000
RSH_{entire}	−13.9570	0.0000	−13.9473	0.0000
RSZ_{entire}	−14.1492	0.0000	−14.1366	0.0000
RTH_{entire}	−16.4006	0.0000	−16.5321	0.0000
RTW_{entire}	−16.0796	0.0000	−16.1633	0.0000
RUS_{entire}	−14.3350	0.0000	−14.3368	0.0000

Table 2. (*Continued*).

Variables	ADF Test		Phillips-Perron Test	
	***t*−statistic**	**Prob.**	**Adj. *t*−statistic**	**Prob.**
Pre-trade conflict subsampling period				
HK_{pre}	0.1866	0.9709	0.0448	0.9603
IDN_{pre}	−0.4468	0.8968	−0.5130	0.8842
JP_{pre}	−1.5028	0.5296	−1.5041	0.5290
KR_{pre}	0.1725	0.9700	0.2296	0.9737
MYS_{pre}	0.3452	0.9799	0.5588	0.9882
SG_{pre}	−0.1248	0.9436	−0.1344	0.9425
SH_{pre}	−2.5266	0.1112	−2.5266	0.1112
SZ_{pre}	−2.3968	0.1444	−2.4680	0.1254
TH_{pre}	0.0366	0.9596	0.1575	0.9690
TW_{pre}	−0.1303	0.9430	−0.0780	0.9487
US_{pre}	−0.3276	0.9167	−0.4644	0.8935
RHK_{pre}	−10.6449	0.0000	−10.6441	0.0000
$RIDN_{pre}$	−9.5688	0.0000	−9.5350	0.0000
RJP_{pre}	−12.6151	0.0000	−12.6061	0.0000
RKR_{pre}	−11.3767	0.0000	−11.4932	0.0000
$RMYS_{pre}$	−9.7405	0.0000	−9.7445	0.0000
RSG_{pre}	−10.4856	0.0000	−10.5238	0.0000
RSH_{pre}	−11.3395	0.0000	−12.9923	0.0000
RSZ_{pre}	−11.2234	0.0000	−11.2544	0.0000
RTH_{pre}	−10.0026	0.0000	−9.9944	0.0000
RTW_{pre}	−11.3569	0.0000	−11.3569	0.0000
RUS_{pre}	−10.4253	0.0000	−11.9572	0.0000

Table 2. (*Continued*).

Variables	ADF Test		Phillips-Perron Test	
	***t*–statistic**	**Prob.**	**Adj. *t*–statistic**	**Prob.**
Post-trade conflict subsampling period				
HK_{post}	−1.9803	0.2954	−1.9803	0.2954
IDN_{post}	−2.3558	0.1560	−2.8810	0.1770
JP_{post}	−2.6434	0.0863	−2.7868	0.0623
KR_{post}	−1.5540	0.5039	−1.5938	0.4836
MYS_{post}	−1.2197	0.6656	−1.1992	0.6742
SG_{post}	−1.7472	0.4057	−1.7728	0.3930
SH_{post}	−2.2935	0.1753	−2.4488	0.1301
SZ_{post}	−1.8490	0.3563	−1.9548	0.3067
TH_{post}	−2.7942	0.0612	−2.5810	0.0989
TW_{post}	−1.7965	0.3813	−1.9514	0.3082
US_{post}	−1.6683	0.4478	−1.9526	0.3077
RHK_{post}	−7.2295	0.0000	−10.3842	0.0000
$RIDN_{post}$	−9.8435	0.0000	−9.8418	0.0000
RJP_{post}	−12.2415	0.0000	−12.1232	0.0000
RKR_{post}	−12.7027	0.0000	−14.1418	0.0000
$RMYS_{post}$	−11.0832	0.0000	−11.5918	0.0000
RSG_{post}	−11.4132	0.0000	−12.1522	0.0000
RSH_{post}	−9.8853	0.0000	−9.8850	0.0000
RSZ_{post}	−10.1123	0.0000	−10.1135	0.0000
RTH_{post}	−13.0449	0.0000	−14.3249	0.0000
RTW_{post}	−11.6661	0.0000	−12.2462	0.0000
RUS_{post}	−10.1495	0.0000	−10.1593	0.0000

By comparing the ADF significance level with the *p*-value, it is found that the ADF probability values of all log-transformed stock markets index in all periods including the entire sampling period, the pre-trade conflict subsampling period and post-trade conflict subsampling period are not stationary. But the 1st difference of these index and the returns in all periods are significant 0.01 level. Therefore, it can be considered that the log-transformed stock market indices' returns for the 11 stock markets are stationary and integrated of order one, . In other words, all series examined in this paper contain a unit root, which is consistent with the idea of weak-form stock market efficiency for the individual markets. Furthermore, we also used Phillips-Perron tests to examine the presence of a unite root. Phillips-Perron test is a generalization of ADF-procedure that allows for milder assumptions regarding the error distribution. And the Phillips-perron test presents the similar results, suggesting that all series examined in this paper are integrated of order one.

4.1.2. Cointegration test results

Cointegration relationships can be conceptualized as a form of "stress-strain" relationship between variables, both aimed at uncovering inter-variable relationships, dynamic behaviors, and system stability through data and modeling. To investigate the long-term relationships co-movements between different stock markets and analyze the "stress and strain" experienced by each country's stock market under the influence of others, this study employs a dynamic analysis model based on Vector Auto-regression (VAR). And as the optimal lag length is an important parameter in the method and the tests that are based upon it, the likelihood-ration test are applied to correctly specify the various VAR models.

As this research focus on the co-movements of the stock markets of China and US, other Asian economies and US, and that of China and other Asian economies, the following research are conducted for three groups, including Group A of the log-transformed stock index of China and US, Group B of the log-transformed stock index of other eight Asian economies and US, Group C of the log-transformed stock index of other eight Asian economies and China.

We first estimated the VAR model with 15 days as the maximum lag length and then implemented the lag-length test for each group. However, the Akaike, Schwarz and Hannan-Quinn information criteria suggested that fewer lags may be sufficient. To capture all the dynamics in the data, we use the and likelihood-ration test statistics in the further analysis. The number of lags in cointegration tests of different groups for the entire period, pre-trade conflict and post-trade conflict are stated in **Table 3**.

From the co-integration test results, it can be found that there exists one cointegration among the stock market of Shanghai, Shenzhen, and US for the entire sampling period and the pre-trade conflict subsampling period. However, this cointegration disappear after the Sino-U.S. trade conflict, suggesting that the relationship of China's stock market and U.S.'s stock market are weaker after the trade conflict.

While, for the group of other eight Asian economies and U.S., the results show that there are 4 cointegrations at 0.05 level for the entire period, but 9 cointegrations before the trade conflict and only 3 cointegration existing after the Sino-U.S. trade conflict. These results suggest that the tariff and the trade barriers not only hurt the relationship between China's stock market and U.S.'s stock market, but also hurt the relationships of stock markets among U.S.'s and other Asian economies.

The results for the group of other eight Asian economies and China's stock market show different pattern with those of group B. Although there are 4 cointegrations among these stock markets for the entire sampling period, 10 cointegrations exist both before and after the trade conflict, suggesting the strong relationships among the stock market of China and other Asian economies.

Table 3. The lag-length specification and the co-integration test results from the Johansen test for the different periods.

Hypothesized No. of CE(s)	**Trace Test**		**Max-Eigenvalue Test**	
	Trace Statistics	**Critical value**	**Max-Eigen Statistic**	**Critical value**
Group A1 (SH, SZ & US) in entire sampling period–7 Lags				
$r = 0$	38.6584	29.7971***	28.6190	21.1316***
$r \leq 1$	10.0394	15.4947	8.9954	14.2646
$r \leq 2$	1.0440	3.8415	1.0440	3.8415
Group A2 (SH, SZ & US) in pre-trade conflict subsampling period–9 Lags				
$r = 0$	45.9722	29.7971***	37.1763	21.1316***
$r \leq 1$	8.7960	15.4947	7.6789	14.2646
$r \leq 2$	1.1171	3.8415	1.1171	3.8415
Group A3 (SH, SZ & US) in post-trade conflict subsampling period–7 Lags				
$r = 0$	28.5525	29.7971	15.3713	21.1316
$r \leq 1$	13.1812	15.4947	8.6844	14.2646
$r \leq 2$	4.4968	3.8415	4.4968	3.8415
Group B1 (HK, IDN, JP, KR, MYS, SG, TH, TW & US) in entire sampling period–14 Lags				
$r = 0$	281.7734	197.3709***	73.5916	58.4335***
$r \leq 1$	208.1819	159.5297***	56.9529	52.3626**
$r \leq 2$	151.2289	125.6154***	45.2473	46.2314*
$r \leq 3$	105.9817	95.7537***	42.5572	40.0776*
$r \leq 4$	63.4245	69.8189	29.1406	33.8769
$r \leq 5$	34.2838	47.8561	13.6112	27.5843
$r \leq 6$	20.6726	29.7971	12.0210	21.1316
$r \leq 7$	8.65163	15.4947	8.5862	14.2646
$r \leq 8$	0.06547	3.8415	0.0655	3.8415
$r = 0$	281.7734	197.3709***	73.5916	58.4335***
$r \leq 1$	208.1819	159.5297***	56.9529	52.3626**
$r \leq 2$	151.2289	125.6154***	45.2473	46.2314*
$r \leq 3$	105.9817	95.7537***	42.5572	40.0776*
$r \leq 4$	63.4245	69.8189	29.1406	33.8769
$r \leq 5$	34.2838	47.8561	13.6112	27.5843
$r \leq 6$	20.6726	29.7971	12.0210	21.1316
$r \leq 7$	8.65163	15.4947	8.5862	14.2646
$r \leq 8$	0.06547	3.8415	0.0655	3.8415

Table 3. (*Continued*).

Hypothesized No. of CE(s)	Trace Test		Max-Eigenvalue Test	
	Trace Statistics	Critical value	Max-Eigen Statistic	Critical value
Group B2 (HK, IDN, JP, KR, MYS, SG, TH, TW & US) in pre-trade conflict subsampling period–12 Lags				
$r = 0$	1057.210	197.3709***	262.0503	58.4335***
$r \leq 1$	795.1596	159.5297***	201.1781	52.3626***
$r \leq 2$	593.9816	125.6154***	186.4094	46.2314***
$r \leq 3$	407.5721	95.7537***	119.9011	40.0776***
$r \leq 4$	287.6710	69.8189***	100.5785	33.8769***
$r \leq 5$	187.0925	47.8561***	81.6975	27.5843***
$r \leq 6$	105.3950	29.7971***	51.9656	21.1316***
$r \leq 7$	53.4295	15.4947***	29.6715	14.2646***
$r \leq 8$	23.7580	3.8415***	23.7580	3.8415***
Group B3 (HK, IDN, JP, KR, MYS, SG, TH, TW & US) in post-trade conflict subsampling period–6 Lags				
$r = 0$	273.1708	197.3709***	65.8259	58.4335***
$r \leq 1$	207.3449	159.5297***	53.0066	52.3626**
$r \leq 2$	154.3383	125.6154***	46.2944	46.2314**
$r \leq 3$	108.0439	95.7537***	35.7020	40.0776
$r \leq 4$	72.3419	69.8189**	27.3749	33.8769
$r \leq 5$	44.9670	47.8561	20.2395	27.5843
$r \leq 6$	24.7275	29.7971	16.9657	21.1316
$r \leq 7$	7.76190	15.4947	6.9439	14.2646
$r \leq 8$	0.8180	3.8415	0.8181	3.8415
Group C1 (HK, IDN, JP, KR, MYS, SG, TH, TW & SH, SZ) in entire sampling period–13 Lags				
$r = 0$	375.8243	239.2354***	113.8930	64.5047***
$r \leq 1$	261.9313	197.3709***	64.5910	58.4335**
$r \leq 2$	197.3403	159.5297***	53.6297	52.3626*
$r \leq 3$	143.7106	125.6154***	43.8372	46.2314
$r \leq 4$	99.8735	95.7537**	37.5111	40.0776
$r \leq 5$	62.3623	69.8189	21.1797	33.8769
$r \leq 6$	41.1826	47.8561	17.0753	27.5843
$r \leq 7$	24.1073	29.7971	14.6788	21.1316
$r \leq 8$	9.4285	15.4947	7.9217	14.2646
$r \leq 9$	1.5068	3.8415	1.5068	3.8415
Group C2 (HK, IDN, JP, KR, MYS, SG, TH, TW & SH, SZ) in pre-trade conflict subsampling period–12 Lags				
$r = 0$	852.4931	239.2354***	229.9827	64.5047***
$r \leq 1$	622.5103	197.3709***	145.6790	58.4335***
$r \leq 2$	476.8313	159.5297***	120.7097	52.3626***
$r \leq 3$	356.1216	125.6154***	91.6912	46.2314***
$r \leq 4$	264.4304	95.7537***	84.9124	40.0776***
$r \leq 5$	179.5181	69.818***	65.5383	33.8769***
$r \leq 6$	113.9798	47.8561***	46.4306	27.5843***
$r \leq 7$	67.5492	29.7971***	38.2685	21.1316***
$r \leq 8$	29.2807	15.4947***	24.7382	14.2646***
$r \leq 9$	4.5426	3.8415**	4.5426	3.8415**

Table 3. (*Continued*).

Hypothesized No. of CE(s)	Trace Test		Max-Eigenvalue Test	
	Trace Statistics	**Critical value**	**Max-Eigen Statistic**	**Critical value**
Group C3 (HK, IDN, JP, KR, MYS, SG, TH, TW & SH, SZ) in post-trade conflict subsampling period–12 Lags				
$r = 0$	1036.661	239.2354***	283.6328	64.5047***
$r \leq 1$	753.0287	197.3709***	213.6289	58.4335***
$r \leq 2$	539.3997	159.5297***	128.0107	52.3626***
$r \leq 3$	411.3890	125.6154***	105.3514	46.2314***
$r \leq 4$	306.0377	95.7537***	94.32776	40.0776***
$r \leq 5$	211.7099	69.8189***	67.4235	33.8769***
$r \leq 6$	144.2864	47.8561***	57.1032	27.5843***
$r \leq 7$	87.1832	29.7971***	42.5916	21.1316***
$r \leq 8$	44.5916	15.4947***	30.4413	14.2646***
$r \leq 9$	14.1504	3.8415***	14.1504	3.8415***

Note: * represents 0.1 significant, ** represents 0.05 significant, ***represents 0.01 significant.

4.1.3. Granger causality test results

From a biomechanical perspective, the stress-strain relationship describes a physical cause-and-effect dynamic, emphasizing the interactive influence of one variable on another. Drawing on this concept, the Granger causality test can be employed to analyze the "stress-strain" relationships between the stock markets of China, the United States, and other Asian economies.Then, we used the Granger causality tests to examine the interdependencies of the stock markets among China, U.S. and other eight Asia economies. As Granger causality results are also very sensitive to the number of lags chosen, this research tests the lag-length with 15 days as the maximum lag length and use the likelihood-ratio test in this part again to identify the number of lags in each period.

As a result, the number of lags in the Granger causality tests are 7, 7, 8 respectively for the entire period, pre-trade conflict period, and post-trade conflict period. The granger causality test results are stated in **Table 4**.

It can be found that in the entire sampling period, the change of return of U.S. stock market can impact most Asian Stock markets' returns, including the stock market in Hong Kong, Indonesia, Japan, South Korea, Malaysia, Singapore, Shanghai, and Taiwan at 0.05 significant value. But these impacts are not the same before and after the trade conflict. The Asian markets seems to be more independent with the U.S. stock market after the Sino-U.S. trade conflict. There is no causality among the returns of stock markets of Indonesia, Shanghai, Shenzhen, Thailand, and Taiwan and that of U.S. after the trade conflict.

Meanwhile, for the Chinese stock market, the results shows that almost all the stock markets in other Asian economies and in U.S. are independent with Chinese stock market both before and after the Sino-U.S. trade conflict, except the market of Hong Kong, which show causality with Shanghai stock market before the trade conflict.

The stock markets of other Asian economies show different trends of dependence with others. For example, the relationships between the stock market in Thailand and that of Singapore and Shenzhen are stronger after the Sino-U.S. trade conflict. But the relationship between the stock market of Indonesia and Thailand, Japan and Indonesia, Japan and Malaysia, Malaysia and Shenzhen become more independent after the Sino-U.S. trade conflict.

Table 4. The granger causality test results of the returns.

Null Hypothesis	Entire period	Pre-trade conflict	Post-trade conflict
	***F*-value**	***F*-value**	***F*-value**
The U.S. Stock Market and other 10 Asian Stock Markets			
US ↛ HK	4.00516***	5.03684***	2.22393**
US ↛ IDN	3.29259***	4.04115***	0.99412
US ↛ JP	5.21601***	2.38421**	4.61926***
US ↛ KR	4.10736***	4.71805***	2.49238**
US ↛ MYS	4.51620***	2.12118**	2.69436**
US ↛ SG	5.02768***	2.55543**	2.54583**
US ↛ SH	2.53361**	1.90068*	1.95212*
US ↛ SZ	1.76335*	1.97064*	1.47025
US ↛ TH	1.44171	0.43063	1.96228*
US ↛ TW	4.29448***	3.82811***	1.59568
The SH Stock Market and other 10 Stock Markets			
SH ↛ HK	2.03426*	2.26704**	1.05904
SH ↛ IDN	1.28126	0.93545	0.68305
SH ↛ JP	0.90548	1.62170	0.67134
SH ↛ KR	0.99607	1.34491	0.57687
SH ↛ MYS	1.22762	2.05764*	0.71505
SH ↛ SG	1.96121	1.12267	1.21472
SH ↛ SZ	1.34366	1.61741	0.65335
SH ↛ TH	0.51549	1.72428	0.91301
SH ↛ TW	1.35796	0.92111	1.49038
SH ↛ US	1.21935	1.38194	0.29120
The SZ Stock Market and other 10 Stock Markets			
SZ ↛ HK	1.27512	1.16334	0.64854
SZ ↛ IDN	1.17885	0.74871	0.66978
SZ ↛ JP	0.62585	1.09755	0.64000
SZ ↛ KR	0.67763	1.11504	0.42389
SZ ↛ MYS	1.41164	1.24885	0.78044
SZ ↛ SG	1.67575	1.11102	1.11569
SZ ↛ SH	0.98332	0.30257	0.73207
SZ ↛ TH	0.97519	0.58108	0.98100
SZ ↛ TW	1.50210	0.67932	1.17700
SZ ↛ US	1.43253	1.04491	0.37477

Table 4. (*Continued*).

Null Hypothesis	Entire period	Pre-trade conflict	Post-trade conflict
	***F*-value**	***F*-value**	***F*-value**
The HK Stock Market and other 10 Stock Markets			
HK ↛ IDN	0.6635	0.83445	1.41190
HK ↛ JP	0.51607	1.27598	0.43065
HK ↛ KR	0.68811	0.47818	0.66196
HK ↛ MYS	1.20256	0.68902	1.30700
HK ↛ SG	1.14029	0.54616	0.74363
HK ↛ SH	0.83560	1.32749	1.00180
HK ↛ SZ	1.03110	1.60557	1.19664
HK ↛ TH	0.31313	1.04783	1.50486
HK ↛ TW	0.89516	0.46072	0.51352
HK ↛ US	1.21906	0.54368	0.65586
The IDN Stock Market and other 10 Stock Markets			
IDN ↛ HK	1.3862	1.13099	1.28959
IDN ↛ JP	1.03524	1.77752	0.62717
IDN ↛ KR	1.05845	0.57333	1.21534
IDN ↛ MYS	2.79778***	1.12717	2.03451**
IDN ↛ SG	1.07889	1.46083	0.86189
IDN ↛ SH	0.87298	1.69687	0.73154
IDN ↛ SZ	1.03871	0.48743	0.87952
IDN ↛ TH	1.82949*	2.69755**	0.99704
IDN ↛ TW	1.86376*	0.81028	1.85502*
IDN ↛ US	0.31032	1.18813	0.21130
The JP Stock Market and other 10 Stock Markets			
JP ↛ HK	2.77746***	1.26002	1.54226
JP ↛ IDN	1.33402	3.32532***	0.43965
JP ↛ KR	1.39959	1.63797	0.74256
JP ↛ MYS	0.54573	2.66113**	1.14830
JP ↛ SG	1.64295	1.66684	1.24099
JP ↛ SH	0.99572	1.31418	0.74888
JP ↛ SZ	0.93005	0.65209	0.84735
JP ↛ TH	0.42255	1.25766	1.90252*
JP ↛ TW	0.60858	2.03896*	0.46154
JP ↛ US	2.09554**	1.17186	3.13561***

Table 4. (*Continued*).

Null Hypothesis	Entire period	Pre-trade conflict	Post-trade conflict
	***F*-value**	***F*-value**	***F*-value**
The KR Stock Market and other 10 Stock Markets			
KR ↛ HK	1.34263	0.29863	1.02507
KR ↛ IDN	1.92608*	1.47507	1.11481
KR ↛ JP	1.50304	1.38569	1.29560
KR ↛ MYS	1.08807	1.45865	1.33689
KR ↛ SG	2.16991**	0.96973	0.91919
KR ↛ SH	1.30124	1.92121*	0.80490
KR ↛ SZ	1.08609	1.37480	0.96862
KR ↛ TH	0.42661	1.67830	1.41144
KR ↛ TW	1.02517	1.07625	0.66283
KR ↛ US	1.87633*	0.26089	1.40627
The MYS Stock Market and other 10 Stock Markets			
MYS ↛ HK	1.27866	0.24595	1.17228
MYS ↛ IDN	0.71954	0.36826	1.28127
MYS ↛ JP	1.11334	2.04185*	0.32111
MYS ↛ KR	1.24862	0.59474	0.65983
MYS ↛ SG	1.20218	0.59426	0.96783
MYS ↛ SH	0.80775	2.38839**	0.88309
MYS ↛ SZ	1.01358	1.65555	1.33621
MYS ↛ TH	1.80502*	0.29085	1.97409*
MYS ↛ TW	1.16100	1.20040	0.74663
MYS ↛ US	0.24799	0.57556	0.34645
The SG Stock Market and other 10 Stock Markets			
SG ↛ HK	0.76324	0.95024	0.60404
SG ↛ IDN	1.31951	0.61389	1.45128
SG ↛ JP	1.22763	0.72633	1.29821
SG ↛ KR	1.46064	0.30409	1.99598*
SG ↛ MYS	1.05242	0.48498	1.85686*
SG ↛ SH	0.63490	0.67889	0.55656
SG ↛ SZ	0.72342	0.85733	0.74324
SG ↛ TH	1.20549	1.15249	1.79325*
SG ↛ TW	0.37059	1.00739	0.69029
SG ↛ US	1.33222	0.26084	0.82141

Table 4. (*Continued*).

Null Hypothesis	Entire period	Pre-trade conflict	Post-trade conflict
	***F*-value**	***F*-value**	***F*-value**
The TH Stock Market and other 10 Stock Markets			
TH ↛ HK	1.57664	1.78619	1.46038
TH ↛ IDN	0.79954	0.30912	0.66014
TH ↛ JP	0.79661	1.19419	1.81029*
TH ↛ KR	0.92527	1.61216	1.11092
TH ↛ MYS	1.04153	0.59675	1.01928
TH ↛ SG	1.94673*	0.87300	2.37062**
TH ↛ SH	1.89184	0.91900	1.89266*
TH ↛ SZ	2.37269**	1.99745*	2.19978**
TH ↛ TW	1.21996	0.76321	1.68808
TH ↛ US	0.33659	1.27487	0.64190
The TW Stock Market and other 10 Stock Markets			
TW ↛ HK	2.11326**	1.00024	0.88846
TW ↛ IDN	0.85321	1.46125	0.60561
TW ↛ JP	1.09376	0.94904	1.02689
TW ↛ KR	1.17707	1.13185	1.36526
TW ↛ MYS	1.46387	2.65469**	0.93636
TW ↛ SG	1.72713	1.31042	0.61376
TW ↛ SH	1.19787	1.32743	1.10919
TW ↛ SZ	1.24839	0.59904	1.49912
TW ↛ TH	0.95675	0.84068	1.26180
TW ↛ US	2.04382*	1.23850	1.86987*

Note: * represents 0.1 significant, ** represents 0.05 significant, *** represents 0.01 significant.

4.1.4. Impulse Response Analysis

Impulse response function can be used to analysis the reaction of variables to the shock, similar to biomechanics, where the state of a biological tissue responds to a force applied to it. In this section, we implement generalized impulse response analyse for different periods, including the entire sampling period, the pre-trade conflict period, and the post-trade conflict period.

As the unit root test results indicated that the return series are integrated of order one and given that no co-integrating relationship exists among the various stock market indices in the different subperiods, the VAR model can be directly employed on the return series. We investigate the impact of a one-unit shock rather than a one standard deviation shock, to account for the changing volatility of stock over time. The results of generalized impulse response analysis during 30 days after an innovation are stated as following figures. It can be found that when a shock given to the stock market, it will bring a impact with fluctuation in the first 15 periods for all the stock markets researched in this study. The positive or negative impact are occurred which will bring to an increase or decrease of the return.

4.2. The test of hypothesis 2

Due to there is no available daily trade data can be used currently, it is hard to test the consistent of the co-movement of the trade volume or that of the export amount with the co-movement of the stock market. The research for the drivers need to be followed up in future study. The Hong Kong Stock Market for entire sampling period is shown in **Figure 1**. The Indonesia Stock Market for entire sampling period is shown in **Figure 2**. The Japan Stock Market for entire sampling period is shown in **Figure 3**. The South Korea Stock Market for entire sampling period is shown in **Figure 4**. The Malaysia Stock Market for entire sampling period is shown in **Figure 5**. The Singapore Stock Market for entire sampling period is shown in **Figure 6**. The Shanghai Stock Market for entire sampling period is shown in **Figure 7**. The Shenzhen Stock Market for entire sampling period is shown in **Figure 8**. The Thailand Stock Market for entire sampling period is shown in **Figure 9**. The Taiwan Stock Market for entire sampling period is shown in **Figure 10**. The U.S. Stock Market for entire sampling period is shown in **Figure 11**.

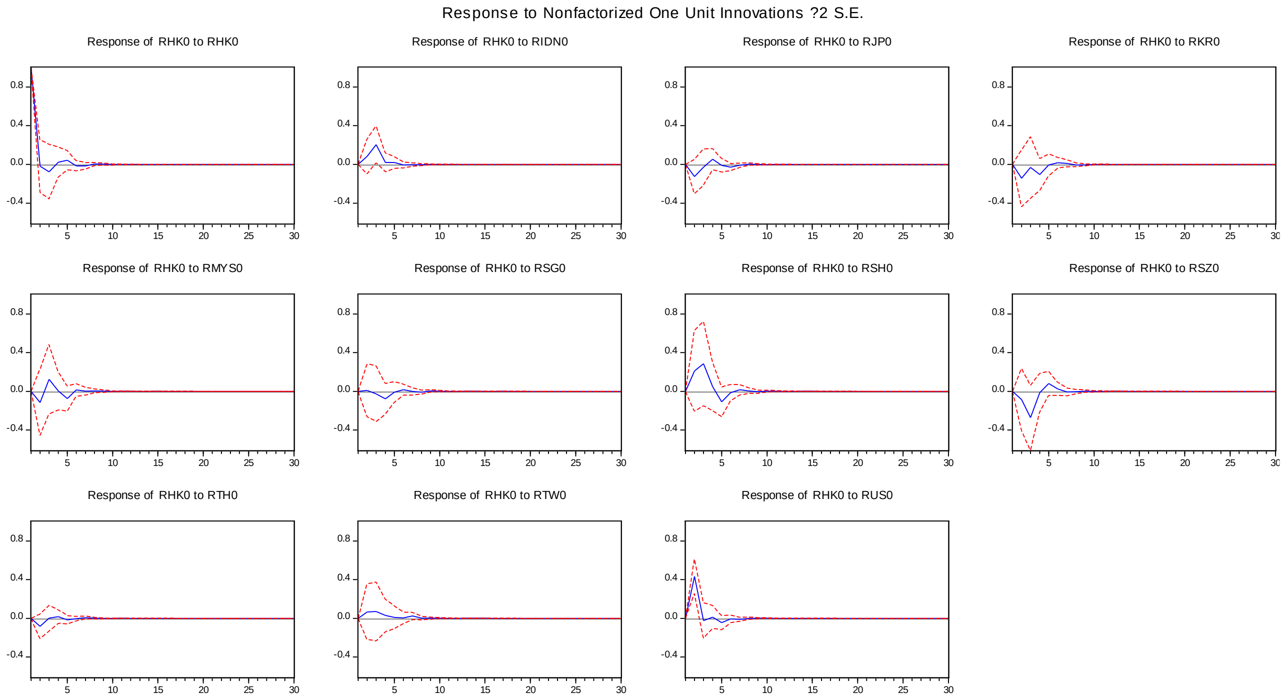

Figure 1. The Hong Kong Stock Market for entire sampling period.

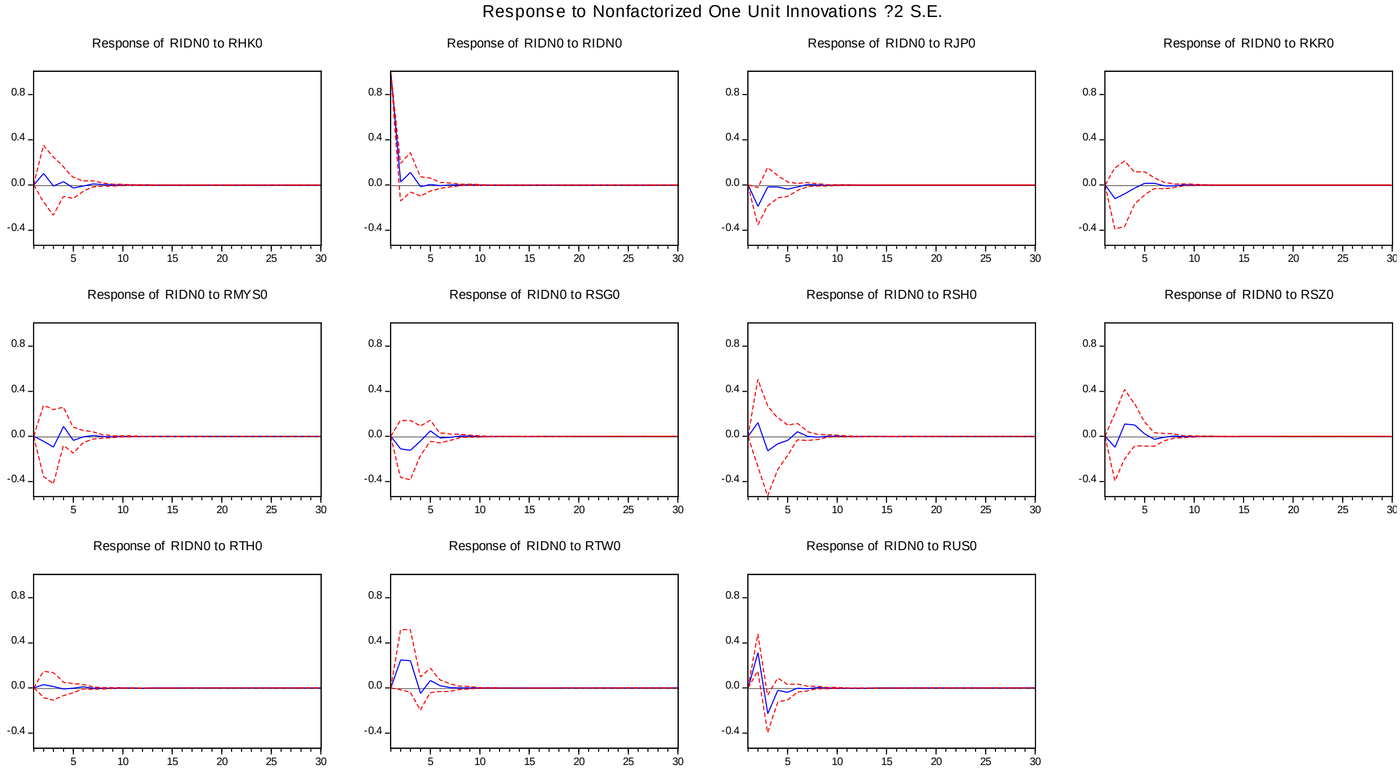

Figure 2. The Indonesia Stock Market for entire sampling period.

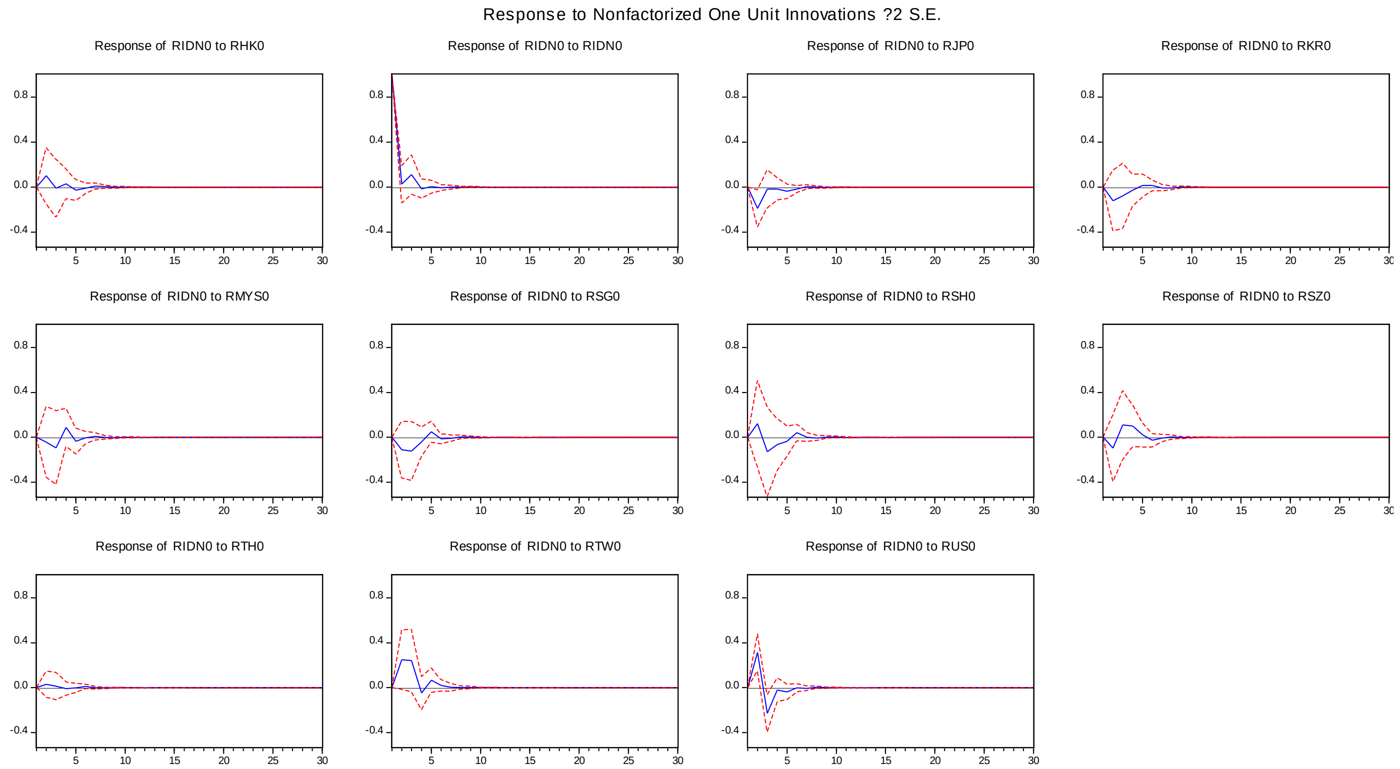

Figure 3. The Japan Stock Market for entire sampling period.

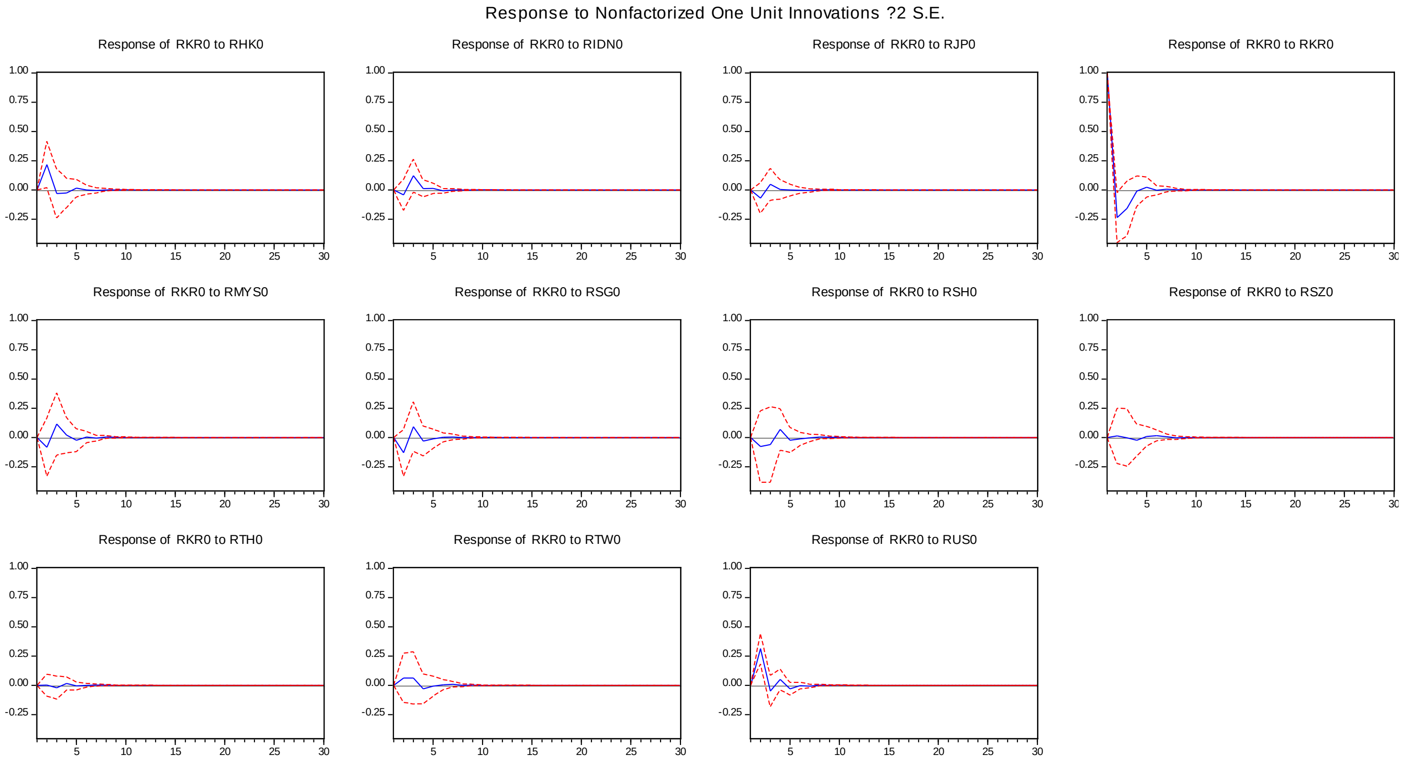

Figure 4. The South Korea Stock Market for entire sampling period.

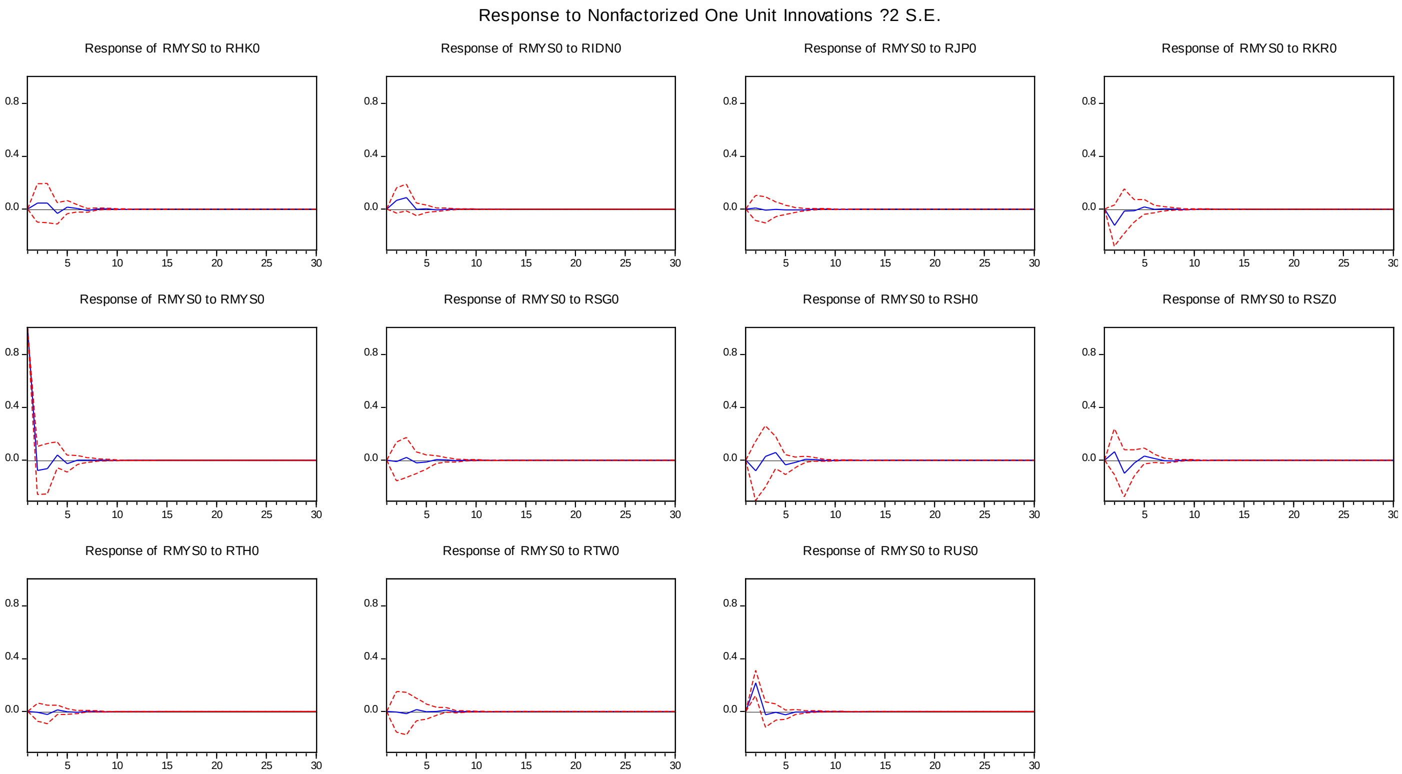

Figure 5. The Malaysia Stock Market for entire sampling period.

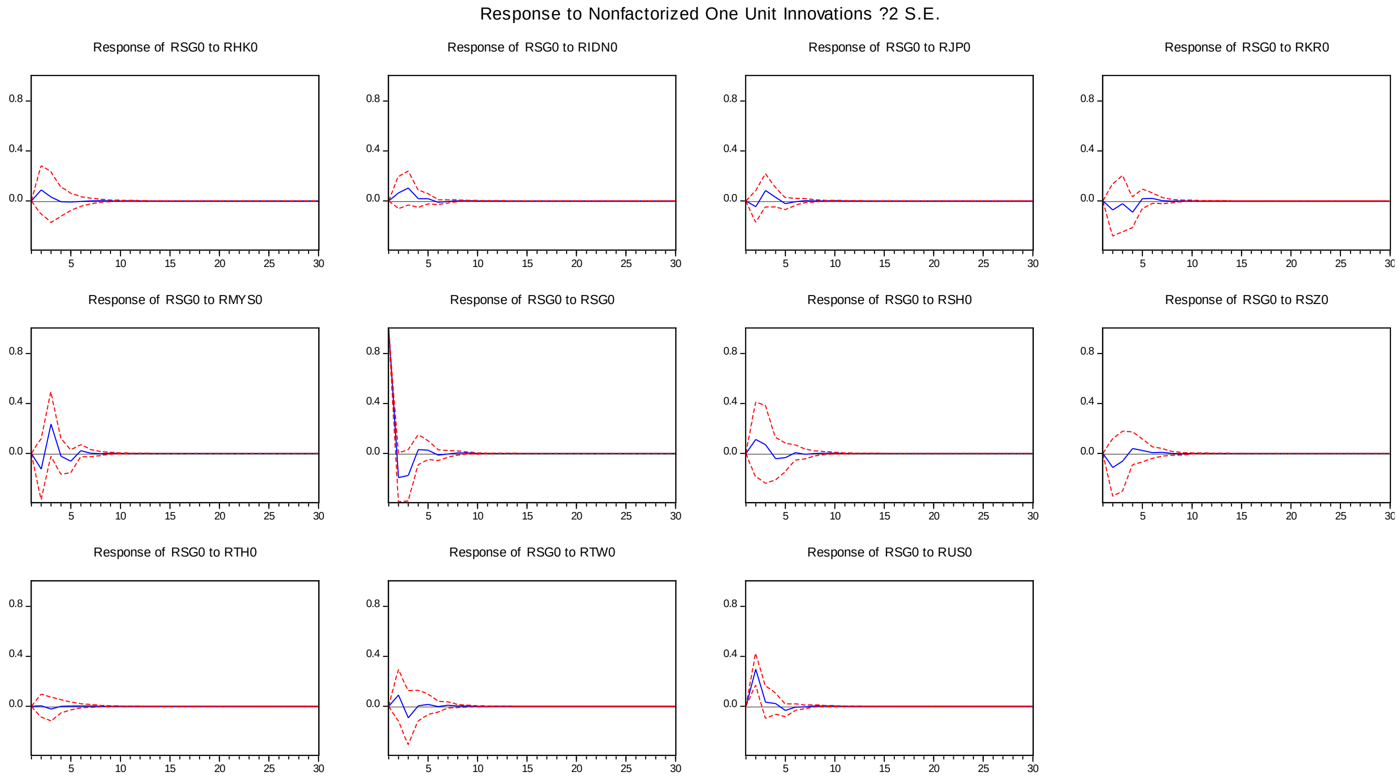

Figure 6. The Singapore Stock Market for entire sampling period.

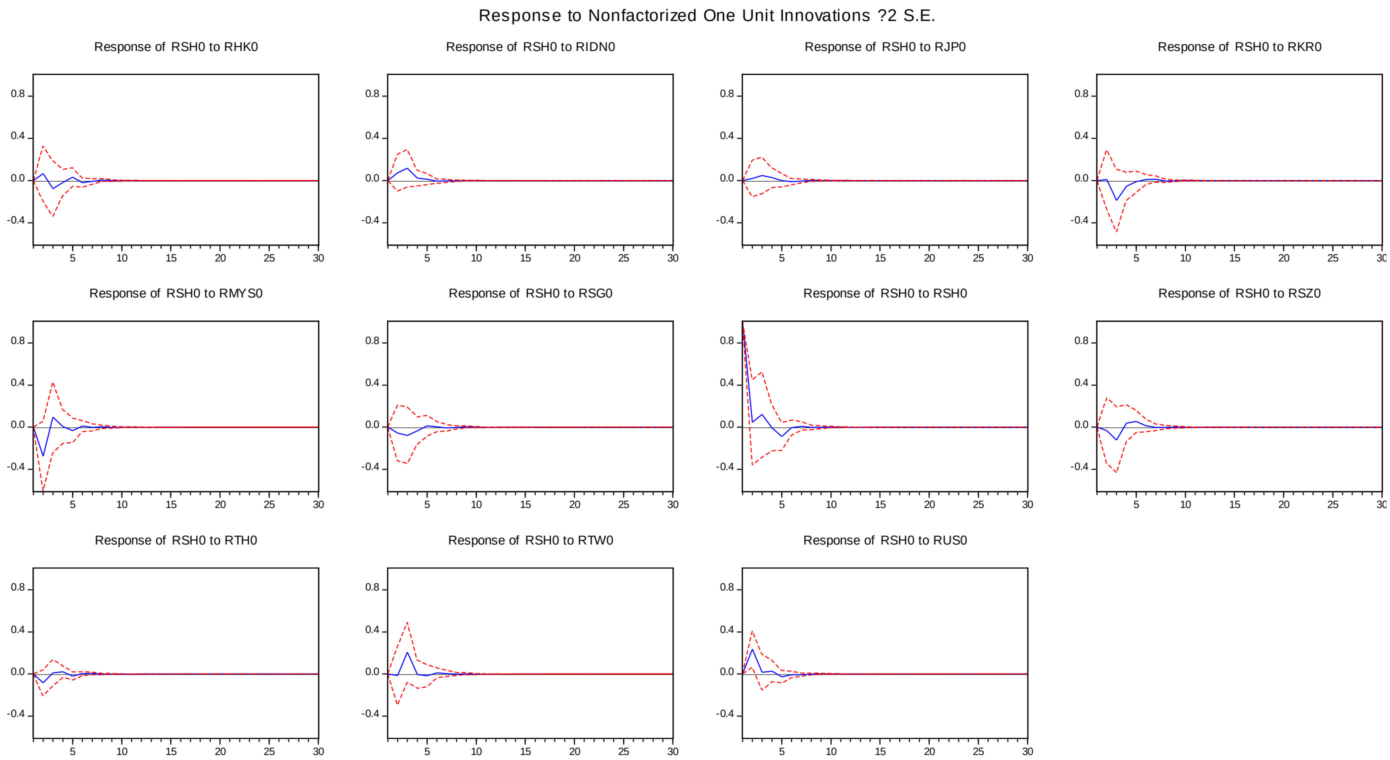

Figure 7. The Shanghai Stock Market for entire sampling period.

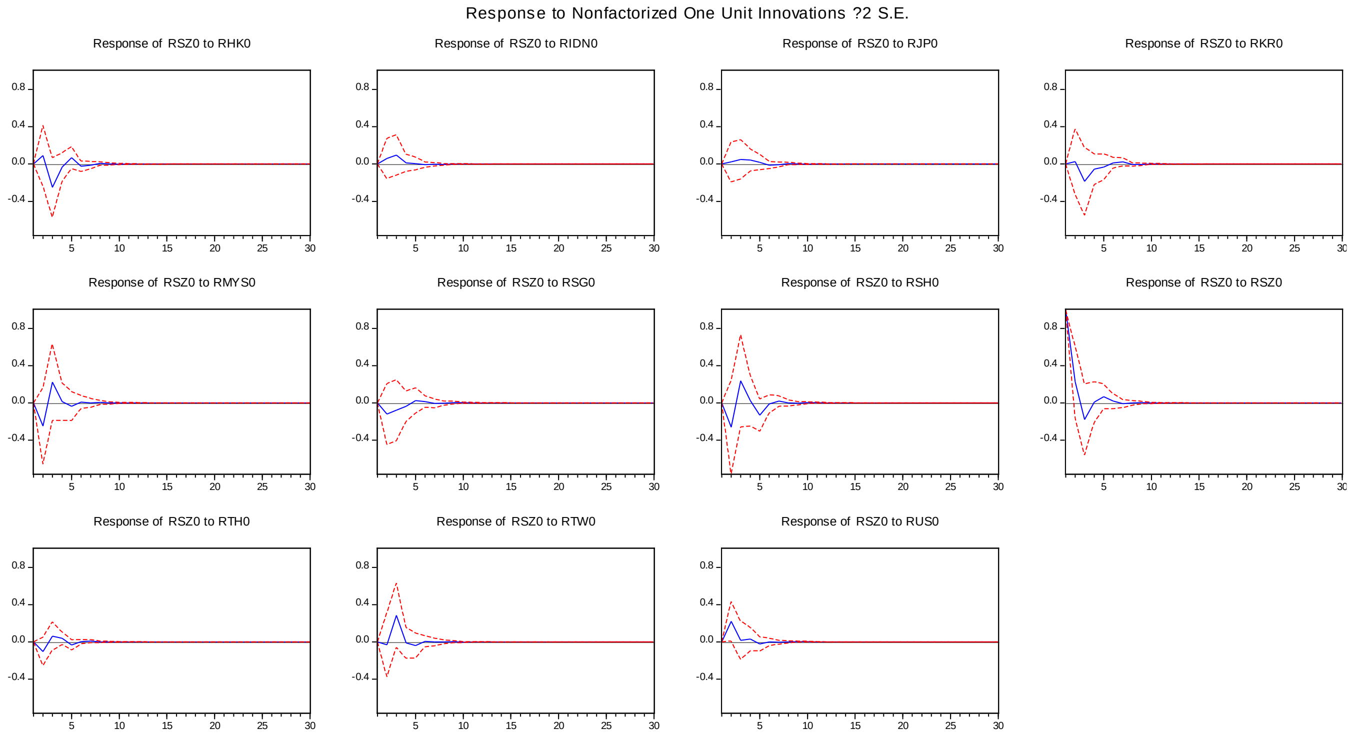

Figure 8. The Shenzhen Stock Market for entire sampling period.

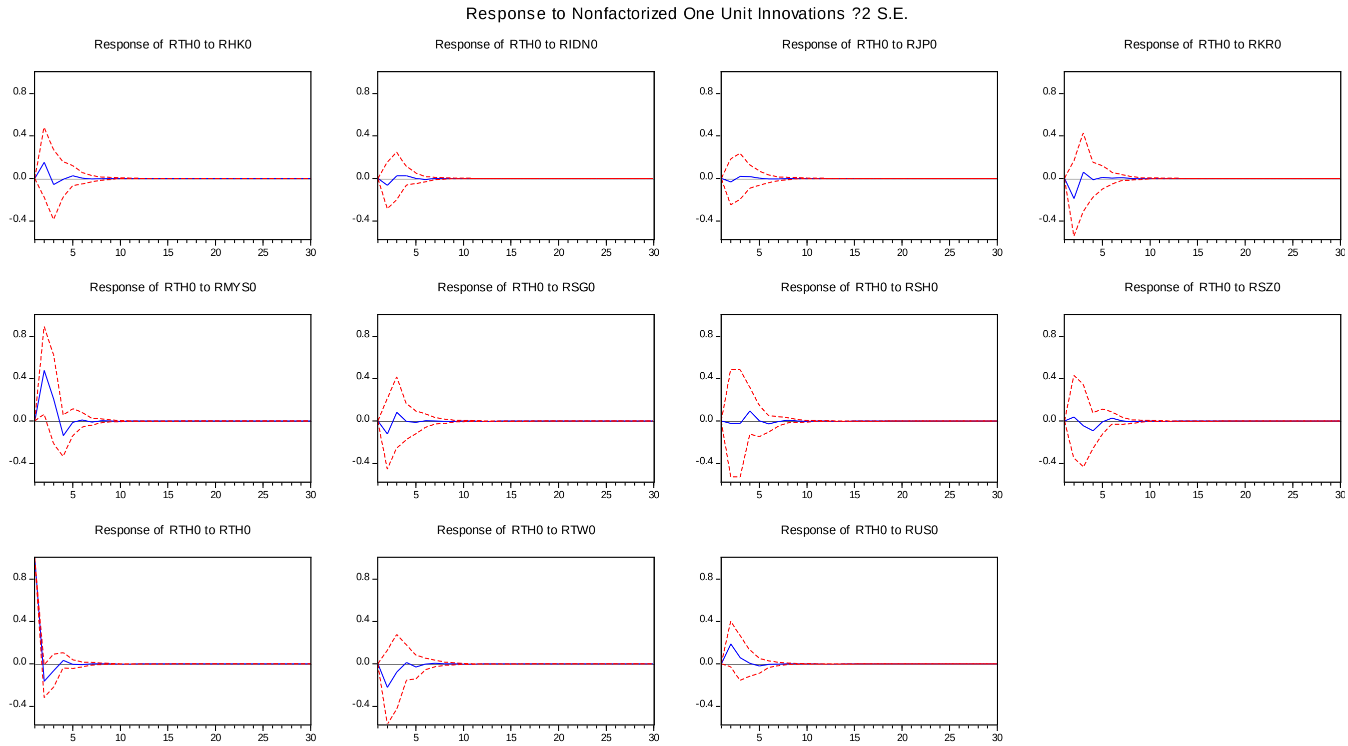

Figure 9. The Thailand Stock Market for entire sampling period.

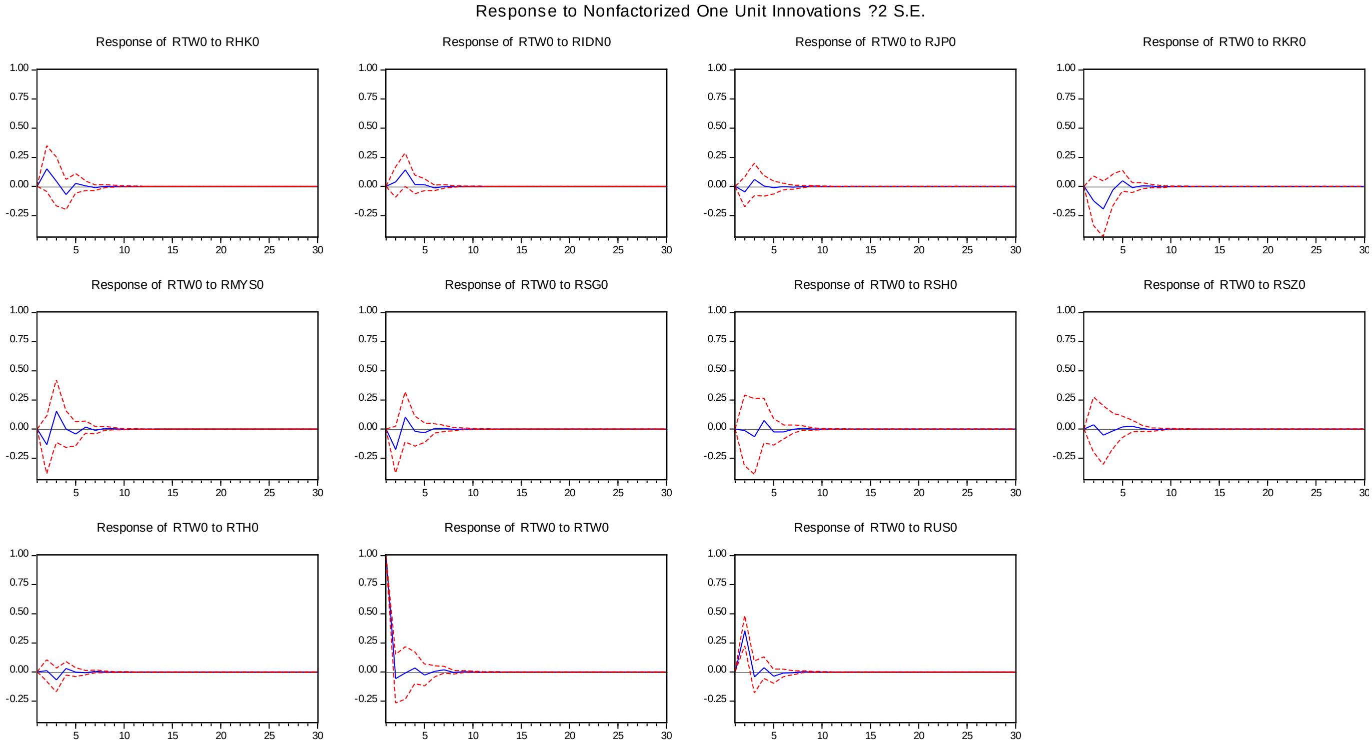

Figure 10. The Taiwan Stock Market for entire sampling period.

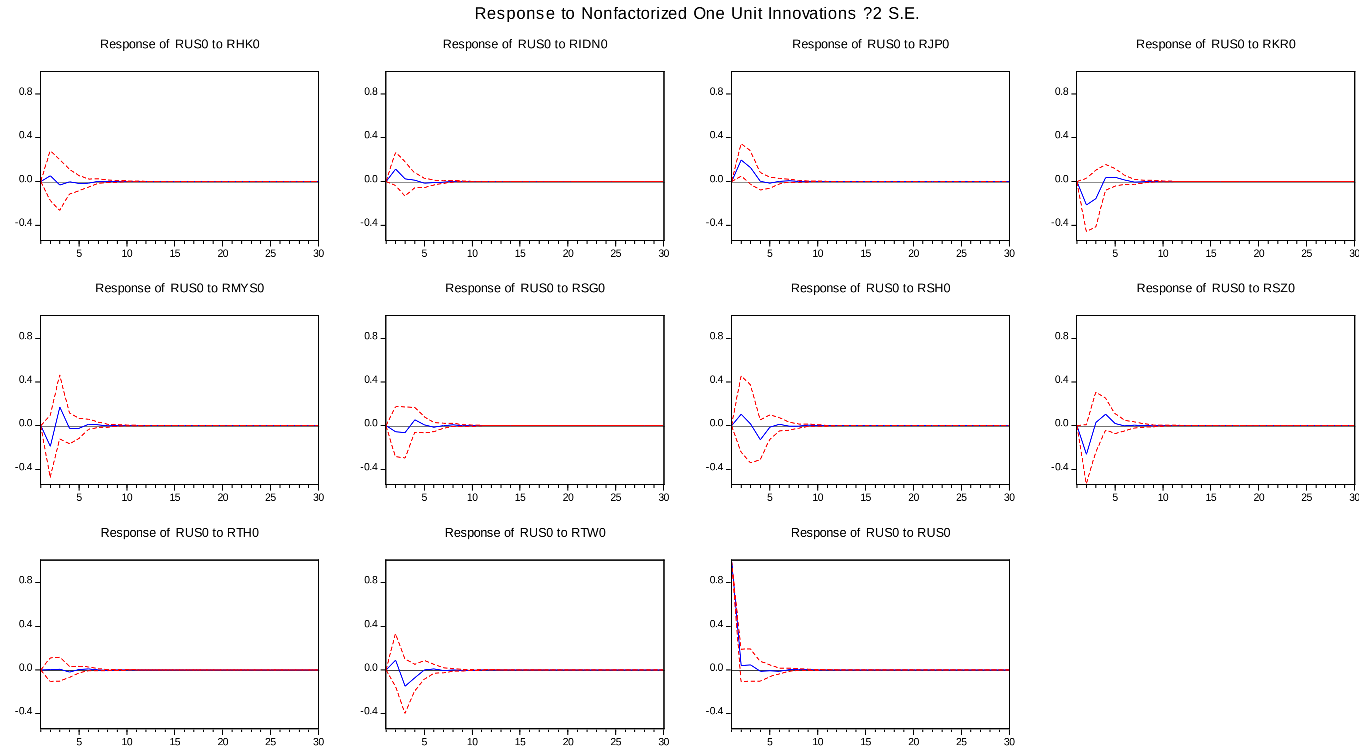

Figure 11. The U.S. Stock Market for entire sampling period.

The Hong Kong Stock Market for pre-trade conflict subsampling period is shown in **Figure 12**. The Indonesia Stock Market for pre-trade conflict subsampling period is shown in **Figure 13**. The Japan Stock Market for pre-trade conflict subsampling period is shown in **Figure 14**. The South Korea Stock Market for pre-trade conflict subsampling period is shown in **Figure 15**. The Malaysia Stock Market for pre-trade conflict subsampling period is shown in **Figure 16**. The Singapore Stock Market for pre-trade conflict subsampling period is shown in **Figure 17**. The Shanghai Stock Market for pre-trade conflict subsampling period is shown in **Figure 18**. The Shenzhen Stock Market for pre-trade conflict subsampling period is shown in **Figure 19**. The Thailand Stock Market for pre-trade conflict subsampling period is shown in **Figure 20**. The Taiwan Stock Market for pre-trade conflict subsampling period is shown in **Figure 21**. The U.S. Stock Market for pre-trade conflict subsampling period is shown in **Figure 22**.

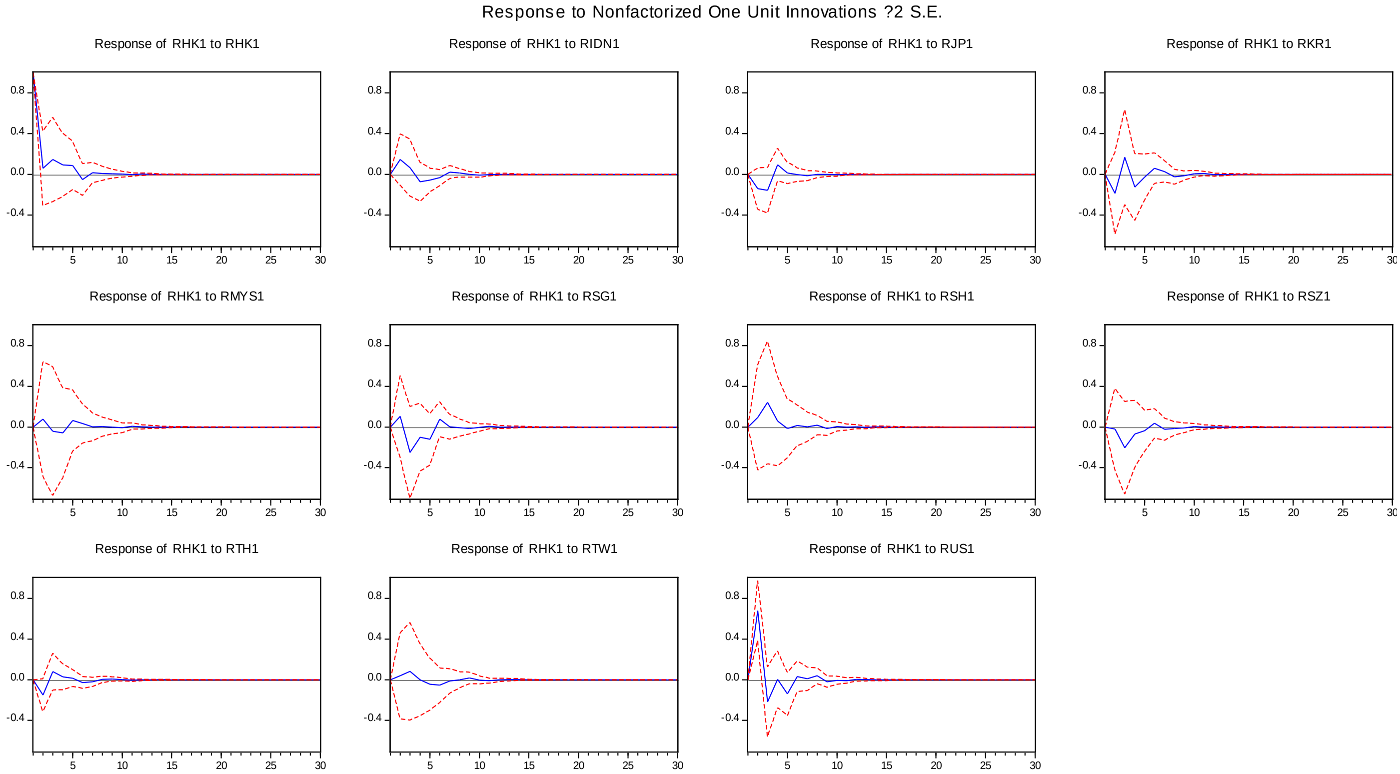

Figure 12. The Hong Kong Stock Market for pre-trade conflict subsampling period.

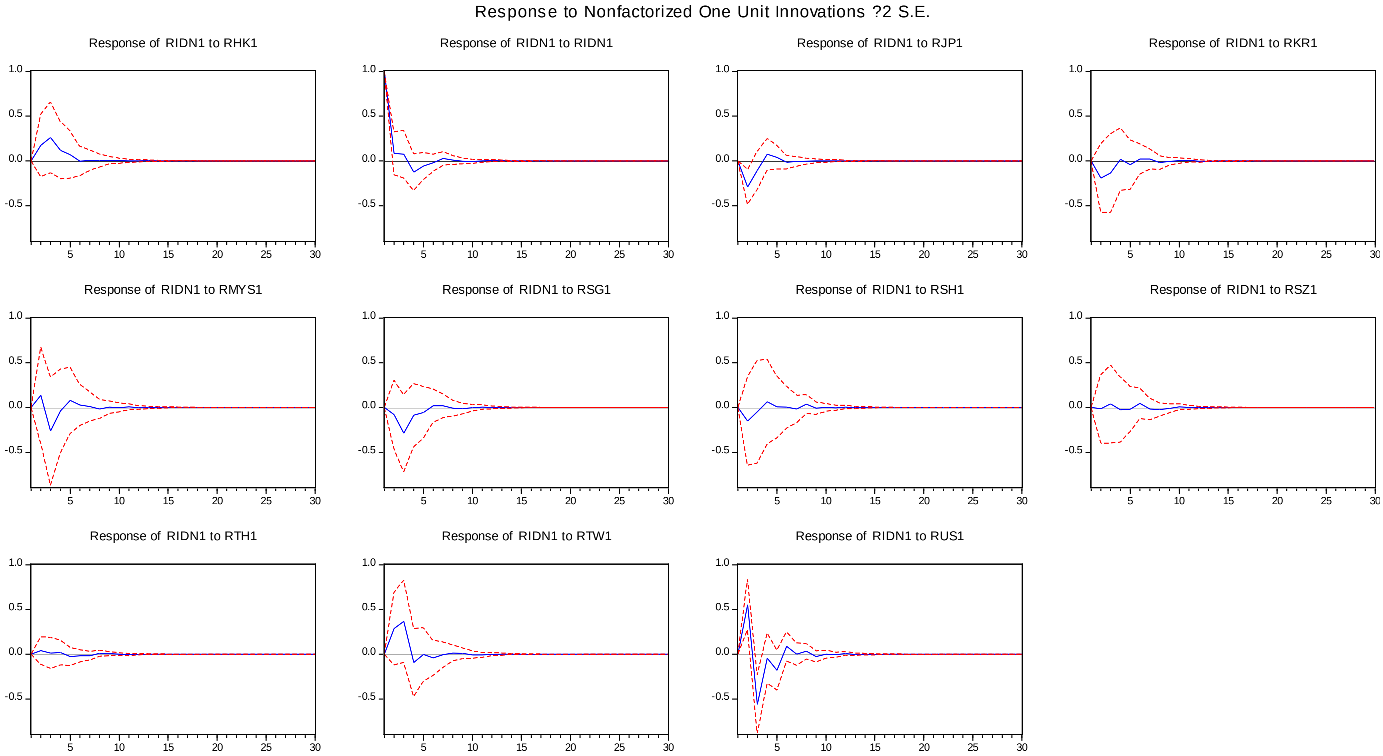

Figure 13. The Indonesia Stock Market for pre-trade conflict subsampling period.

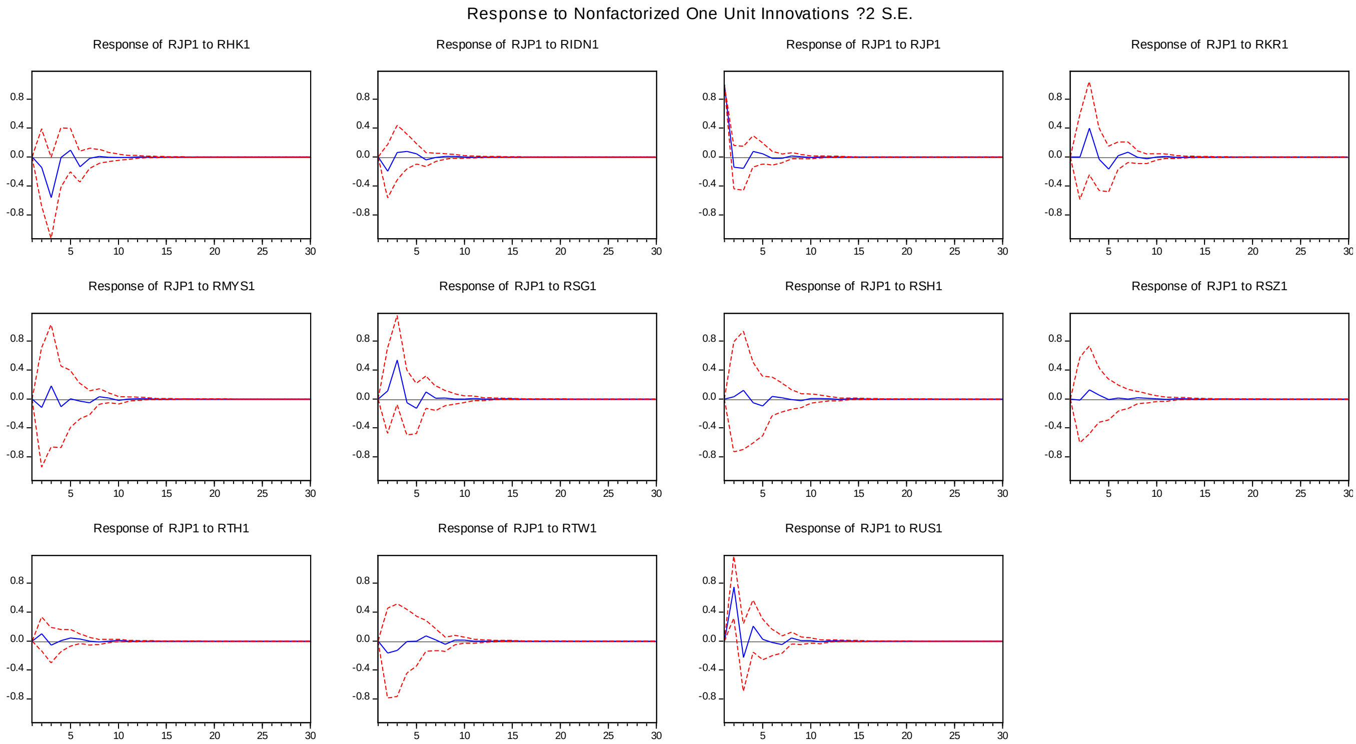

Figure 14. The Japan Stock Market for pre-trade conflict subsampling period.

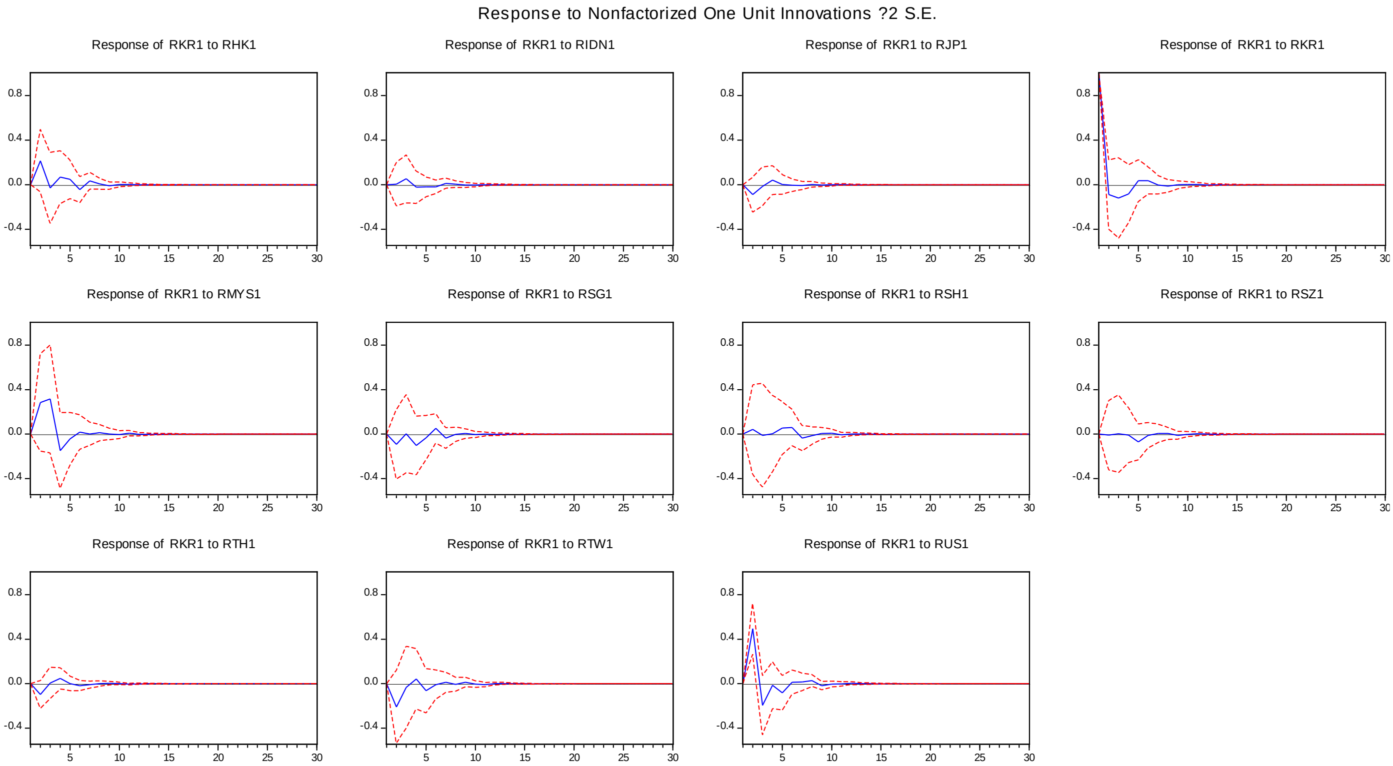

Figure 15. The South Korea Stock Market for pre-trade conflict subsampling period.

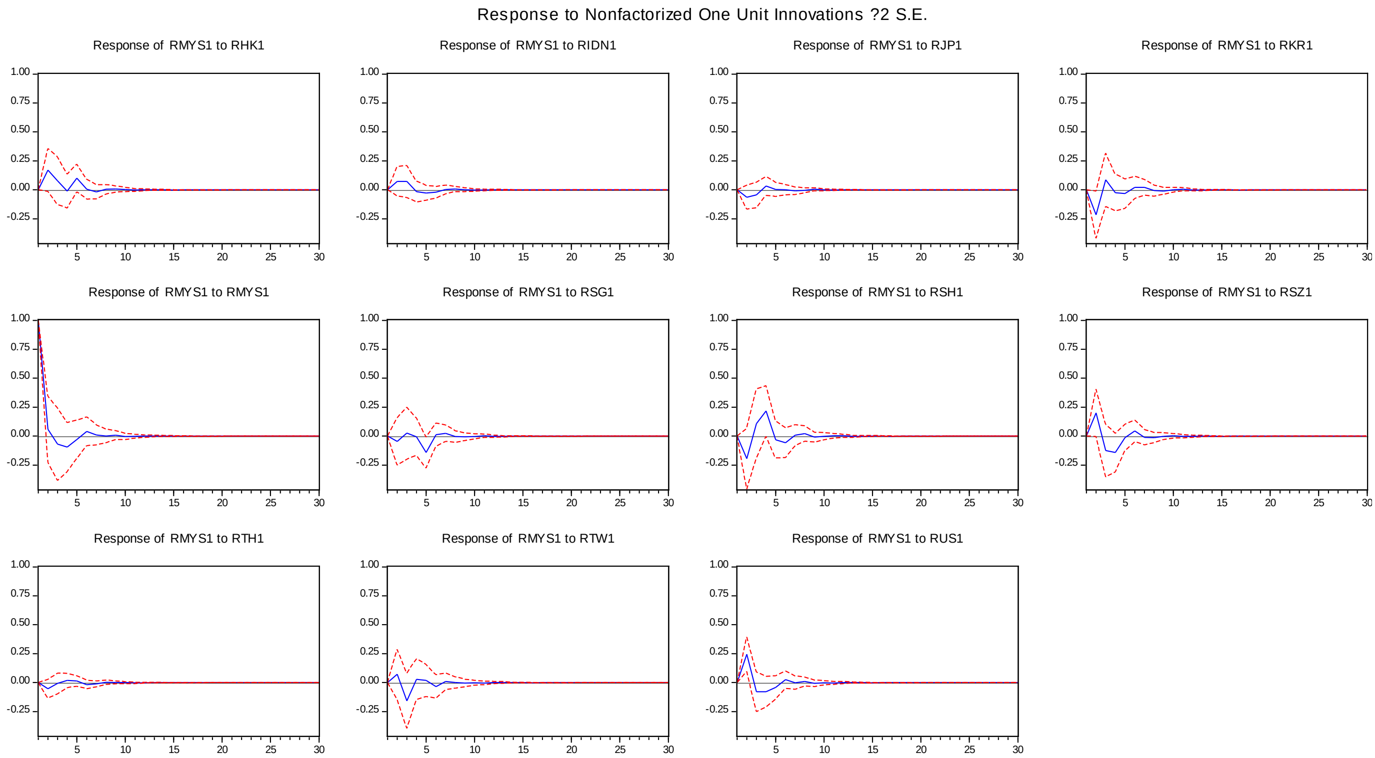

Figure 16. The Malaysia Stock Market for pre-trade conflict subsampling period.

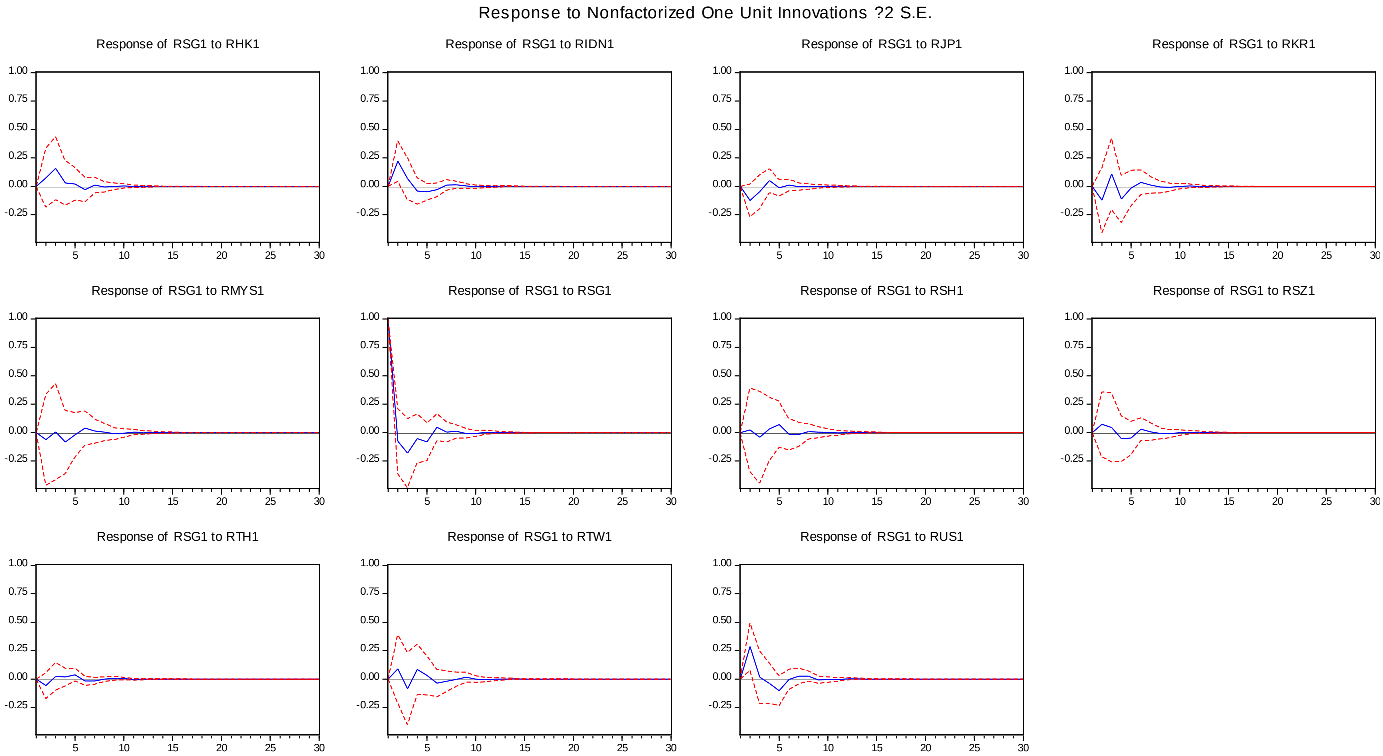

Figure 17. The Singapore Stock Market for pre-trade conflict subsampling period.

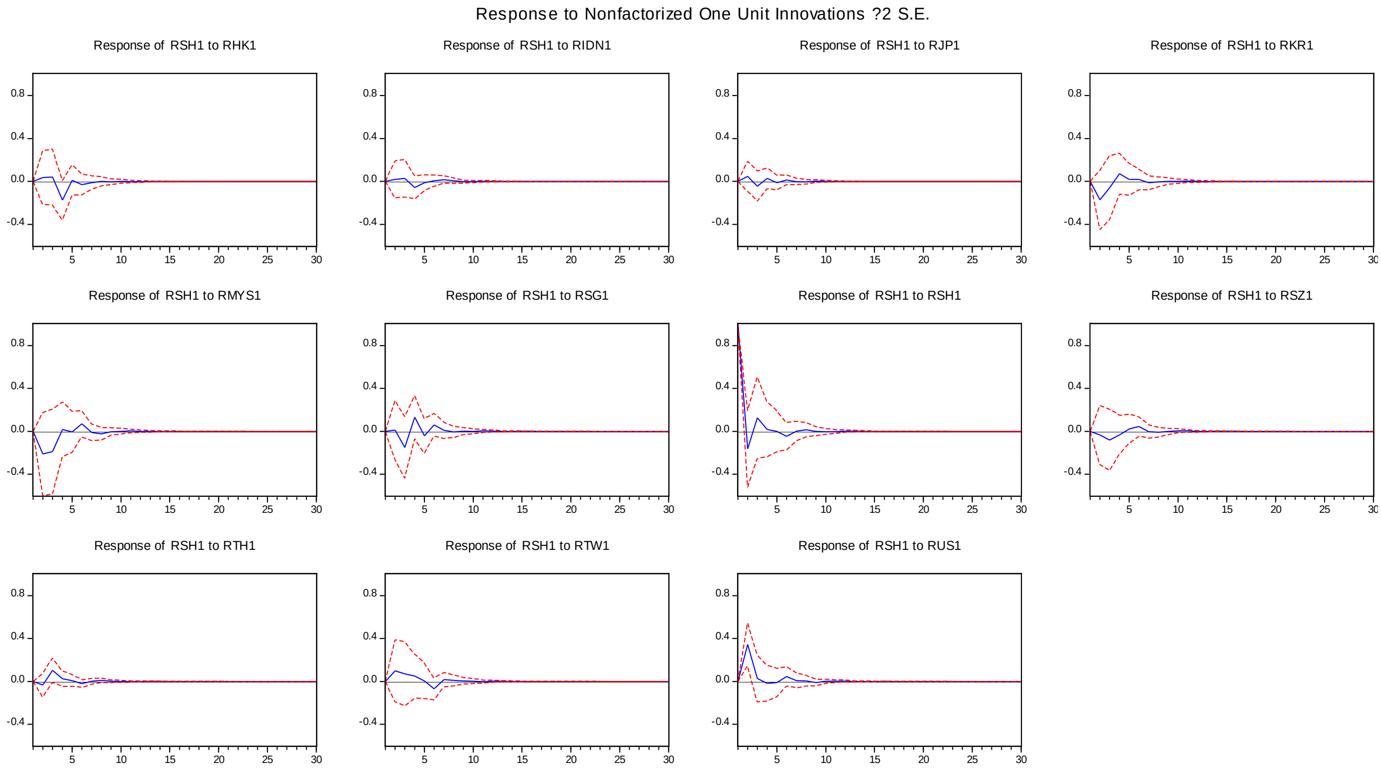

Figure 18. The Shanghai Stock Market for pre-trade conflict subsampling period.

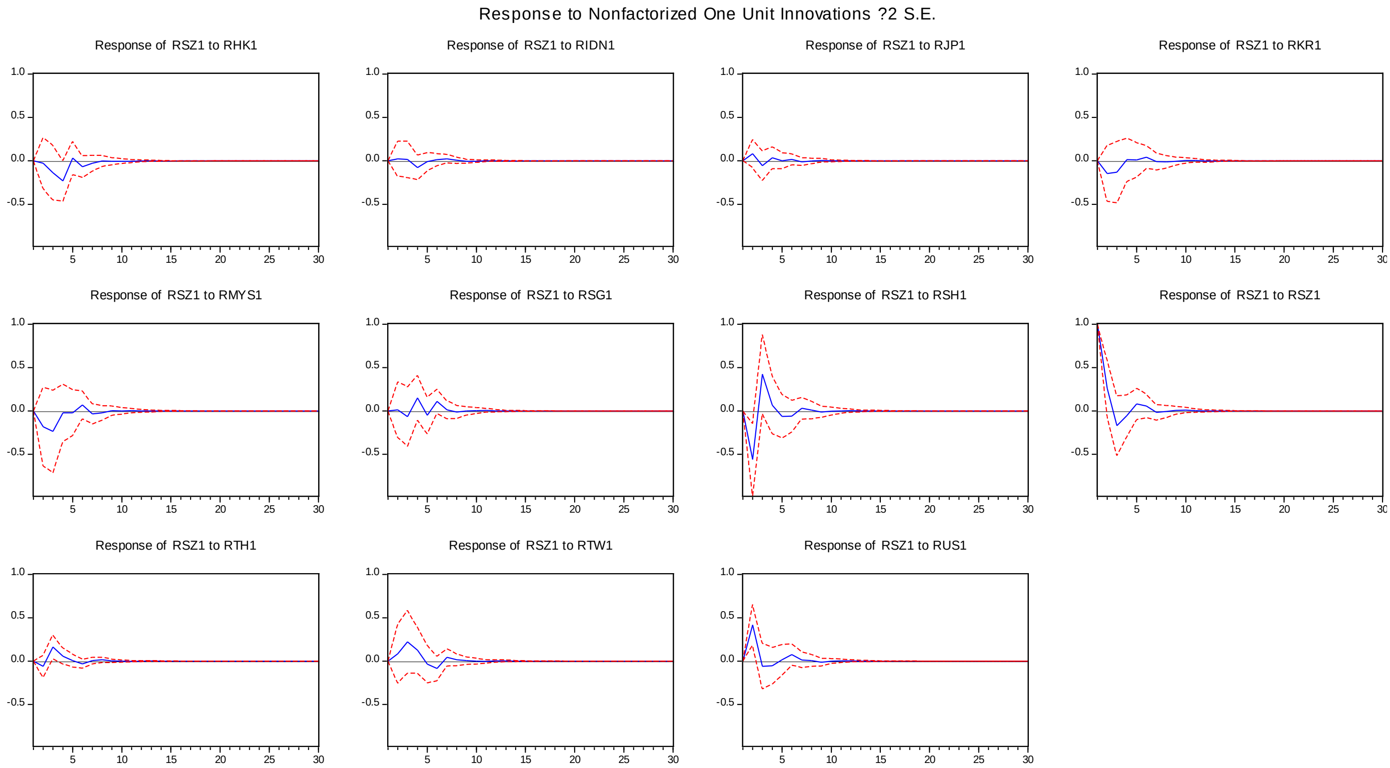

Figure 19. The Shenzhen Stock Market for pre-trade conflict subsampling period.

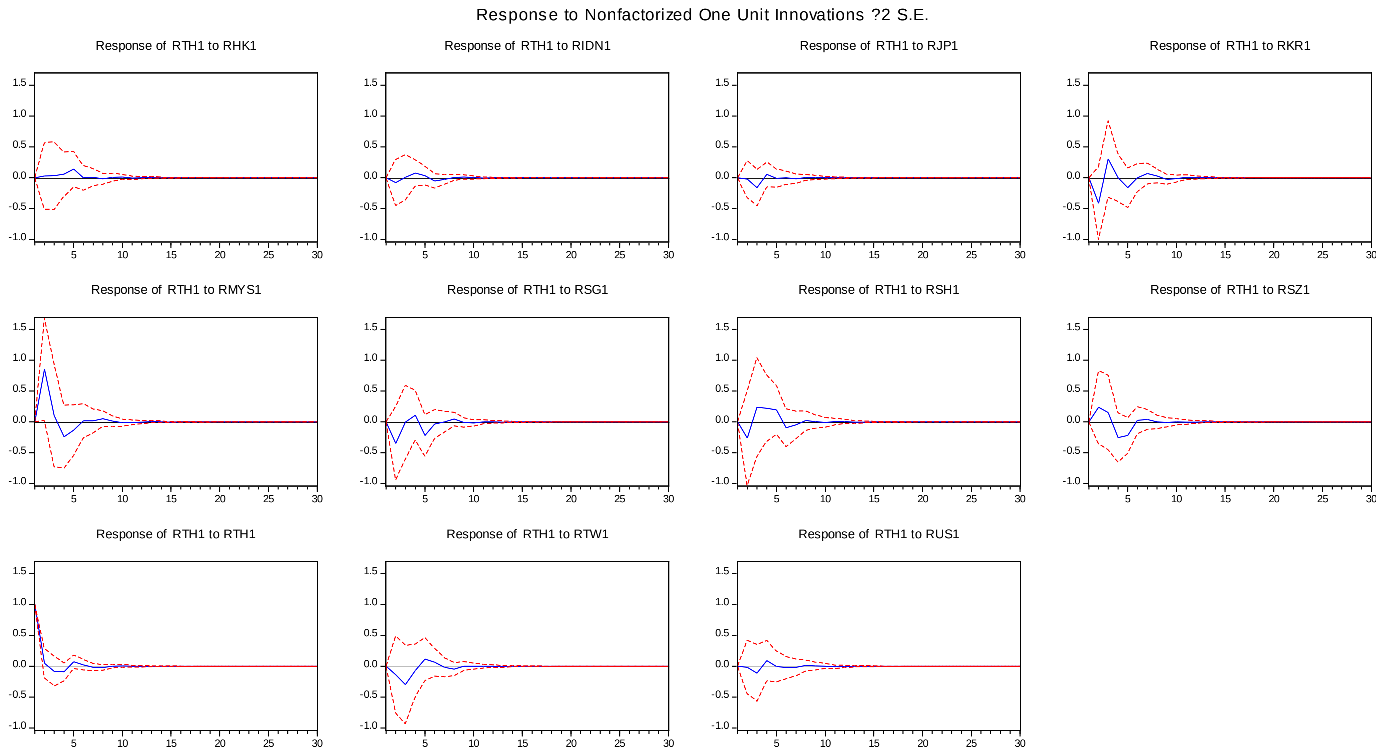

Figure 20. The Thailand Stock Market for pre-trade conflict subsampling period.

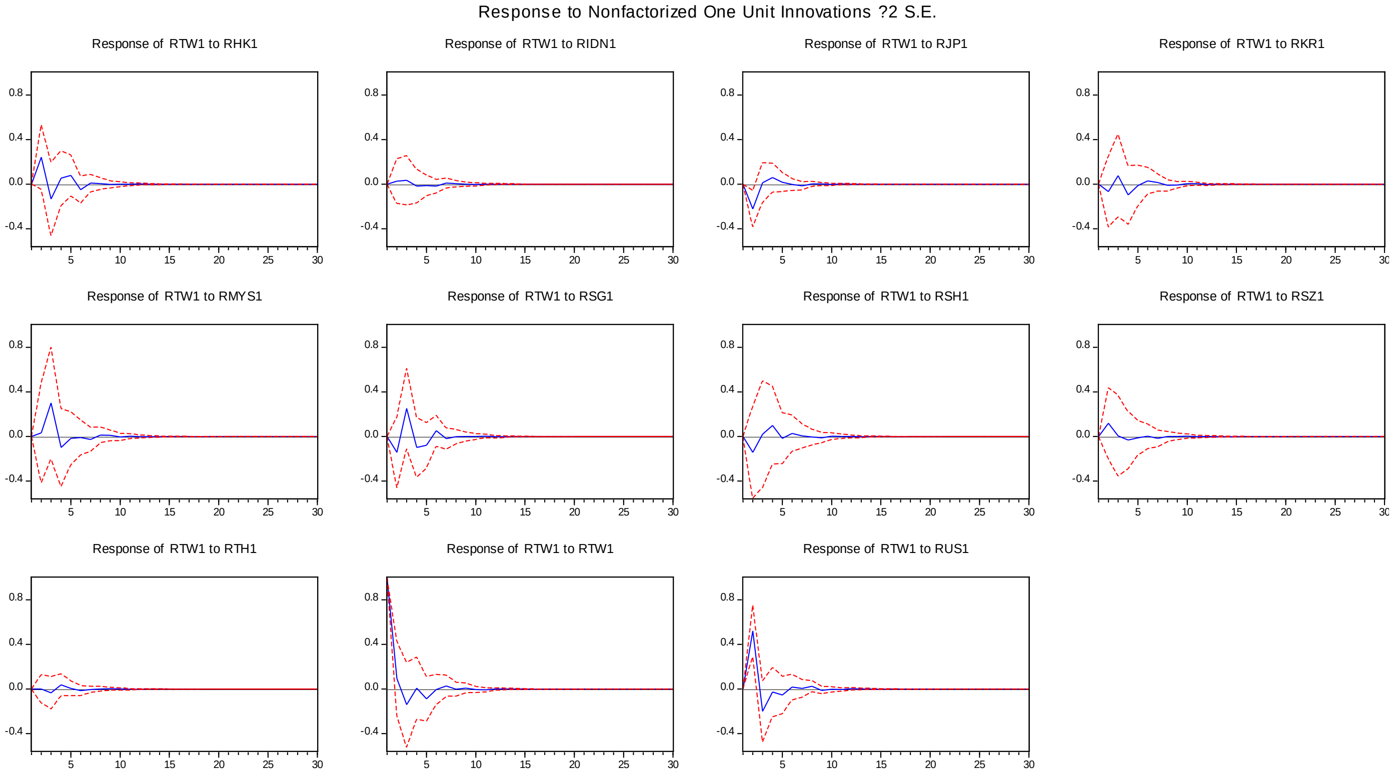

Figure 21. The Taiwan Stock Market for pre-trade conflict subsampling period.

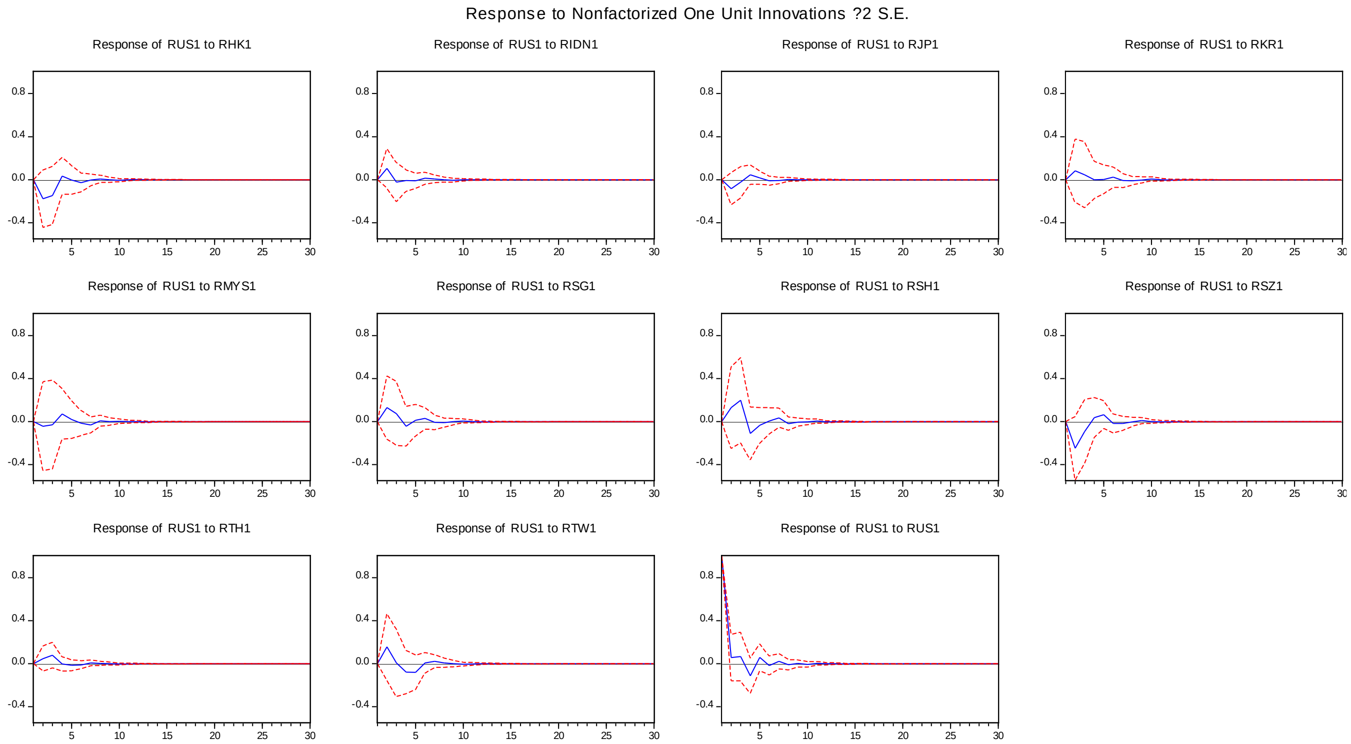

Figure 22. The U.S. Stock Market for pre-trade conflict subsampling period.

The Hong Kong Stock Market for post-trade conflict subsampling period is shown in **Figure 23**. The Indonesia Stock Market for post-trade conflict subsampling period is shown in **Figure 24**. The Japan Stock Market for post-trade conflict subsampling period is shown in **Figure 25**. The South Korea Stock Market for post-trade conflict subsampling period is shown in **Figure 26**. The Malaysia Stock Market for post-trade conflict subsampling period is shown in **Figure 27**. The Singapore Stock Market for post-trade conflict subsampling period is shown in **Figure 28**. The Shanghai Stock Market for post-trade conflict subsampling period is shown in **Figure 29**. The Shenzhen Stock Market for post-trade conflict subsampling period is shown in **Figure 30**. The Thailand Stock Market for post-trade conflict subsampling period is shown in **Figure 31**. The Taiwan Stock Market for post-trade conflict subsampling period is shown in **Figure 32**. The U.S. Stock Market for post-trade conflict subsampling period is shown in **Figure 33**.

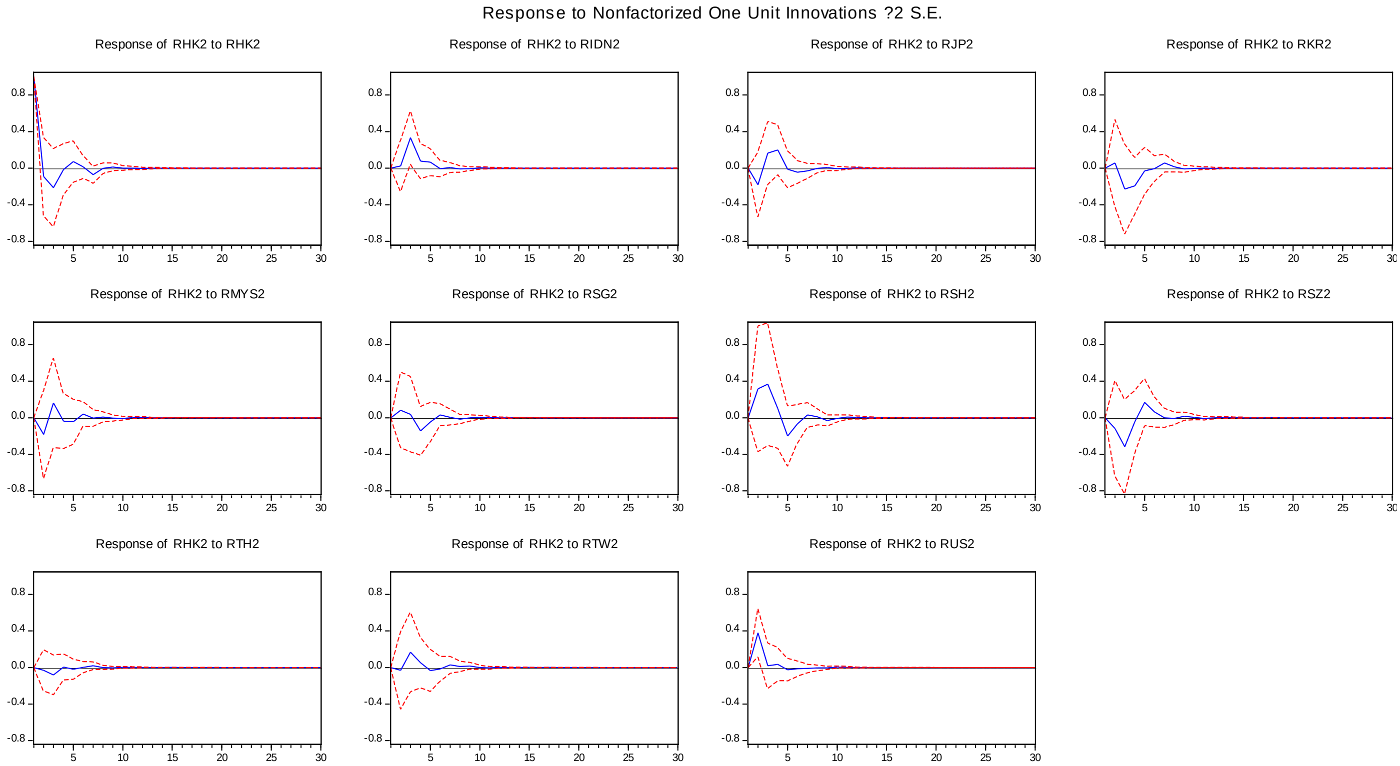

Figure 23. The Hong Kong Stock Market for post-trade conflict subsampling period.

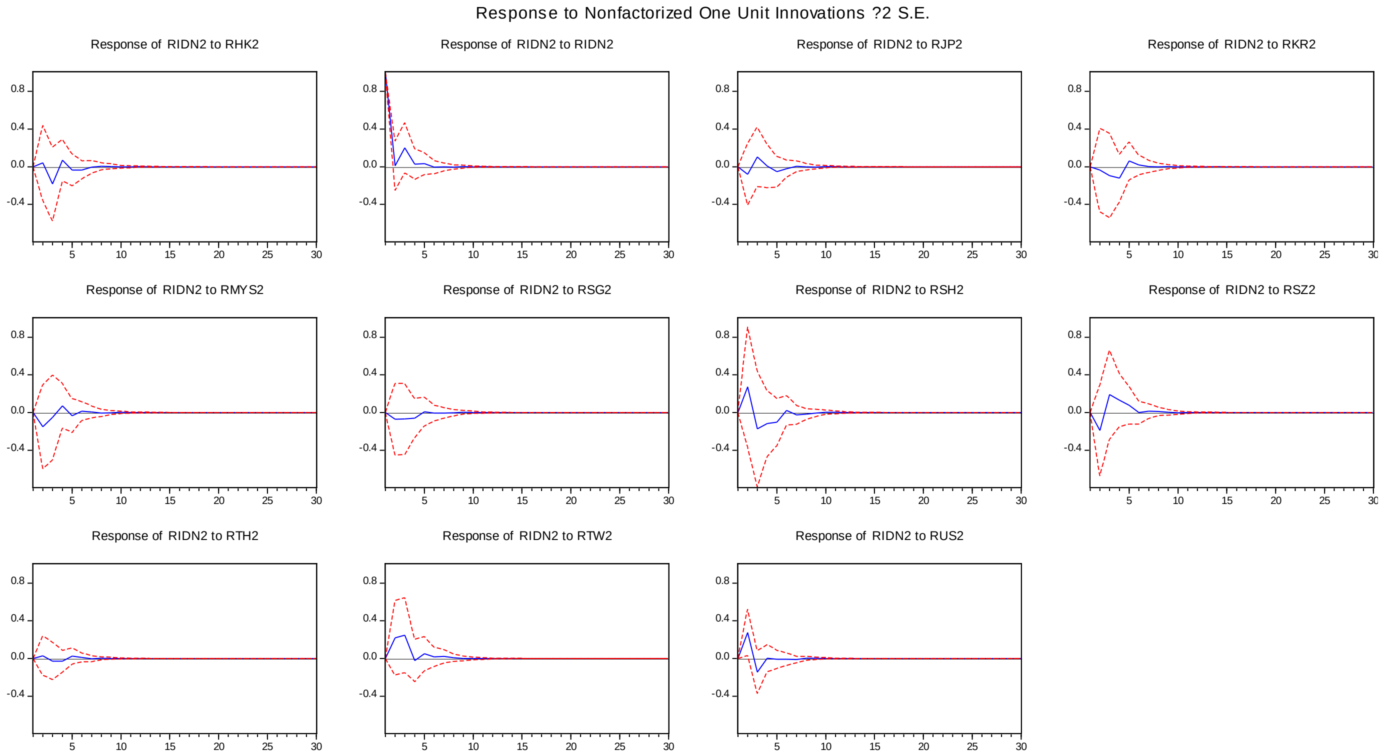

Figure 24. The Indonesia Stock Market for post-trade conflict subsampling period.

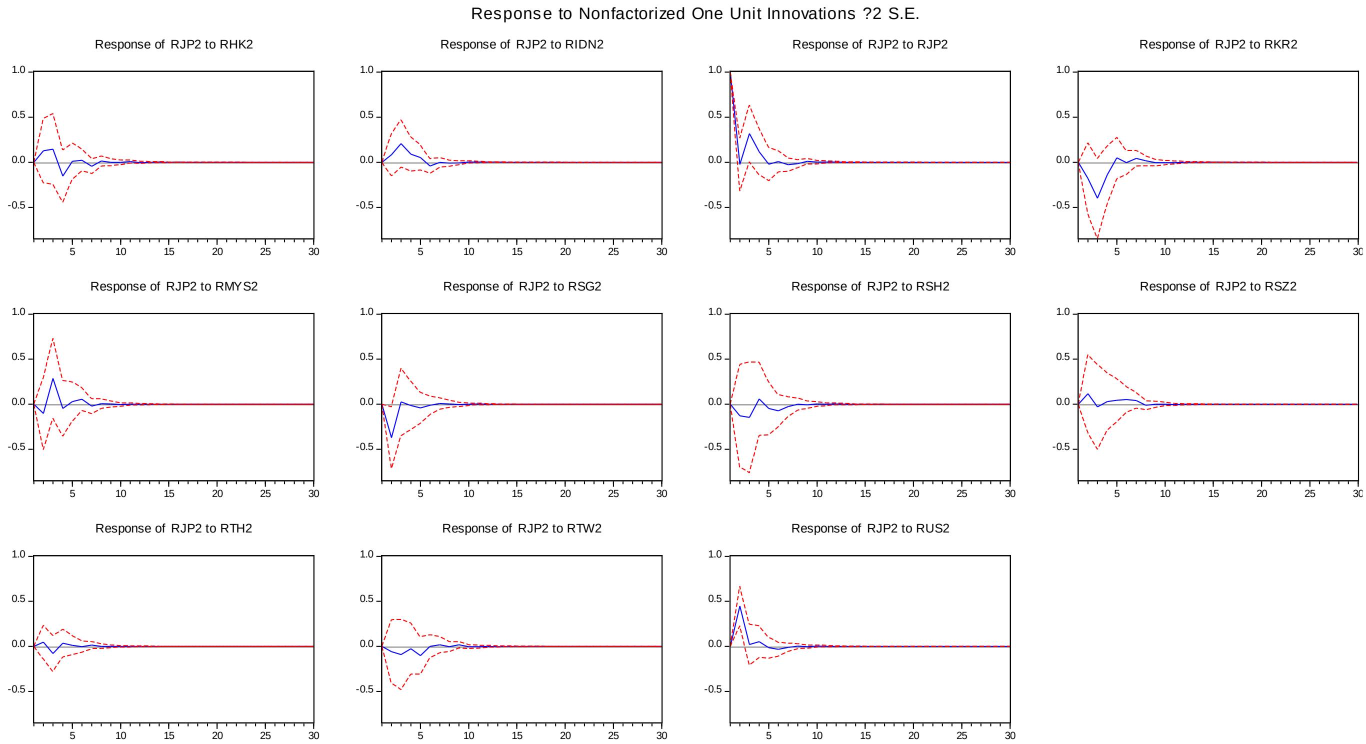

Figure 25. The Japan Stock Market for post-trade conflict subsampling period.

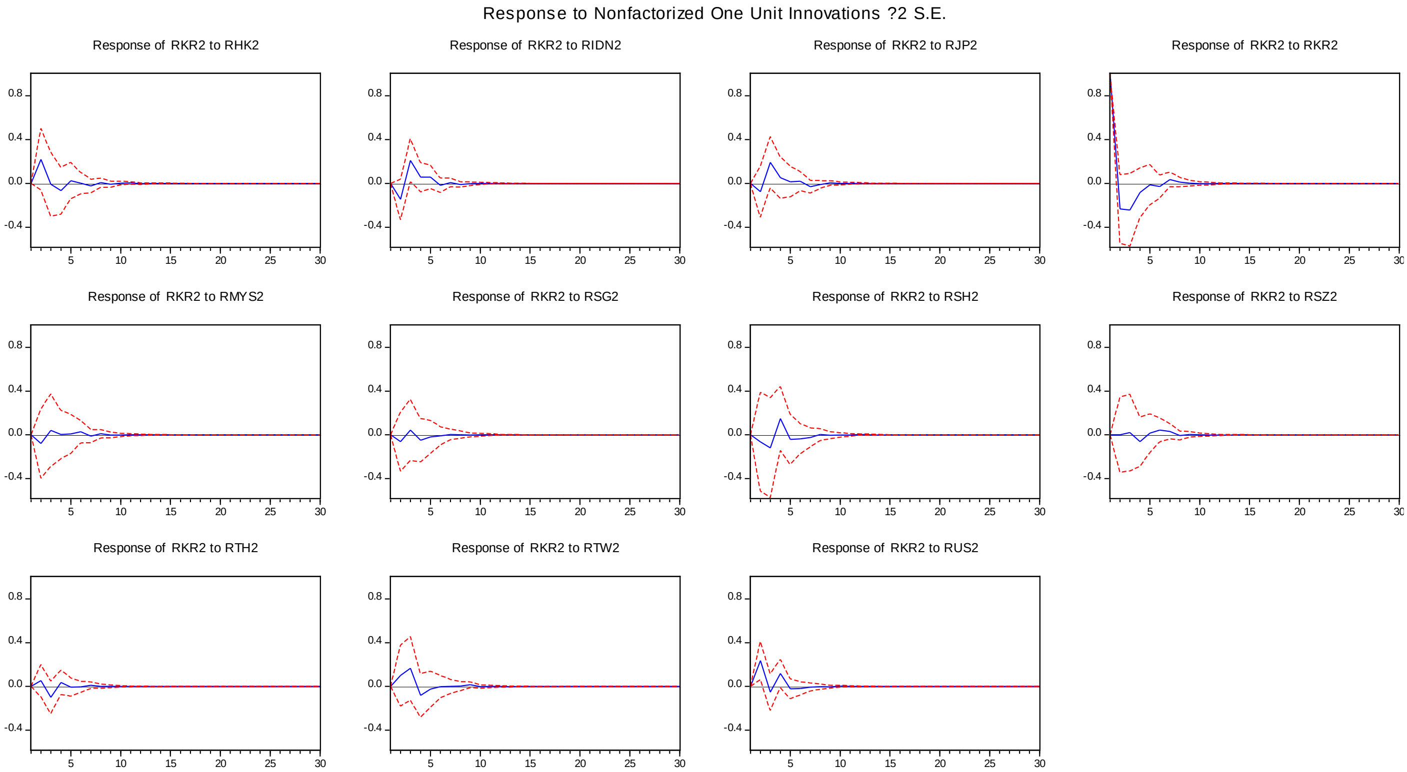

Figure 26. The South Korea Stock Market for post-trade conflict subsampling period.

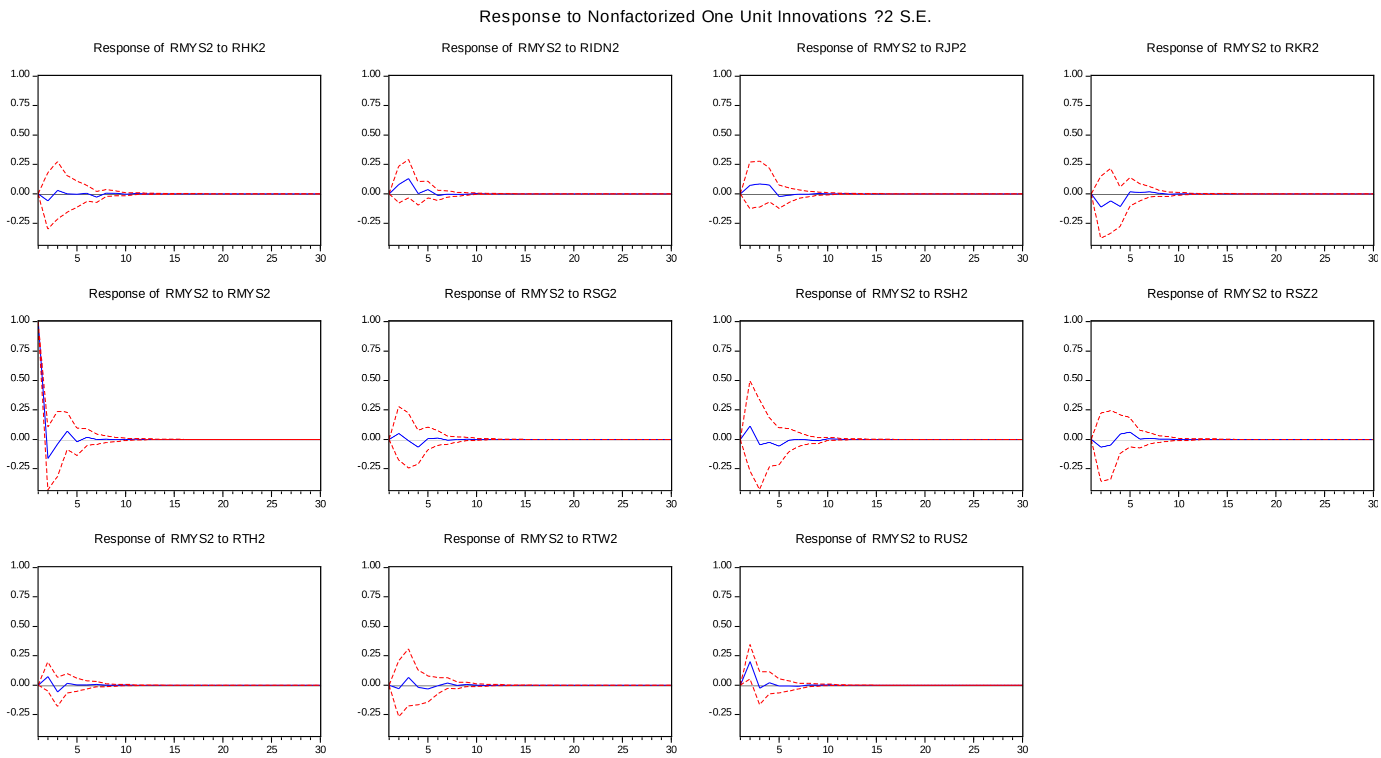

Figure 27. The Malaysia Stock Market for post-trade conflict subsampling period.

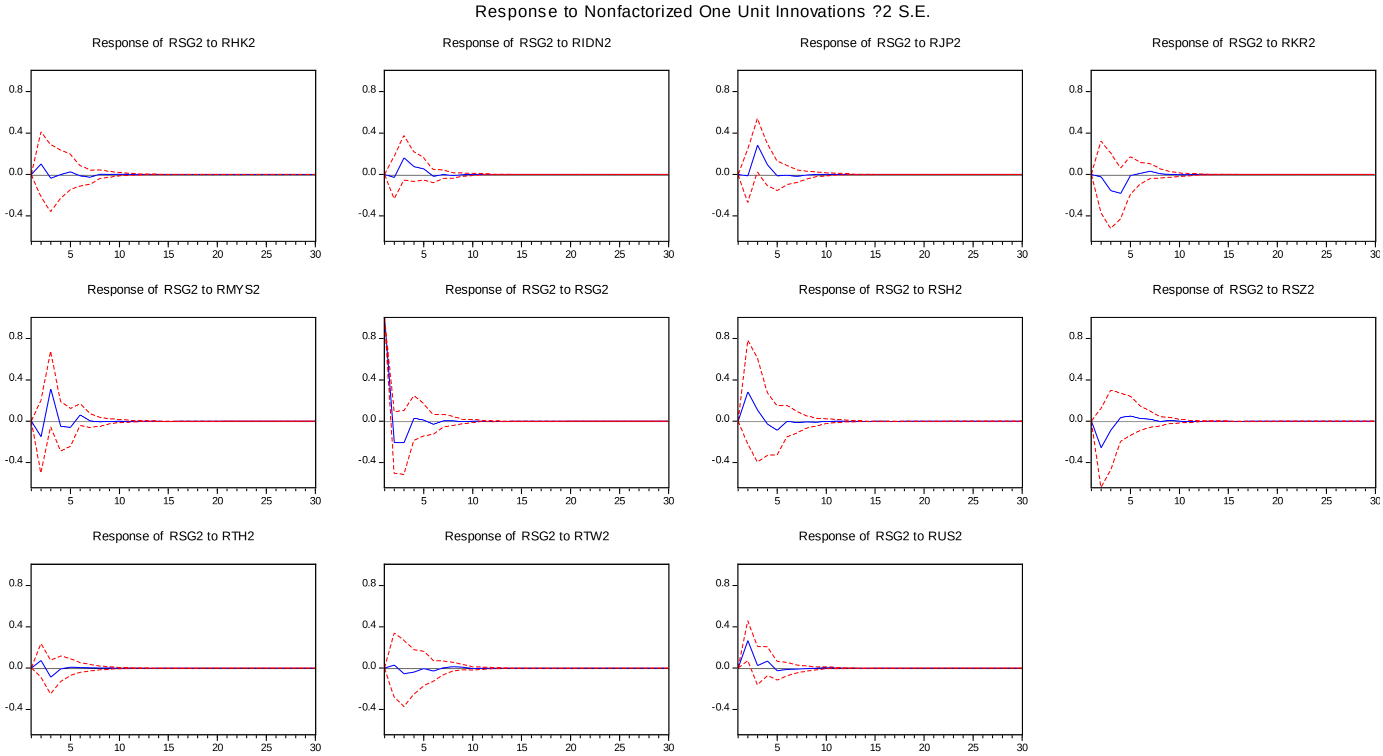

Figure 28. The Singapore Stock Market for post-trade conflict subsampling period.

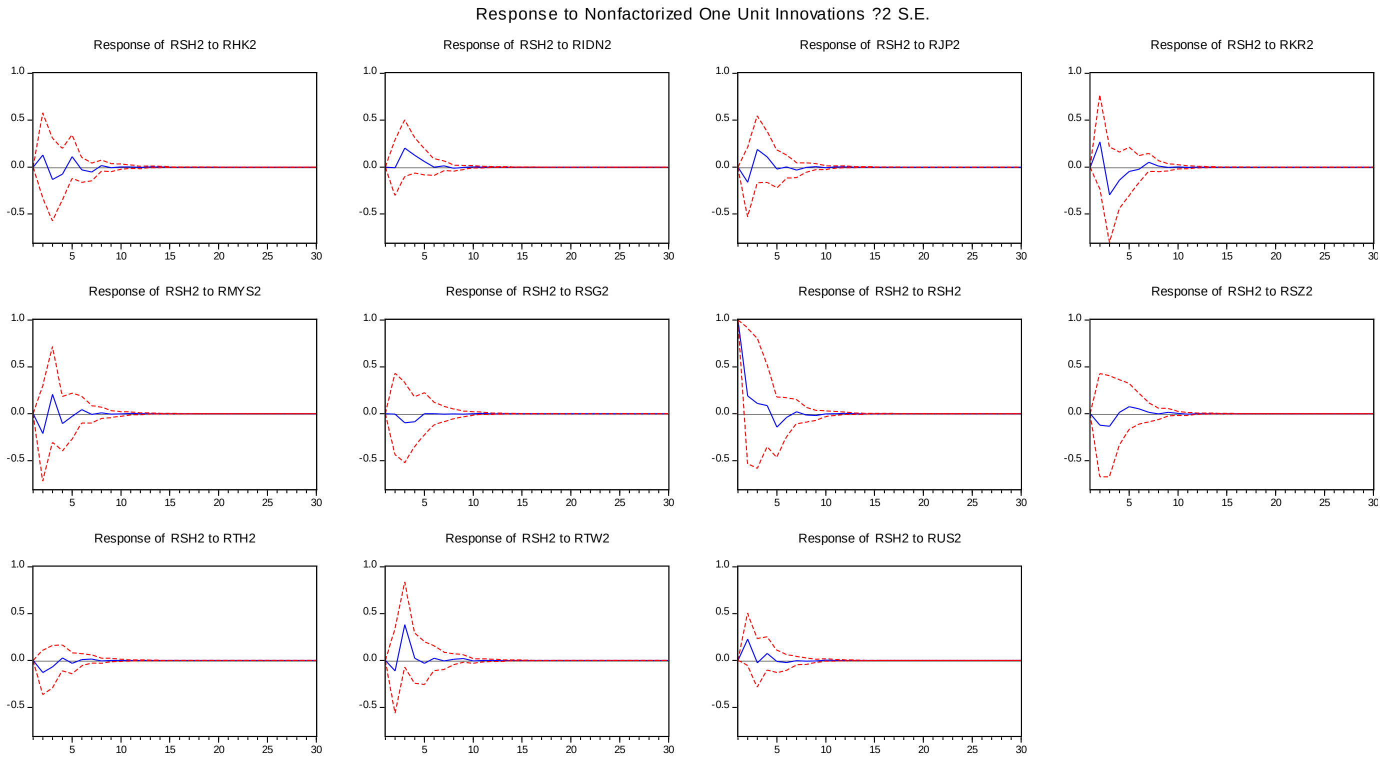

Figure 29. The Shanghai Stock Market for post-trade conflict subsampling period.

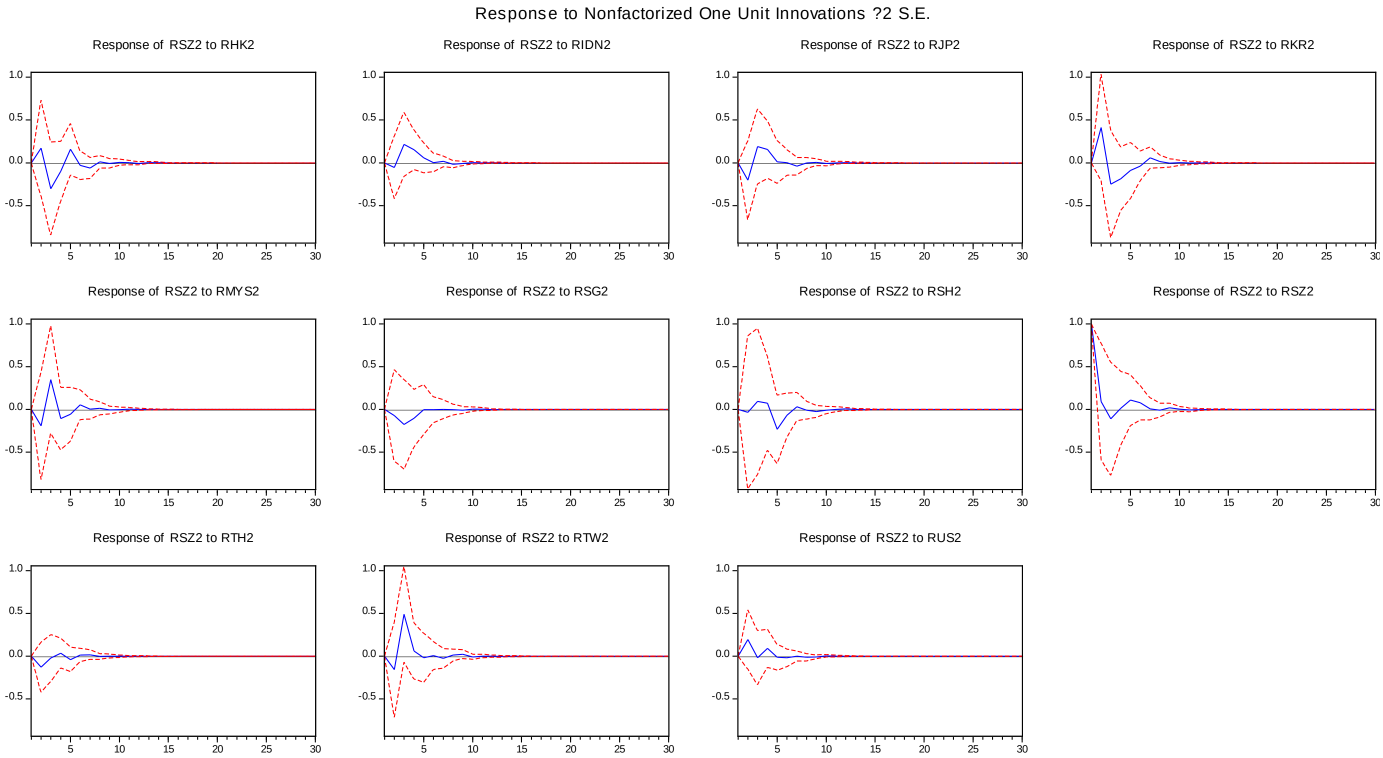

Figure 30. The Shenzhen Stock Market for post-trade conflict subsampling period.

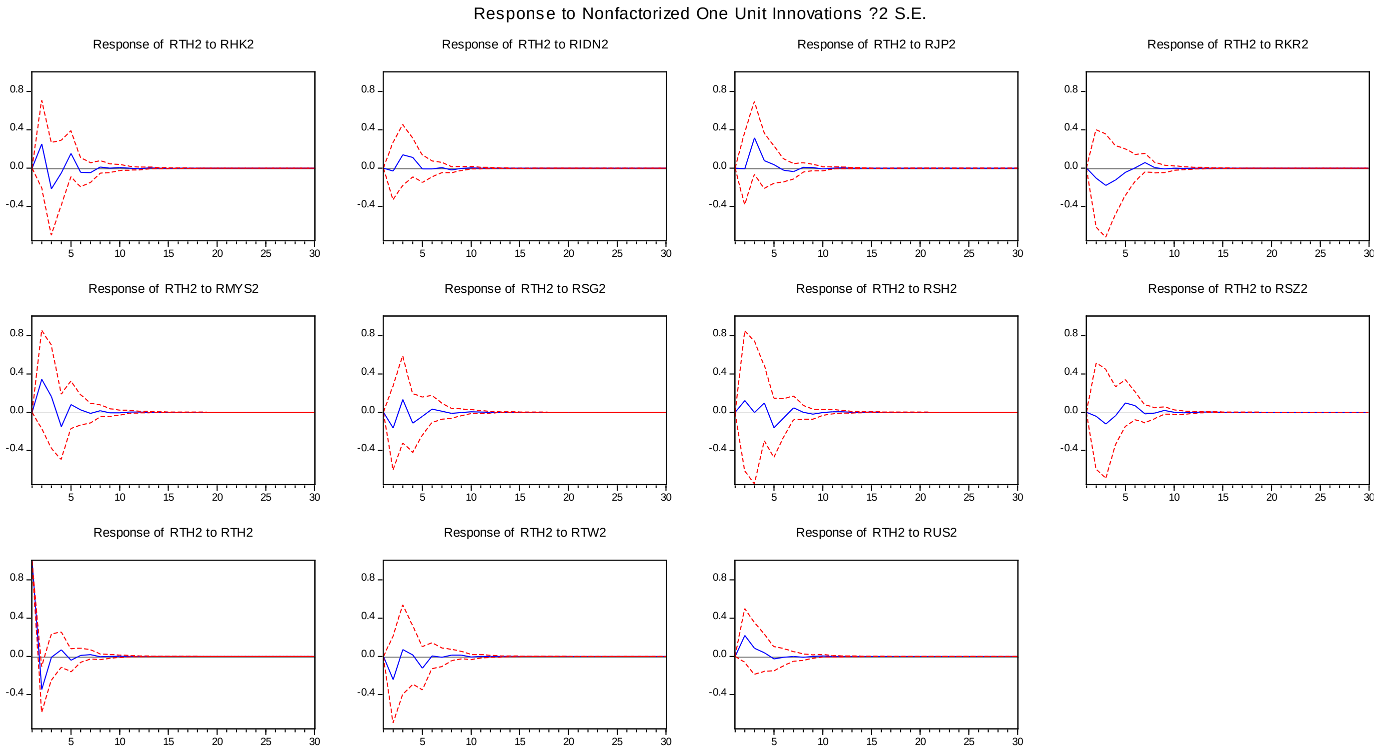

Figure 31. The Thailand Stock Market for post-trade conflict subsampling period.

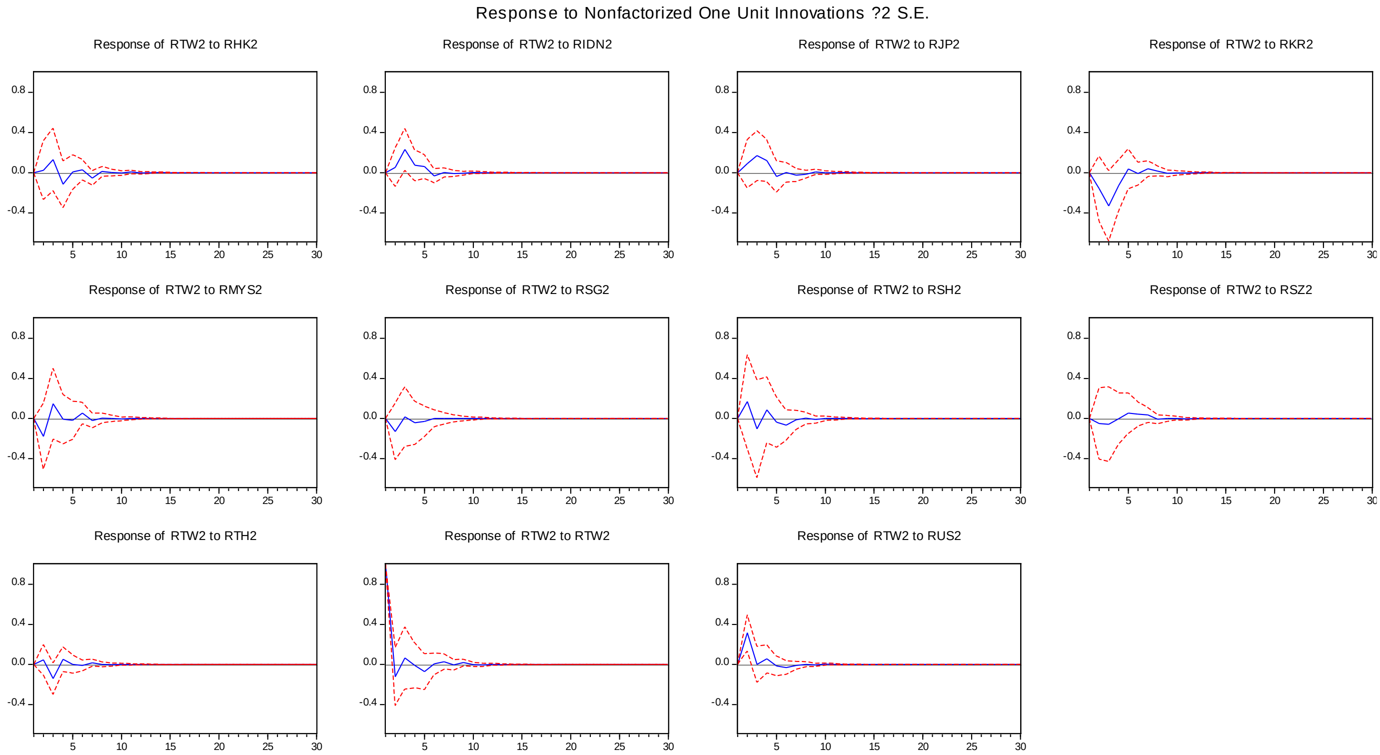

Figure 32. The Taiwan Stock Market for post-trade conflict subsampling period.

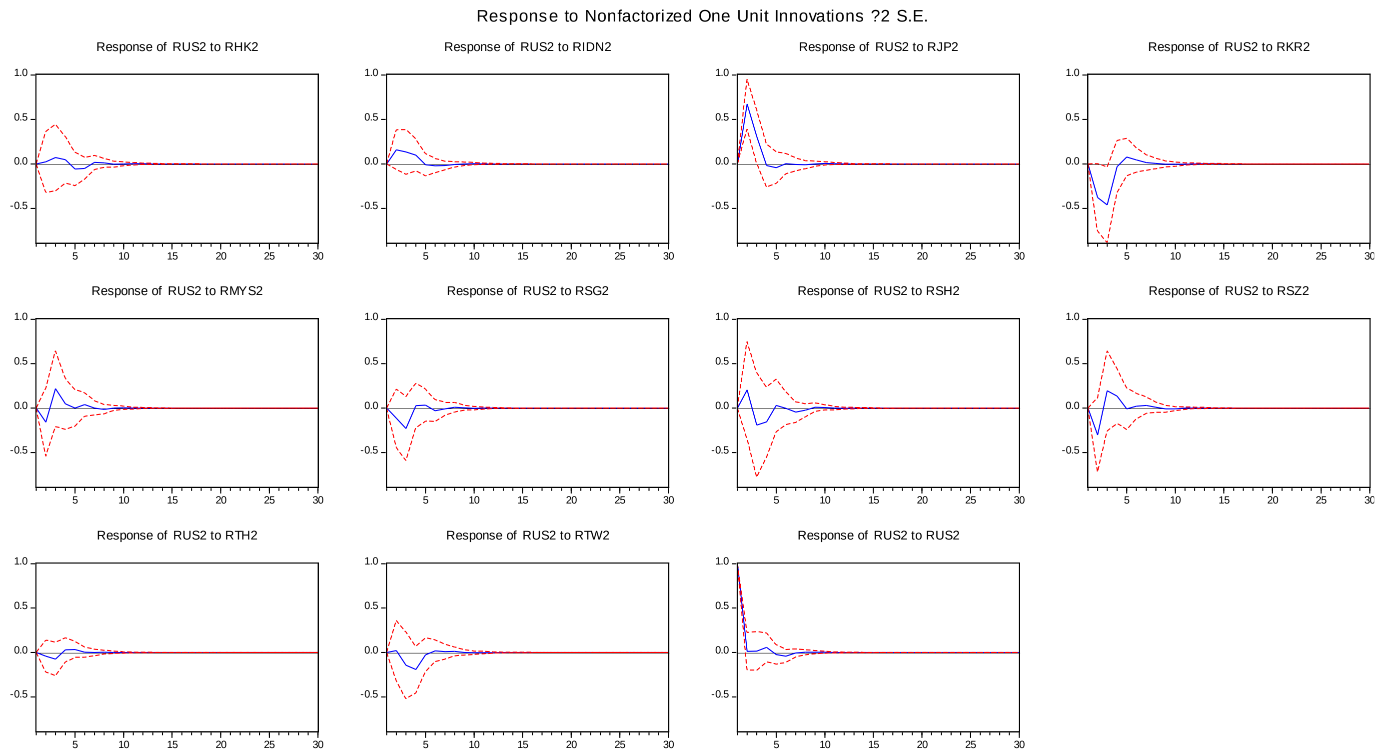

Figure 33. The U.S. Stock Market for post-trade conflict subsampling period.

5. Conclusion

This paper used the dynamic analytical model based on Vector Auto-Regressive (VAR) method to investigate the impact of Sino-U.S. trade conflict on the stock markets of China, U.S. and other Asian economies in the Perspective of Biomechanics and Bioinformatics. To address the relationships of stock market among countries and the "stress-strain" relationships among the stock markets and the trade, the granger causality and co-integration analysis are conducted on the empirical daily stock price data from 21 September 2016 to 22 September 2019. Benchmarking on Sino-US trade conflict on 22 March 2018, the data is divided into two phases, including 21 September 2016 to 21 March 2018, and 22 March 2018 to 22 September 2019.

The results of this study show that the Asian markets seems to be more independent with the U.S. stock market after the Sino-U.S. trade conflict. There is no causality among the returns of stock markets of Indonesia, Shanghai, Shenzhen, Thailand, and Taiwan and that of U.S. after the trade conflict. Meanwhile, for the Chinese stock market, the results shows that almost all the stock markets in other Asian economies and in U.S. are independent with Chinese stock market both before and after the Sino-U.S. trade conflict, except the market of Hong Kong, which show causality with Shanghai stock market before the trade conflict. And the results of VAR also suggest that the tariff and the trade barriers not only hurt the relationship between China's stock market and U.S.'s stock market, but also hurt the relationships of stock markets among U.S.'s and other Asian economies.

Author contributions: Conceptualization, WQ and ZS; methodology, ZS; software, ZS; validation, WQ; formal analysis, ZS; investigation, ZS; resources, WQ; data curation, WQ; writing—original draft preparation, ZS; writing—review and editing, ZS; visualization, ZS; supervision, WQ; project administration, WQ; funding acquisition, ZS. All authors have read and agreed to the published version of the manuscript.

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

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