Modeling and forecasting volatility of stock index financial series and volatility spillover effect in Eviews: GARCH families approach

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Abstract

As the covid-19 pandemic spreads around the globe, the stock market is shrouded in fear of this new black swan, generating disproportionate economic impact in the APAC regions. Utilizing GARCH(1,1), EGARCH, GJR-GARCH, and diagonal BEKK-GARCH methods, we study the disproportionate effect on these financial markets caused by the COVID-19 pandemic and examine volatility characteristics, forecast, and spillover effects for China and its top five trading partners. This study first measures distinct features like risk persistence and leverage effects through GARCH(1,1), EGARCH, and GJR-GARCH. The US and Japan stock market's leverage effect dropped in the period of covid. China, South Korea, Hong Kong, and Taiwan's leverage increased with covid. Then the study conducts an in-sample forecast of existing date's volatility in 2022 utilizing data from 2015-2021 and decides upon the best model for the stock market of each country or region. Finally, the study conducts a volatility spillover analysis by diagonal BEKK-GARCH between China and the rest of the countries and areas, comparing the extent of covariance and correlation. Results show that China's stock market is most correlated with the Hong Kong stock market, followed by Japan, Korea, and Taiwan, which exhibit similar extent, while least correlated with the US stock market. Understanding the volatility of stock markets in different countries and regions during this time of uncertainty may shed light on the possible economic impact of such infectious disease outbreaks and have significance in cooperation of policy implementation and trading strategies.

1. Introduction

At the beginning of 2020, the outbreak of COVID-19 cast a shadow on the world economy as a whole. It has become one of the inseparable economic backgrounds and tremendously destructed the global economy. In December 2019, the first case of COVID-19 was reported in Wuhan, China. Within the first fifty days of the epidemic, more than eighteen hundred lives were lost, and over seventy thousand individuals were infected [1]. Due to the virus's highly transmissible and pathogenic characteristics, to the day this essay is written, COVID-19 has resulted in the loss of 6.48 million lives, with 603.1 Million infections in 192 countries and regions [2]. Upon entering the third year since the pandemic outbreak, the world has seen sorrows and tragedies and witnessed human intelligence and resilience. Keeping that in mind, we incorporate the covid-19 element into the volatility study, hoping that this research would somehow pay tribute to the hardship of time and can provide some rethinking in the future.

The APEC is one of the most vibrant economic cooperatives today, playing an essential role in its economic development. It is a regional economic forum established in 1989 to leverage the Asia-Pacific's growing interdependence, promoting free trade and investment, economic growth and development, and cooperation in the Asia-Pacific region. There are in total 21 member economies in APEC: Australia; Brunei Darussalam; Canada; Chile; People's Republic of China; Hong Kong, China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; The Philippines; The Russian Federation; Singapore; Chinese Taipei; Thailand; United States of America; Viet Nam. China joined APEC in 1991, the nation's first to join a regional economic cooperation organization. According to the CCPIT, China's trade volume in 2020 with APEC economies reached $2.87 trillion, accounting for 62 percent of its total foreign trade. Considering China's substantial economic capital, advanced technology, and excellent traffic network in terms of trade, the study is interested in whether the trading partners can also have this cooperation shown in the correlation and covariance in the stock index and if the volatility characteristics changes before and during the covid pandemic. A comparative study of modeling and forecasting volatility of stock index financial series and volatility spillover effect will contribute to judging their volatility level and potential policy recommendations. Therefore, we use the GARCH families approach to evaluate the volatilities' characteristics, forecast and relationship of the stock indexes from China and its top five trading partners within APEC for 2015-2022.

The contributions of this study are as follows. First, this paper estimates the modeling, forecasting, and volatility spillover effect within one research. It incorporates six countries and regions, whereas a large number of current research only studies one stock index's characteristics or two stock market's interactions and connections. Therefore, the study can provide contrasting information and a more comprehensive picture. It supplements the research on modeling stock index in the APEC area and opens up directions for future research. Second, through the detailed analysis of before and during the covid sample, we can clearly understand the change during this time of turbulence, open up room for discussion, and formulate targeted improvement measures for specific countries or regions with the conclusions of this research. Third, this paper uses various GARCH models and both EGARCH and GJR-GARCH to conclude on volatility concisely and accurately to avoid the model error. In the forecasting section, the study employs dynamic and static models to improve conclusiveness, and whether symmetric and asymmetric, easy and hard models are all incorporated into the same context for finding the optimal forecasting models.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 introduces the methodologies, variables, and data. Section 4 analyzes the empirical results, and finally, Section 5 presents the conclusion.

2. Literature review

2.1. Pandemic and economic cost

Before COVID-19, there were other worldwide pandemics like Severe Acute Respiratory Syndrome (SARS) and Ebola, also generating tremendous economic costs in different societies and studied by various scholars. Hai et al. (2004) discover that SARS significantly negatively impacts the Chinese economy, with the tourism industry suffering the most [3]. Siu and Wong (2004) observe that SARS has struck Hong Kong's economy by affecting its demand [4]. Chou et al. (2004) apply a multiregional computable general equilibrium model. The simulation result predicts that in the short term, Taiwan, Hong Kong, and mainland China will all experience a GDP loss due to the negative impact of SARS [5]. Similarly, for the outbreak of the Ebola virus, Huber et al. (2018) examine the overall economic and social burden caused by the 2014 Ebola virus [6], while Adegun (2014) discovers the GDPs of West African countries will be affected by the Ebola virus [7]. During this COVID-19 pandemic, Rizvi et al. (2020) discover a significant decrease in valuation among all sectors in the EU markets [8]. The findings of Yarovaya et al. (2020) indicate a reduction in capital adequacy and higher possibilities of defaults across 10 EU member states [9]. Susilawati et al. (2020) find out that the COVID-19 pandemic has impacted different economic sectors of Indonesia, especially the household sector [10]. The epidemic can also cause a loss of human capital, which blocks economic progress in the long run. Barro and Sala-i-Martin (1995) point out that human capital is crucial for the long-term growth of an economy [11], and Bloom et al. (2001) claim that human capital loss does affect economic growth negatively [12].

2.2. Pandemic and financial markets

In addition to economic impact, global pandemics have also influenced financial markets worldwide. Chen et al. (2007) used an event study approach and found that during SARS, the Taiwanese hotel industry experienced a sharp decline in stock price [13]. Wang et al. (2013) found that infectious diseases will lead investors to adjust their portfolios accordingly [14]. The research of Chen et al. (2018) indicates that SARS has impacted the long-term relationship between China and four other Asian stock markets [15]. Del Giudice & Paltrinieri (2017) observe that Ebola and the Arab Spring severely impacted African mutual funds market by decreasing the fund flows [16]. Wang et al. (2013) found that infectious diseases will lead investors to adjust their portfolios accordingly [17]. Research focusing on the current COVID-19 shows it has impacted stock markets more forcefully than previous epidemics (Baker et al., 2020; Umar, Rizvi, et al., 2021; Zhang et al., 2020) [18].

Volatility indicates the risk in the financial market and thus is of great interest to stock market participants. Since pandemics are often unpredictable and cause huge impacts, researchers have tried to establish the relationship between pandemics and market volatility to predict better and manage investment risks. Baig et al. (2021) prove that pandemics significantly increase permanent volatility in the US, China, the UK, and Japan [19]. Baker et al. (2020) find that the primary cause of the increased volatility is the government's restrictions on commercial activities during pandemics

[20], and Onali (2020) points out that the increase in identified cases contributes to the increased volatility [21].

Researchers have also focused on the transmission of pandemics' impact on financial markets from one region to another. Umar et al. (2021) studied the connection between emerging markets and US bonds. They found that the US bond is more resilient to the pandemic changes caused by the pandemic than developing countries [22]. Zhang et al. (2021) investigate COVID-19's impact on the volatility of stock markets in five technologically advanced countries and conclude that during the pandemic. The returns volatility from advanced countries has no significant effect on China's stock market, while China's volatility significantly impacts the other countries except the US [23]. Some researchers focus more specifically on Asian markets. Estrada (2020) discovers that pandemics can quickly affect major Asian markets like Japan, South Korea, Hong Kong, and Taiwan [24]. Rahman (2021) studies the resilience of some Asia Pacific markets against COVID-19 and points out that the pandemic-related events have asymmetric impacts on Asian Pacific markets [25].

2.3. Volatility Spillover Effects

Volatility spillover is the phenomenon of instability transferring from one market to another. It is widely observed and thus has always been a focus of scholars. When studying the volatility of a stock market, the volatility spillover effect captures the impact of the market's own early performances. It incorporates the influence of the volatility of other financial products and markets. Liu and Pan (1997) investigate the mean return and volatility spillover effects from the US and Japan to other Pacific-Basin stock markets and notice that the US market is more influential than the Japanese market between 1984-1991 [26]. Likewise, Ng (2000) discovers significant volatility spillover effects from Japan and the US to the Pacific-Basin stock markets [27]. Bala and Takimoto (2017) use the multivariate-GARCH model to study the volatility spillover effects of stock return in both emerging and developing markets and find out that the correlation between developing markets is higher than the correlation between developed markets [28]. Baele (2009) studies the spillover effect from the US and the aggregate EU markets to 13 individual European equity markets. The result suggests that higher trade integration leads to higher spillover intensity [29]. Similarly, Christiansen (2007) studies the spillover effect of the bond markets of the US and aggregate EU to other European bond markets and concludes that spillover effects from the US are weaker than those from the European EMU countries [30]. Lee (2009) focuses on Asian markets and points out significant spillover effects exist between six Asian stock markets - Hong Kong, Taiwan, Japan, South Korea, Singapore, and India [31]. Barbgalia et al. (2020) find the spillover effect between different commodities like agricultural products and energy [32]. Literature shows that spillover effects commonly exist between regions and sectors.

2.3. Data Analysis Methods

The data analysis methods included in this study are ARCH, GARCH(1,1), EGARCH, GJR-GARCH, BEKK-GARCH. To conclude certain characteristics of the volatility of the time series, the study used GARCH(1,1), EGARCH, GJR-GARCH by observing the behavior of ARCH term, GARCH term and respective term. The ARCH, GARCH(1,1), EGARCH, GJR-GARCH are used in the forecasting process and compare varies models' effectiveness. BEKK-GARCH is introduced to analyze volatility spillover effect.

2.4.1. ARCH

ARCH stands for Autoregressive Conditional Heteroskedasticity. It was introduced by R. Engle in a 1982 paper entitled "Autoregressive Conditional Heteroskedasticity" with estimates of the variance of United Kingdom Inflation [33]. ARCH refers to the series with time-varying volatility conditional to previous lags autocorrelation. One of the most important aspects of ARCH is homoscedasticity, which means the variance of the residual is constant. Yet, economic time series oftentimes face periods of higher volatility which doesn't comply with the homoscedasticity assumption. Volatility models are performed over stationary time series like return, but with a non-constant variance. Therefore, estimating not only the return but also the variance of the assets holds great significance.

Main equation and variance equation of ARCH is as follows

$$y_t = \theta_0 + \theta_1 y_{t-1} + \cdots + \theta_n y_{t-n} + \epsilon_t$$

$$\text{Where } \sigma^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \cdots + \alpha_n \epsilon_{t-n}^2$$

$$\text{Satisfy } \alpha_0 > 0 \text{ and } \alpha_i > 0,\ 0 \le \sum_{i=1}^{i=n} \alpha_i \le 1, \alpha_1 > \alpha_2 > \cdots > \alpha_n > 0$$

2.4.2. GARCH families

The ARCH model was later expanded to GARCH in 1986 by Tim Bolleslev, which stands for Generalized Auto Regressive Conditional Heteroskedasticity, used for estimation when variance is serially correlated [34]. The "Generalized autoregressive" indicates that heteroscedasticity over different time periods may autocorrelate. The "Conditional" means that variance is based on past errors. Heteroscedasticity implies the series displays unequal variance, which is already modeled by ARCH. GARCH differs from ARCH in that it conveys that the series has a time-varying variance that depends on lagged effects or autocorrelation. The GARCH models holds significance in modeling the volatility of the variance, which reflects risk embedded in error terms of shocks or news. With variance being a crucial volatility measurement in asset pricing theories, GARCH models have become important as most financial time series like stock prices, exchange rates, and oil prices exhibit random walks that are nonstationary.

The family of GARCH models grew rapidly in response to the need for forecasting in different financial markets scenarios. After Engle and Bollerslev developed the IGARCH (Integrated GARCH) model in 1986 [35], Nelson proposed the EGARCH (Exponential GARCH) model in the year of 1991 [36]. The GJR-GARCH model came out as a collaborated work of Zakoian, 1994 [37], and Glosten et al, 1993 [38], though published separately from one another. The

TGARCH (Threshold GARCH) model and the QGARCH (Quadratic GARCH) model were introduced independently by Zakoian in the year of 1994 [39] and by Sentana in the year of 1995 [40]. The BEKK GARCH model was first introduced by Baba, et. al in 1990, named with the acronym Baba–Engle–Kraft–Kroner [41]. It was then expanded into a multivariate GARCH model by Engle and Krone in 1995, and named the VAR-BEKK-GARCH model [42].

2.4.3. General Introduction of Various Tests

This study covers the main types of tests: stationarity test/ADF test, Correlogram/Ljung-Box test, Correlogram test, and ARCH LM test.

2.4.3.1 stationarity test/ADF test

The augmented Dickey-Fuller test addresses whether the time series of interest has a unit root, widely employed in testing the stationarity of a time series. Stationarity is the process where unconditional joint probability distribution does not change over time; thus, parameters like mean and variance remain constant over time [43]. The unit root is what makes the time series unstationary. Checking the stationary is crucial for GARCH implementation, as the ADF test has to pass at first unstationary in close price, then check for stationary in stock return.

The stationarity test/ADF test is based on the statistic:

$$y_t = c + \beta t + \alpha y_{t-1} + \phi \Delta Y_{t-1} + e_t$$

The null hypothesis for this test is that it contains a unit root and is unstationary. The alternate hypothesis is that it is stationary and doesn’t contain a unit root.

2.4.3.2 Correlogram/ Ljung-Box test

Correlogram, also called Auto Correlation Function Plot, shows financial series data's serial correlation. Ljung-Box test is a diagnostic tool for testing lack of fit, proposed by Ljung and Box in 1978 Biometrika [44]. It ensures the residuals do not suffer from autocorrelation and only works when the number of lags is more than p+q+1. An autoregressive process is where the dependent variable is dependent solely on its previous values. An example of an AR(1) process would be as follows.

$$y_t = \mu + \varphi y_{t-1} + u_t \; where \; u_t \sim N(0, \sigma^2)$$

An example of an AR(2) process would be as follows.

$$y_t = \mu + \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + u_t \; where \; u_t \sim N(0, \sigma^2)$$

The Ljung-Box test is based on the statistic [45].

$$Q(m) = n(n + 2) \sum_{j=1}^{m} \frac{r_j^2}{n-j}$$

The null hypothesis of the Ljung-Box test is that the data are not serially correlated, and the autocorrelations of the given sample are all zero. The alternative hypothesis is that the data are serially correlated. Therefore, if the p-value is below 0.05, the study cannot reject the null hypothesis, and the data are not serially correlated, successfully passing the Ljung-Box test for serial correlation. With the autocorrelations being very small, we don't have to worry much about ARCH correlation. The Ljung-Box test concludes that the model does not exhibit a significant lack of fit [46].

2.4.3.3 ARCH-LM test

Engle's (1982) ARCH-LM test is the standard approach to detect financial time series data's ARCH (autoregressive conditional heteroscedasticity) [47]. It is computed from regressing the squared residuals on a constant and p lags of the residuals, where p in this study is selected according to which the lag which minimizes an Schwarz information criterion, which is 1. If the test fails to find any ARCH effect present in the residuals, modeling the variable using an ARCH or GARCH model is not needed.

The formula of the regression equation upon which ARCH-LM test is based on is:

$$e_t^2 = \hat{\delta}_0 + \sum_{s=1}^{q} \hat{\delta}_s e_{t-s}^2 + v_t$$

The null hypothesis is that there is no ARCH effect in the residuals up to the specified lag p. The alternative hypothesis is that there are ARCH effects present in the residuals up to the specified lag. Therefore, if the p-value is above 0.05, the study reject the null hypothesis and confirm the existence of ARCH effects.

3. Methodologies, variables, and data

3.1. Data

The study obtains monthly trade data from The Development Research Center of the State Council and draws the below APEC region's import and export trade comparison diagram. The time period we draw starts from 2020, the year when COVID-19 broke out. From Figure 1, we vaguely observe that the USA, Japan, South Korea, Hong Kong, and Taiwan stand out from other countries and regions in terms of trading import and export. Table 1 entails various countries and regions' trading export and import with China during the covid with data retrieved from the General Administration of Customs of the People's Republic of China, followed by Fig 2, which is a graphical representation of Table 1. We confirm the assumption that China's top trading partners are the US, Japan, South Korea, Hong Kong, and Taiwan. Choosing China and its top trading partners have implications for later research when the volatility spill-over effect is studied. We wish to explore whether these countries and regions are connected tightly in trade also correlate with stock market returns and the degree of the correlation and covariance of those returns.

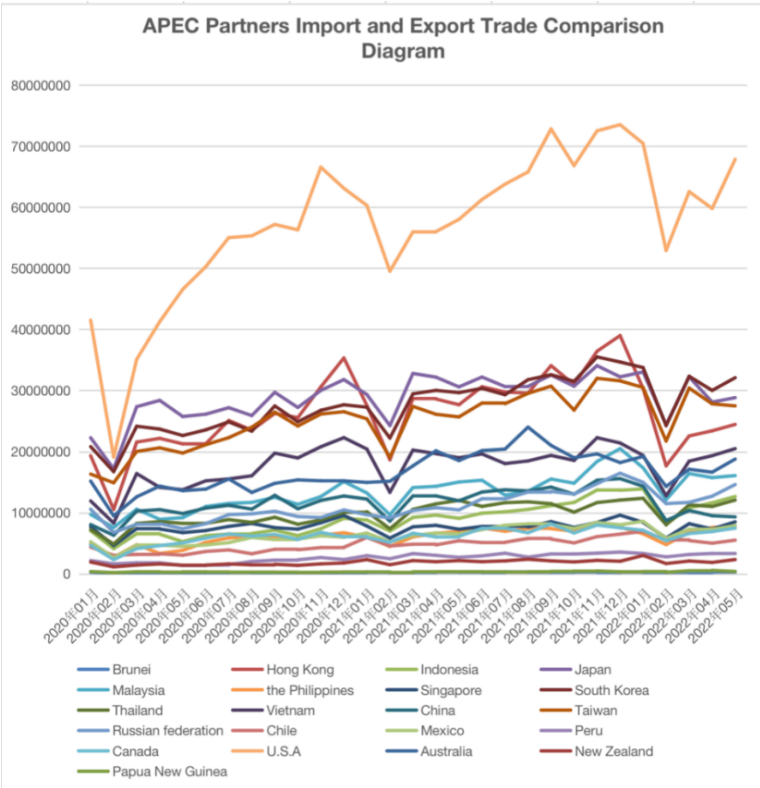


Figure 1. Import and export trade comparison diagram for all APEC members
Source: Author's calculation based on data obtained from The Development Research Center of the State Council.

Table 1. Trading export and import with China volume for all APEC members during covid-19

Num	Trading Partner	2020.1-12	2021.1-12	2022.1-5	sum
502	U.S.A	586,979,636,456	755,701,280,118	313,569,996,722	1.65625E+12
116	Japan	317,282,958,519	371,335,250,379	146,541,334,958	8.3516E+11
133	South Korea	285,580,741,898	362,310,452,182	152,262,933,111	8.00154E+11
110	Hong Kong	279,558,186,869	360,302,768,174	118,136,174,314	7.57997E+11
143	Taiwan	260,615,359,263	328,240,849,313	137,646,770,883	7.26503E+11
141	Vietnam	192,290,082,708	230,224,025,872	90,336,079,794	5.1285E+11
601	Australia	171,162,255,057	229,887,953,176	86,686,939,431	4.87737E+11
122	Malaysia	131,475,736,085	176,974,690,312	77,708,566,435	3.86159E+11
142	China	125,266,279,538	156,824,525,091	52,103,204,032	3.34194E+11
344	Russian federation	108,189,145,471	147,164,638,430	65,812,978,935	3.21167E+11
136	Thailand	98,653,976,767	131,176,280,077	54,671,670,864	2.84502E+11
112	Indonesia	78,463,077,472	124,563,951,873	57,040,682,020	2.60068E+11
132	Singapore	89,244,193,188	93,926,339,533	38,254,687,134	2.21425E+11
429	Mexico	61,045,482,560	86,580,268,081	36,767,236,481	1.84393E+11
501	Canada	64,157,931,135	81,974,806,061	33,444,684,962	1.79577E+11
129	the Philippines	61,217,180,198	82,068,750,544	33,489,576,769	1.76776E+11
412	Chile	45,267,549,016	65,865,118,997	28,405,965,564	1.39539E+11
434	Peru	23,601,217,044	37,535,909,956	15,743,990,300	76881117300
609	New Zealand	18,129,149,863	24,716,470,022	10,884,005,635	53729625520
611	Papua New Guinea	3,193,716,086	4,050,588,350	2,008,290,844	9252595280

105	Brunei	1,942,218,236	2,860,864,519	1,261,557,059	6064639814

Source: Author's calculation based on data obtained from General Administration of Customs of the People's Republic of China.

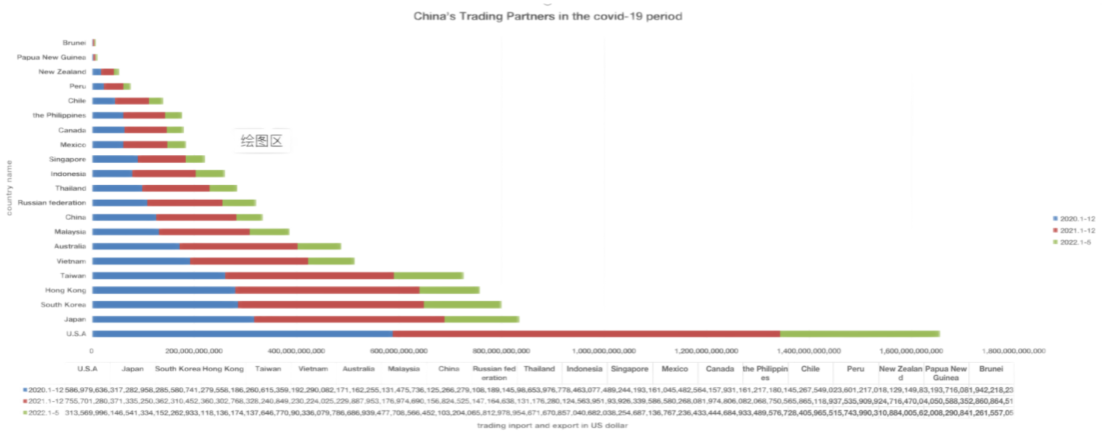


Figure 2. All APEC members' import and export trade with volume China

From the analysis above, the six countries and regions chosen as China's top trading partners in this study are the USA, Japan, South Korea, Hong Kong, and Taiwan. The study decides on one representative stock index for each country and region. The stock indexes chosen are the SSE Composite Index, S&P 500, Nikkei 225, KOSPI Composite Index, Hang Seng Index, and TSEC weighted index. Table 2 shows the stock indexes' names, locations, and currencies.

Table 2. Corresponding relationship between relevant countries/ regions and stock index

	China	**USA**	**Japan**	**South Korea**	**Hong Kong**	**Taiwan**
Stock Index Name	SSE Composite Index	S&P 500	Nikkei 225	KOSPI Composite Index	Hang Seng Index	TSEC weighted index
Location	Shanghai	SNP	Osaka	KSE	HKSE	Taiwan
Currency	CNY	USD	JPY	KRW	HKD	TWD

The study retrieves the stock information of each stock index representing their respective countries and regions from Yahoo Finance, and the period starts on 01/05/2015 and ends on 08/12/2022. Calculation of return in this study uses natural logarithmic returns transformed from the daily close price of the stock index.

$$\text{return} = ln(S_t/S_{t-1}) = C_1 + \epsilon_t$$

This study employs the LOCF (Last Observation Carried Forward) method for missing dates, so the previous non-missing values are carried forward to replace the new missing value. The adjustments for specific missing values are listed in Appendix.

In the comparison part of the study, to divide the total sample into before covid dates and during covid dates, this study chooses the cutoff date to be 2020/2/11. In January and February of 2020, China and several neighboring Asian countries mainly received the impact of the COVID-19 virus. Since the end of February, the virus has spread to other countries in Europe and America. The World Health Organization declared the outbreak a Public Health Emergency of International Concern on January 30, 2020, and a pandemic on March 11, 2020. On February 11, 2020, at the global research and Innovation Forum jointly organized by World Health Organization (WHO) and the global infectious disease prevention and control research cooperation organization, the virus was first recognized as coronavirus disease (COVID-19). The

International Committee on Taxonomy of Viruses adopted the virus's official name, "severe acute respiratory syndrome coronavirus 2" (SARS-CoV-2), on the same day. This study will separate the total sample into two samples according to the official COVID-19 name date 2020.2.11 since it generally lies before the more extensive scale transmission to countries and regions involved in this study, serving as a significant historical point. Table 3 demonstrates the start and end dates of the three sample types employed in this study for different stock markets.

Table 3. Different sample start and end date

Full sample	**China**	**USA**	**Japan**	**South Korea**	**Hong Kong**	**Taiwan**
Start date	1/6/2015	1/5/2015	1/6/2015	1/5/2015	1/5/2015	1/6/2015
End date	8/12/2022	8/12/2022	8/12/2022	8/12/2022	8/12/2022	8/12/2022

Before covid sample	**China**	**USA**	**Japan**	**South Korea**	**Hong Kong**	**Taiwan**
Start date	1/6/2015	1/5/2015	1/6/2015	1/5/2015	1/5/2015	1/6/2015
End date	2/10/2020	2/10/2020	2/10/2020	2/10/2020	2/10/2020	2/10/2020

After covid sample	**China**	**USA**	**Japan**	**South Korea**	**Hong Kong**	**Taiwan**
Start date	2/11/2020	2/11/2020	2/12/2020	2/11/2020	2/11/2020	2/11/2020
End date	8/12/2022	8/12/2022	8/12/2022	8/12/2022	8/12/2022	8/12/2022

In choosing between a normal distribution and student t distribution in modeling and forecasting, this study sticks with the normal distribution hypothesis since the T-distribution function when population standard deviation is unknown. Generally, normal distribution work for better results if the population standard deviation is known and the sample size is large enough. Yet when examining the volatility spillover effect, this study employs student t distribution. Previous studies conducted by scholars like Dahiru A. Bala, and Taro Takimoto, use student t distribution since they consider the thick tail and skew characteristics that often occur in financial returns and discover better results in the volatility spillover studies [48].

3.2. Data descriptions

The descriptive statistics of our sample data generate from Eviews and entail information of individual countries and regions, thus featuring different numbers of observations due to differences in trade days. Table 4 presents the summary statistics of China and its five top trading partners in the total sample from 01/05/2015 to 08/12/2022, which includes approximately 1800 observations for each country or region. The US, South Korea, Taiwan, and Japan have respectively positive returns of 0.000344, 0.000210, 0.000315, and 0.000248, while in contrast, China and Hong Kong have negative returns of -0.000012 and -0.000150. The medians remain all positive in the total sample. There are more significant standard deviations in China, followed by South Korea and Hong Kong. The USA's volatility level stays in the middle, where Japan and Taiwan demonstrate low volatility compared to other countries and regions in the total sample.

Table 5 presents the summary statistics of China and its five top trading partners before the cutoff date of the COVID-19 pandemic, which includes approximately 1200 observations for each country or region. The average values of the USA, Japan, South Korea, Hong Kong, and Taiwan stock returns are 0.000414, 0.000336, 0.000232, 0.0000741, and 0.000145, all numbers positive. Yet, China has a negative return of -0.000119, and this slightly not ideal average return probably resulted from the 2015 Chinese stock market crash. The medians remain all positive for all countries and regions in the before covid sample. Overall the standard deviation shows relatively larger values in China and Japan compared to the USA, South Korea, Hong Kong, and Taiwan compared to the full sample.

Table 6 presents the summary statistics of China and its five top trading partners after the cutoff date of the COVID-19 pandemic, which includes approximately 600 observations for each country or region. The average values of stock returns of China, the USA, Japan, South Korea, and Taiwan are 0.000205, 0.0002, 0.00027, 0.000166, and 0.000457, all numbers positive. Yet, Hong Kong has a negative return of -0.000606 in the during-covid sample. The medians remain positive for all countries and regions in the during-covid sample. All the other countries and areas studied besides China feature more standard deviation. Its reality implication is that covid-19 pandemic generally increases uncertainty and thus causes more significant variation.

Table 4. Descriptive analysis of full sample

Full sample	China	USA	Japan	South Korea	Hong Kong	Taiwan
Mean	-1.20E-05	0.000344	0.000210	0.000315	-0.000150	0.000248
Median	0.000689	0.000633	0.000610	0.000569	0.000475	0.000598
Maximum	0.056036	0.089683	0.082513	0.077314	0.086928	0.061726
Minimum	-0.088732	-0.127652	-0.087670	-0.082529	-0.060183	-0.065206
Std. Dev	0.013964	0.011757	0.010295	0.012788	0.012595	0.009698
Skewness	-1.279197	-1.075467	-0.303115	-0.089972	-0.115104	-0.575513
Kurtosis	10.36884	20.59697	11.99563	8.065915	6.450021	8.338162
Jarque-Bera	4614.344	23453.13	6056.018	1891.859	896.6729	2234.077
Sum	-0.022221	0.615246	0.376224	0.555956	-0.269826	0.446553
Sum Sq. Dev.	0.360564	0.247427	0.189402	0.288804	0.285393	0.169008
Observations	1850	1791	1788	1767	1800	1798

Table 5. Descriptive analysis of before covid sample

Full sample	China	USA	Japan	South Korea	Hong Kong	Taiwan
Mean	-0.000119	0.000414	0.000336	0.000232	7.41E-05	0.000145
Median	0.000697	0.000553	0.000576	0.000456	0.000612	0.000554
Maximum	0.056036	0.048403	0.074262	0.034728	0.041251	0.035175
Minimum	-0.088732	-0.041843	-0.082529	-0.045411	-0.060183	-0.065206
Std. Dev	0.015200	0.008504	0.012094	0.007825	0.011032	0.008273
Skewness	-1.275818	-0.546765	-0.213822	-0.473648	-0.343761	-0.893162
Kurtosis	10.17024	6.959767	9.258346	5.365257	5.281863	9.324659
Jarque-Bera	2987.872	843.0750	1944.535	323.2380	285.6358	2163.213
Sum	-0.147690	0.496787	0.398852	0.277683	0.089470	0.174270
Sum Sq. Dev.	0.285791	0.086646	0.173311	0.073118	0.146778	0.082190
Observations	1238	1199	1186	1195	1207	1202

Table 6. Descriptive analysis of during covid sample

Full sample	China	USA	Japan	South Korea	Hong Kong	Taiwan
Mean	0.000205	0.000200	0.000270	0.000166	-0.000606	0.000457
Median	0.000656	0.000940	0.000558	0.001108	0.000218	0.000794
Maximum	0.055542	0.089683	0.077314	0.082513	0.086928	0.061726
Minimum	-0.052680	-0.127652	-0.062736	-0.087670	-0.058867	-0.060055
Std. Dev	0.011059	0.016493	0.014111	0.014015	0.015292	0.012077
Skewness	-0.426903	-1.009416	0.073594	-0.189989	0.110416	-0.348368
Kurtosis	6.089749	15.09565	6.373392	9.500663	6.136074	6.338138
Jarque-Bera	262.0261	3709.382	276.0098	1047.707	244.2104	288.7771
Sum	0.125469	0.118459	0.157104	0.098541	-0.359296	0.272284
Sum Sq. Dev.	0.074731	0.160763	0.115491	0.116283	0.138432	0.086779
Observations	612	592	581	593	593	596

3.2.1. Skewness

Skewness is a feature of the degree of asymmetry in statistical data distribution. The number represents the asymmetry level of the probability distribution density curve concerning the average value. Intuitively, it is the relative length of the tail of the density function curve.

The normal distribution skewness is 0, and the tail lengths on both sides are symmetrical. Skewness < 0 means that the distribution has a negative deviation, also known as left skewness, where the data on the left of the mean is less than that on the right. Skewness > 0 means that the distribution has a positive deviation, also known as right skewness, where data on the right of the mean is less than that on the left.

In finance, negative skewness indicates that investors should expect more frequent small returns and significant losses and vice versa. According to the summary statistics, the skewness of the six regions are all negative in the full sample and the sample before pandemic. Only Japan and Hong Kong data are positively skewed in the during pandemic sample, indicating that these two stock markets have performed relatively better during the pandemic.

3.2.2. Kurtosis

Kurtosis, similar to skewness, is a statistic describing the steepness and calmness of the distribution compared with the normal distribution. A kurtosis of 0 indicates that the overall data distribution has the same steepness as the normal distribution. A kurtosis > 0 suggests that the overall data distribution is steep and sharp compared with the normal distribution. The kurtosis < 0 indicates that the general data distribution is flat compared with the normal distribution. The greater the absolute value of kurtosis, the greater the difference between its steepness and the normal distribution version.

In finance, kurtosis suggests the risk of investments, for higher kurtosis means a higher possibility of extremely high or low returns. In the three tables above, the kurtosis of the six markets are all positive and significant. The US stock market has the highest kurtosis of 15.1 during the pandemic, indicating high financial risk.

3.2.3. Jarque-Bera test

In statistics, the Jarque-Bera test checks whether the skewness and kurtosis of a sample data conform to the normal distribution, and a result much greater than zero indicates the data do not have a normal distribution.

For our sample data, we test if the statistic JB is large enough, and the result shows the Jarque-Bera test is significantly greater than zero, indicating the sample data of all countries and regions does not have a normal distribution. Yet as known before, if the population standard deviation is known and the sample size is large enough, the normal distribution should be used for better results. For consistency and conciseness, we use the normal distribution as an assumption.

4. Empirical Analysis

4.1 Check for stationarity

The stationary check involves two vital steps. In the 4.1.1 sections, we check the ADF test for nonstationarity in variables, namely the stock price. In the 4.1.2 sections, we check the ADF test for nonstationarity in dfference, namely stock returns. This is a necessary step before applying GARCH as the stock price should be tested unstationary, and the stock returns should be tested stationary for the latter analysis to unfold.

Stationary or nonstationary check employs the Augmented Dickey-Fuller test, also known as the unit root test. Failure to carry out the unit root test could lead to conducting regressions with nonstationary variables, which result in spurious regressions where the R-squared is abnormally high. The original Dickey-Fuller test conducts the following regression

$$\Delta y_t = \Psi y_{t-1} + u_t \, where \, u_t \sim N(0, \sigma^2)$$

As there exist issues of the dependent variable being auto-correlated with its previous values, so we regress the dependent variable on some more of its previous values. The format of the test is as follows:

$$\Delta y_t = \Psi y_{t-1} + \sum_{i=1}^{p} a_i \Delta y_{t-1} + u_t$$

H0: : Ψ=0 (The series contains a unit root and is unstationary)
HA: Ψ<0 (The series doesn't contain unit root and is stationary).

4.1.1 Graph analysis of stock price and ADF test for nonstationarity in variable

First, figure 3 demonstrates the graphical representation of stock indexes' close prices generated by Eviews, which is our interest variable in the first stationarity check. Carrying out the stationary check examines the existence of the unit root and whether the time series is stationary. In the first check, this study expects to contain a unit root and is unstationary. Only then is the condition met, and later analysis can be carried out.

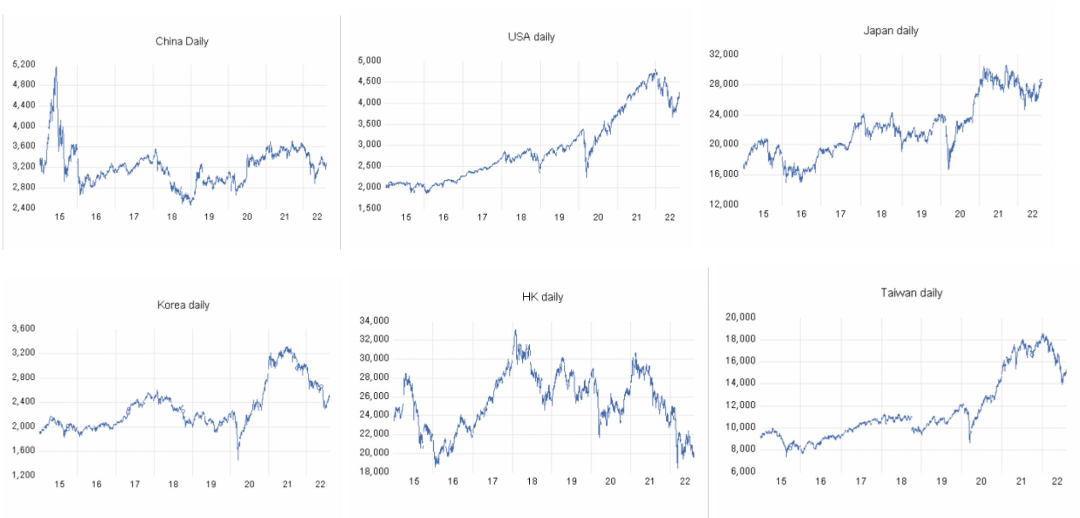


Figure 3. Stock close price graphical representation

The Augmented Dickey-Fuller test is carried out to check nonstationarity in the variable, and figure 4 present the test result for the full sample. Table 7 is a summary table of the ADF results in figure 4, highlighting the t-statistics and probabilities.

Augmented Dickey-Fuller Unit Root Test on CHINA_DAILY

Null Hypothesis: CHINA_DAILY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.908493	0.1599
Test critical values:	1% level	-3.963013	
	5% level	-3.412241	
	10% level	-3.128049	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CHINA_DAILY)
Method: Least Squares
Date: 08/19/22 Time: 17:13
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1849 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CHINA_DAILY(-1)	-0.008522	0.002930	-2.908493	0.0037
D(CHINA_DAILY(-1))	0.071410	0.023222	3.075136	0.0021
C	27.53984	9.828080	2.802159	0.0051
@TREND("1/05/2015")	-0.000136	0.002065	-0.065802	0.9475

R-squared	0.009065	Mean dependent var	-0.040322
Adjusted R-squared	0.007454	S.D. dependent var	47.44451
S.E. of regression	47.26735	Akaike info criterion	10.55168
Sum squared resid	4122104.	Schwarz criterion	10.56362
Log likelihood	-9751.026	Hannan-Quinn criter.	10.55608
F-statistic	5.626071	Durbin-Watson stat	1.990834
Prob(F-statistic)	0.000775		

Augmented Dickey-Fuller Unit Root Test on USA_DAILY

Null Hypothesis: USA_DAILY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 13 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.784976	0.9654
Test critical values:	1% level	-3.967667	
	5% level	-3.414516	
	10% level	-3.129398	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(USA_DAILY)
Method: Least Squares
Date: 08/19/22 Time: 15:56
Sample (adjusted): 2/09/2015 8/12/2022
Included observations: 957 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
USA_DAILY(-1)	-0.003267	0.004161	-0.784976	0.4327
D(USA_DAILY(-1))	-0.077219	0.032274	-2.392606	0.0169
D(USA_DAILY(-2))	0.053716	0.032154	1.670574	0.0951
D(USA_DAILY(-3))	-0.043289	0.032362	-1.337626	0.1813
D(USA_DAILY(-4))	-0.000411	0.032257	-0.012737	0.9898
D(USA_DAILY(-5))	0.056400	0.031495	1.790733	0.0737
D(USA_DAILY(-6))	-0.092107	0.031449	-2.928744	0.0035
D(USA_DAILY(-7))	0.093819	0.031449	2.983203	0.0029
D(USA_DAILY(-8))	-0.104289	0.031635	-3.296604	0.0010
D(USA_DAILY(-9))	0.100069	0.031768	3.149961	0.0017
D(USA_DAILY(-10))	0.016582	0.031611	0.524559	0.6000
D(USA_DAILY(-11))	-0.011078	0.032026	-0.345924	0.7295
D(USA_DAILY(-12))	-0.000139	0.032163	-0.004323	0.9966
D(USA_DAILY(-13))	-0.089127	0.032054	-2.780502	0.0055
C	3.107135	7.138197	0.435283	0.6635
@TREND("1/05/2015")	0.009648	0.006220	1.551072	0.1212

R-squared	0.120182	Mean dependent var	2.329352
Adjusted R-squared	0.106157	S.D. dependent var	36.67555
S.E. of regression	34.67427	Akaike info criterion	9.946450
Sum squared resid	1131369.	Schwarz criterion	10.02777
Log likelihood	-4743.377	Hannan-Quinn criter.	9.977423
F-statistic	8.569267	Durbin-Watson stat	2.036010
Prob(F-statistic)	0.000000		

Augmented Dickey-Fuller Unit Root Test on JAPAN_DAILY

Null Hypothesis: JAPAN_DAILY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.854741	0.1779
Test critical values:	1% level	-3.963554	
	5% level	-3.412505	
	10% level	-3.128206	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(JAPAN_DAILY)
Method: Least Squares
Date: 08/19/22 Time: 16:03
Sample (adjusted): 1/06/2015 8/10/2022
Included observations: 1668 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
JAPAN_DAILY(-1)	-0.009683	0.003392	-2.854741	0.0044
C	166.4162	57.67584	2.885372	0.0040
@TREND("1/05/2015")	0.058374	0.024253	2.406938	0.0162

R-squared	0.004872	Mean dependent var	5.991130
Adjusted R-squared	0.003676	S.D. dependent var	279.1199
S.E. of regression	278.6064	Akaike info criterion	14.09927
Sum squared resid	1.29E+08	Schwarz criterion	14.10902
Log likelihood	-11755.79	Hannan-Quinn criter.	14.10289
F-statistic	4.075516	Durbin-Watson stat	2.036935
Prob(F-statistic)	0.017153		

Augmented Dickey-Fuller Unit Root Test on KOREA_DAILY

Null Hypothesis: KOREA_DAILY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.678937	0.7604
Test critical values:	1% level	-3.963368	
	5% level	-3.412415	
	10% level	-3.128152	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(KOREA_DAILY)
Method: Least Squares
Date: 08/19/22 Time: 16:07
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1726 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
KOREA_DAILY(-1)	-0.003380	0.002013	-1.678937	0.0933
C	6.959033	3.949236	1.762121	0.0782
@TREND("1/05/2015")	0.001435	0.001447	0.992027	0.3213

R-squared	0.001652	Mean dependent var	0.437856
Adjusted R-squared	0.000493	S.D. dependent var	23.89404
S.E. of regression	23.88815	Akaike info criterion	9.186379
Sum squared resid	983219.2	Schwarz criterion	9.195858
Log likelihood	-7924.845	Hannan-Quinn criter.	9.189885
F-statistic	1.425308	Durbin-Watson stat	2.001655
Prob(F-statistic)	0.240718		

Augmented Dickey-Fuller Unit Root Test on HK_DAILY

Null Hypothesis: HK_DAILY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.855243	0.6771
Test critical values:	1% level	-3.963280	
	5% level	-3.412371	
	10% level	-3.128127	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(HK_DAILY)
Method: Least Squares
Date: 08/19/22 Time: 16:09
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1755 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HK_DAILY(-1)	-0.004711	0.002539	-1.855243	0.0637
C	124.5375	64.50288	1.930728	0.0537
@TREND("1/05/2015")	-0.005696	0.014487	-0.393211	0.6942

R-squared	0.002233	Mean dependent var	-0.882381
Adjusted R-squared	0.001094	S.D. dependent var	320.1399
S.E. of regression	319.9648	Akaike info criterion	14.37601
Sum squared resid	1.79E+08	Schwarz criterion	14.38536
Log likelihood	-12611.95	Hannan-Quinn criter.	14.37946
F-statistic	1.960461	Durbin-Watson stat	1.995157
Prob(F-statistic)	0.141102		

Augmented Dickey-Fuller Unit Root Test on TAIWAN_DAILY

Null Hypothesis: TAIWAN_DAILY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.304854	0.4305
Test critical values:	1% level	-3.963277	
	5% level	-3.412370	
	10% level	-3.128126	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TAIWAN_DAILY)
Method: Least Squares
Date: 08/19/22 Time: 16:13
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1756 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TAIWAN_DAILY(-1)	-0.004451	0.001931	-2.304854	0.0213
C	32.16887	14.92086	2.155966	0.0312
@TREND("1/05/2015")	0.023671	0.010715	2.209129	0.0273

R-squared	0.003119	Mean dependent var	2.394569
Adjusted R-squared	0.001982	S.D. dependent var	118.4909
S.E. of regression	118.3734	Akaike info criterion	12.38727
Sum squared resid	24563506	Schwarz criterion	12.39662
Log likelihood	-10873.03	Hannan-Quinn criter.	12.39073
F-statistic	2.742382	Durbin-Watson stat	1.931621
Prob(F-statistic)	0.064693		

Figure 4. Eviews ADF test for price result

Table 7. Eviews ADF test for price result t statistics and probabilities

Full Sample	statistic	Prob.
China	-2.908493	0.1599
USA	-0.784976	0.9654
Japan	-2.854741	0.1779
South Korea	-1.678937	0.7604
Hong Kong	-1.855243	0.6771
Taiwan	-2.304854	0.4305

As shown in the outcome, all the countries and regions studied successfully pass the ADF test for nonstationarity in the variable with probabilities greater than 0.05. Therefore the study concludes that the series contains a unit root and is unstationary.

Before moving on to ADF tests in differences, checking intercept and trend is necessary when implementing section 4.1.2. ADF test for difference requires the knowledge of the existence of intercept and trend or not, and the decision is based on the ADF result of the variable in 4.1.1. The summary table is demonstrated in table 8.

For China, Japan, and Taiwan at 5% significance levels, the intercept option in the next section studying ADF for the difference is necessary since their probabilities are less than 0.05. The constant intercept is unnecessary with probabilities greater than 0.05 for the USA, Korea, and Hong Kong, yet is necessary with probabilities smaller than 0.05 for China (really close), Japan, and Taiwan. The trend is not necessary for China, USA, South Korea, and Hong Kong since their probabilities of the trend are more significant than 0.05, signaling no apparent trend. Yet for Japan and Taiwan, their probabilities are less than 0.05. This trend can be confirmed by the close price graph going upward in figure 3 and thus need to be included in 4.1.2.

Table 8. Eviews ADF test result intercept and trend t statistics and probabilities

Full Sample	Intercept statistic	Intercept Prob.	Trend statistic	Trend Prob.
China	27.53984	0.0051	-0.000136	0.9475
USA	3.107135	0.6635	0.009648	0.1212
Japan	166.4162	0.0040	0.058374	0.0162
South Korea	6.959033	0.0782	0.001435	0.3213
Hong Kong	124.5375	0.0537	-0.005696	0.6942
Taiwan	32.16887	0.0312	0.023671	0.0273

4.1.2 Graph analysis of stock return and ADF test for difference

After testing nonstationarity in the closing price, the study explores stationary in difference. The dependent variable is the natural logarithmic returns calculated from the daily close price of the index. Figure 5 demonstrates the graphical representation of the return series generated by Eviews, which is our interest variable in the second stationarity check. Carrying out the stationary check examines the existence of the unit root and whether the time series is stationary. In the second check, this study expects the series doesn't contain unit roots and to be stationary. Only then is the condition met, and later analysis can be carried out.

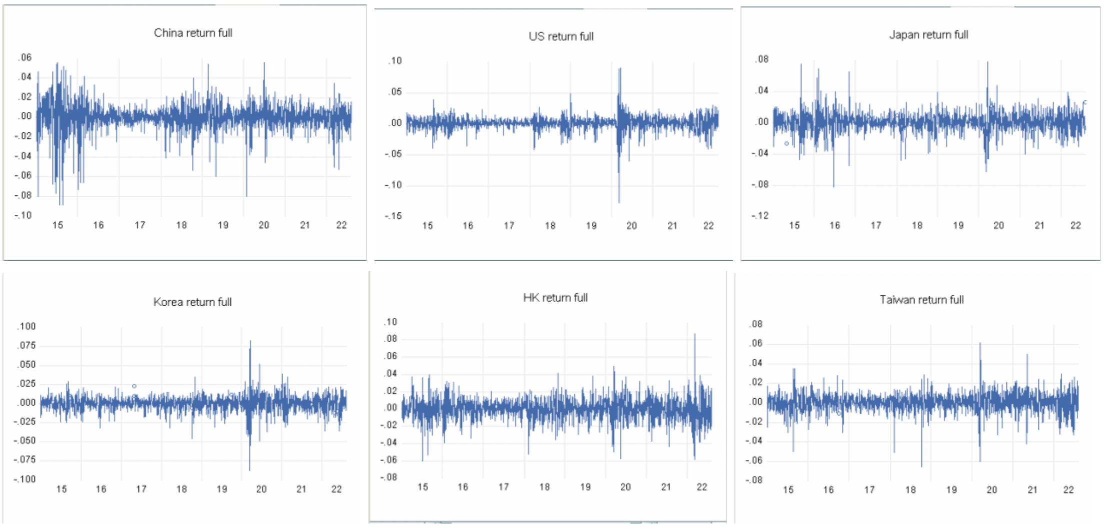


Figure 5. Natural logarithmic returns for China and its top five trading partners' chosen stock index full sample

In light of the graphical representation, volatility is not static and possesses particular aggregation effects. The graph shows convergence points, and the yields near the convergence point seem to be significant. The study easily observes volatility clustering, where periods of large changes are followed by further periods of similar large changes while small changes follow periods of small changes. The wild and calm periods with large and small values occurring persistently in clusters are an initial indication of the ARCH effect in the return series. The variance looks stationary and nonconstant, which will be proved by the ADF result.

Figure 5 presents the test result for the full sample where the Augmented Dickey-Fuller test is carried out to check stationarity in the difference. Table 9 summarizes the ADF results in figure 6, highlighting the t-statistics and probabilities. As shown in the outcome, all the countries and regions studied successfully pass the ADF test for stationarity in the difference with probabilities greater than 0.05. Therefore the study concludes that the series doesn't contain a unit root and is stationary.

Augmented Dickey-Fuller Unit Root Test on CHINA_RETURN_FULL

Null Hypothesis: CHINA_RETURN_FULL has a unit root
Exogenous: Constant
Lag Length: 13 (Automatic - based on AIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-12.14336	0.0000
Test critical values:	1% level	-3.433710	
	5% level	-2.862911	
	10% level	-2.567547	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CHINA_RETURN_FULL)
Method: Least Squares
Date: 08/18/22 Time: 22:25
Sample (adjusted): 1/26/2015 8/12/2022
Included observations: 1836 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CHINA_RETURN_FULL(-1)	-1.009517	0.083133	-12.14336	0.0000
D(CHINA_RETURN_FULL(-1))	0.063528	0.080338	0.790761	0.4292
D(CHINA_RETURN_FULL(-2))	0.049007	0.076977	0.636649	0.5244
D(CHINA_RETURN_FULL(-3))	0.068902	0.073479	0.937703	0.3485
D(CHINA_RETURN_FULL(-4))	0.091072	0.069922	1.302472	0.1929
D(CHINA_RETURN_FULL(-5))	0.086706	0.066585	1.302184	0.1930
D(CHINA_RETURN_FULL(-6))	0.016880	0.062981	0.268020	0.7887
D(CHINA_RETURN_FULL(-7))	0.049763	0.058887	0.845051	0.3982
D(CHINA_RETURN_FULL(-8))	0.081471	0.054142	1.504749	0.1326
D(CHINA_RETURN_FULL(-9))	0.094594	0.049666	1.904605	0.0570
D(CHINA_RETURN_FULL(-10))	0.049156	0.044797	1.097310	0.2727
D(CHINA_RETURN_FULL(-11))	0.033498	0.038992	0.859105	0.3904
D(CHINA_RETURN_FULL(-12))	0.026253	0.031772	0.826277	0.4088
D(CHINA_RETURN_FULL(-13))	0.095681	0.022996	4.160720	0.0000
C	-1.51E-05	0.000319	-0.047449	0.9622

R-squared	0.490257	Mean dependent var	-2.16E-06
Adjusted R-squared	0.486338	S.D. dependent var	0.019049
S.E. of regression	0.013652	Akaike info criterion	-5.741673
Sum squared resid	0.339410	Schwarz criterion	-5.696613
Log likelihood	5285.856	Hannan-Quinn criter.	-5.725056
F-statistic	125.0993	Durbin-Watson stat	1.996141
Prob(F-statistic)	0.000000		

Augmented Dickey-Fuller Unit Root Test on US_RETURN_FULL

Null Hypothesis: US_RETURN_FULL has a unit root
Exogenous: None
Lag Length: 7 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.31978	0.0000
Test critical values:	1% level	-2.566738	
	5% level	-1.941067	
	10% level	-1.616536	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(US_RETURN_FULL)
Method: Least Squares
Date: 08/19/22 Time: 17:02
Sample (adjusted): 1/15/2015 8/12/2022
Included observations: 1303 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
US_RETURN_FULL(-1)	-1.102107	0.082742	-13.31978	0.0000
D(US_RETURN_FULL(-1))	-0.019873	0.078045	-0.254631	0.7990
D(US_RETURN_FULL(-2))	0.067944	0.071396	0.951649	0.3415
D(US_RETURN_FULL(-3))	0.078055	0.065171	1.197693	0.2313
D(US_RETURN_FULL(-4))	0.011645	0.058316	0.199695	0.8418
D(US_RETURN_FULL(-5))	0.046159	0.051758	0.891833	0.3726
D(US_RETURN_FULL(-6))	-0.026192	0.043152	-0.606976	0.5440
D(US_RETURN_FULL(-7))	0.100728	0.028349	3.553121	0.0004

R-squared	0.617750	Mean dependent var	0.000129
Adjusted R-squared	0.615684	S.D. dependent var	0.018857
S.E. of regression	0.011690	Akaike info criterion	-6.054052
Sum squared resid	0.176968	Schwarz criterion	-6.022295
Log likelihood	3952.215	Hannan-Quinn criter.	-6.042138
Durbin-Watson stat	2.026050		

Augmented Dickey-Fuller Unit Root Test on JAPAN_RETURN_FULL

Null Hypothesis: JAPAN_RETURN_FULL has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on SIC, maxlag=24)

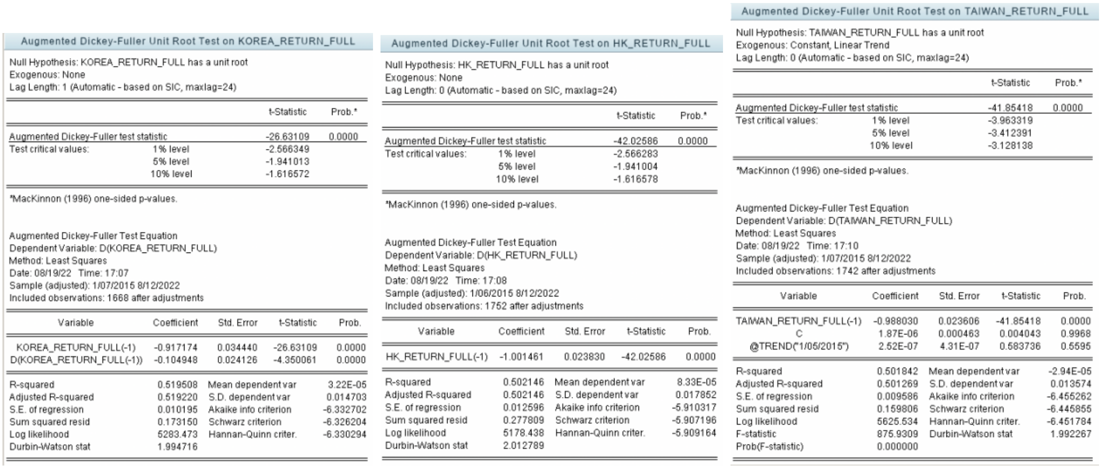
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-17.82215	0.0000
Test critical values:	1% level	-3.964893	
	5% level	-3.413160	
	10% level	-3.128594	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(JAPAN_RETURN_FULL)
Method: Least Squares
Date: 08/19/22 Time: 17:05
Sample (adjusted): 1/20/2015 8/10/2022
Included observations: 1343 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
JAPAN_RETURN_FULL(-1)	-1.086285	0.060951	-17.82215	0.0000
D(JAPAN_RETURN_FULL(-...	0.079651	0.053423	1.490955	0.1362
D(JAPAN_RETURN_FULL(-...	0.095904	0.045227	2.120535	0.0341
D(JAPAN_RETURN_FULL(-...	0.050226	0.036981	1.358140	0.1746
D(JAPAN_RETURN_FULL(-...	0.010448	0.025487	0.409935	0.6819
C	0.000540	0.000661	0.815945	0.4147
@TREND("1/05/2015")	-2.65E-07	6.16E-07	-0.430530	0.6669

R-squared	0.514736	Mean dependent var	-2.42E-05
Adjusted R-squared	0.512557	S.D. dependent var	0.017384
S.E. of regression	0.012137	Akaike info criterion	-5.979949
Sum squared resid	0.196796	Schwarz criterion	-5.952831
Log likelihood	4022.535	Hannan-Quinn criter.	-5.969790
F-statistic	236.1903	Durbin-Watson stat	1.997585
Prob(F-statistic)	0.000000		



Augmented Dickey-Fuller Unit Root Test on KOREA_RETURN_FULL

Null Hypothesis: KOREA_RETURN_FULL has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-26.63109	0.0000
Test critical values:	1% level	-2.566349	
	5% level	-1.941013	
	10% level	-1.616572	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(KOREA_RETURN_FULL)
Method: Least Squares
Date: 08/19/22 Time: 17:07
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1668 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
KOREA_RETURN_FULL(-1)	-0.917174	0.034440	-26.63109	0.0000
D(KOREA_RETURN_FULL(-1))	-0.104948	0.024126	-4.350061	0.0000

R-squared	0.519508	Mean dependent var	3.22E-05
Adjusted R-squared	0.519220	S.D. dependent var	0.014703
S.E. of regression	0.010195	Akaike info criterion	-6.332702
Sum squared resid	0.173150	Schwarz criterion	-6.326204
Log likelihood	5283.473	Hannan-Quinn criter.	-6.330294
Durbin-Watson stat	1.994716		

Augmented Dickey-Fuller Unit Root Test on HK_RETURN_FULL

Null Hypothesis: HK_RETURN_FULL has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-42.02586	0.0000
Test critical values:	1% level	-2.566283	
	5% level	-1.941004	
	10% level	-1.616578	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(HK_RETURN_FULL)
Method: Least Squares
Date: 08/19/22 Time: 17:08
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1752 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HK_RETURN_FULL(-1)	-1.001461	0.023830	-42.02586	0.0000

R-squared	0.502146	Mean dependent var	8.33E-05
Adjusted R-squared	0.502146	S.D. dependent var	0.017852
S.E. of regression	0.012596	Akaike info criterion	-5.910317
Sum squared resid	0.277809	Schwarz criterion	-5.907196
Log likelihood	5178.438	Hannan-Quinn criter.	-5.909164
Durbin-Watson stat	2.012789		

Augmented Dickey-Fuller Unit Root Test on TAIWAN_RETURN_FULL

Null Hypothesis: TAIWAN_RETURN_FULL has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-41.85418	0.0000
Test critical values:	1% level	-3.963319	
	5% level	-3.412391	
	10% level	-3.128138	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TAIWAN_RETURN_FULL)
Method: Least Squares
Date: 08/19/22 Time: 17:10
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1742 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TAIWAN_RETURN_FULL(-1)	-0.988030	0.023606	-41.85418	0.0000
C	1.87E-06	0.000463	0.004043	0.9968
@TREND("1/05/2015")	2.52E-07	4.31E-07	0.583736	0.5595

R-squared	0.501842	Mean dependent var	-2.94E-05
Adjusted R-squared	0.501269	S.D. dependent var	0.013574
S.E. of regression	0.009586	Akaike info criterion	-6.455262
Sum squared resid	0.159806	Schwarz criterion	-6.445855
Log likelihood	5625.534	Hannan-Quinn criter.	-6.451784
F-statistic	875.9309	Durbin-Watson stat	1.992267
Prob(F-statistic)	0.000000		

Figure 6. Eviews ADF test for difference result

Table 9. Eviews ADF test for difference result t statistics and probabilities

Full Sample	**statistic**	**p.value**
China	-12.14336	0.0000
USA	-13.31978	0.0000
Japan	-17.82216	0.0000
South Korea	-26.63109	0.0000
Hong Kong	-42.02586	0.0000
Taiwan	-41.85418	0.0000

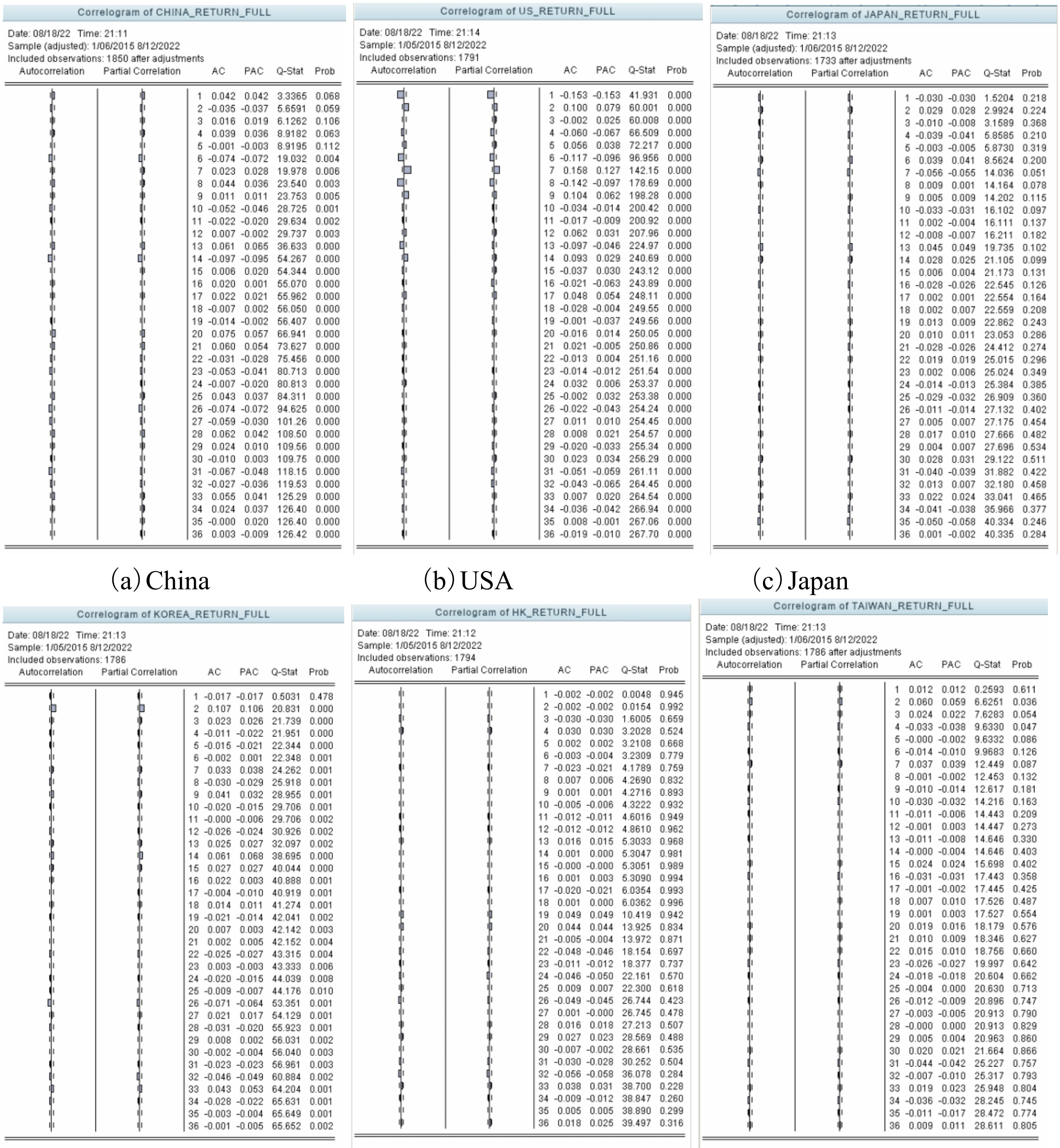
As shown in the outcome, all the countries and regions studied successfully pass the ADF test for stationarity in the difference. In all cases, probabilities are 0.0000, below 0.05, and reject the null hypothesis that the variable contains a unit root and is not stationary.

From the above tests, we confirm that our variable is nonstationary in levels but is stationary in log differences returns. Fulfilling these two stationary requirements allows the study's following estimate of the ARMA model and the best specifications.

4.2 Estimation of the mean equation

4.2.1 Auto-correlation, partial autocorrelation and best ARMA specification

This study intends to use model estimation and forecasting with the best ARMA specifications. The study first looks at the correlograms of returns to decide whether the processes are autoregressive, moving average, or both. The best ARMA specification requires determining the respective order of p and q. From Figure 7, correlograms of return generated by Eviews, the study observes that the plots of auto-correlation functions don't have exponentially declining ACF, nor are the spikes in the first one or more lags of the PACF evident enough to indicate the ARMA order.



(a) China (b) USA (c) Japan

(d) South Korea (e) Hong Kong (f) Taiwan

Figure 7. Eviews correlogram for difference result

Therefore, this study determines the p and q value for the ARMA model by finding the specification which minimizes the Schwarz information criterion value. Since ARMA specifications generally do not exceed ARMA(5,5) models in common reality practice, the research used Eviews to conduct one-by-one tests for the best combination. The best ARMA specification result is listed below in Table 10-12 by selecting the most minor Schwarz information criterion term among all the specifications within ARMA(5,5). The complete process is attached to the appendix.

Table 10. Estimation of ARMA(p,q) models for the best ARMA model specification full sample.

Full Sample	China	USA	Japan	South Korea	Hong Kong	Taiwan
Chosen specification	ARMA(5,4)	ARMA(4,2)	AR(1)	AR(2)	AR(1)	AR(1)

Table 11. Estimation of ARMA(p,q) models for the best ARMA model specification before covid.

Before Covid Sample	China	USA	Japan	South Korea	Hong Kong	Taiwan
Chosen specification	ARMA(3,2)	AR(1)	AR(1)	AR(2)	MA(1)	AR(1)

Table 12. Estimation of ARMA(p,q) models for the best ARMA model specification after covid.

During Covid Sample	China	USA	Japan	South Korea	Hong Kong	Taiwan
Chosen specification	MA(1)	ARMA(4,4)	MA(1)	MA(2)	MA(1)	MA(1)

This study finds the most suitable ARMA specification for each return series from the above tests. Thus model estimation and forecasting in the following sections will employ the optimal ARMA specification results.

4.3 Model estimation with GARCH(1,1)

In GARCH(1,1) model, past volatility influences current volatility, and the error term's variance is captured using the error term's variance value in the previous periods. This characteristic implies that if volatility is significant in the previous period, the forecast will predict higher volatility.

The conditional variance equation is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

Section 4.3.1 presents the estimation output of the Garch(1,1) with the result analysis focusing on the variance equation than the mean equation. Section 4.3.2 offers the Diagnostic tests following the result, comprised of section 4.3.2.1, the Ljung-Box test, and section 4.3.2.1, the ARCH-LM test.

4.3.1 Model estimation and general characteristic on variance forecast and shock

In Eviews implementation, this study employs the order ARCH 1, GARCH 1, Threshold Order 0, and Eviews legacy as the optimization method. The mean equation uses the ARMA specification determined in 4.2.1. Figure 8 illustrates the Eviews GARCH(1,1) full sample result, and Table 13 highlights the ARCH term and GARCH term in the GARCH(1,1) result.

The result shows that future forecasts of persisting high variance come with significant excessive returns, and the return will experience consistent shocks, including those of covid-19 pandemic. For China, the US, Japan, South Korea, Hong Kong, and Taiwan, the ARCH and GARCH terms are significant at 5%, which is 0.0000 in all cases. Since the GARCH term is significant, a large excess return value will lead to future forecasts of the variance being high for a prolonged period. The sums of GARCH and ARCH coefficients in China, USA, Japan, South Korea, Hong Kong, and Taiwan are respectively 0.996399, 0.969144, 0.949389, 0.954360, 0.982081, 0.944738, all very close to 1. This result implies that any shocks experienced by conditional variance will be highly consistent, indicating that shocks persist with the ongoing shock of the COVID-19 pandemic.

The GARCH term is significant, which implies that GARCH generally works better than ARCH in high volatility. Thus the study goes beyond GARCH(1,1) and looks into EGARCH in 4.4 and GJR-GARCH in 4.5.

Dependent Variable: CHINA_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 09:01
Sample (adjusted): 1/13/2015 8/12/2022
Included observations: 1845 after adjustments
Convergence achieved after 45 iterations
MA Backcast: 1/07/2015 1/12/2015
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.494213	0.025239	-19.58118	0.0000
AR(2)	0.033993	0.017418	1.951674	0.0510
AR(3)	-0.478777	0.013195	-36.28533	0.0000
AR(4)	-0.945381	0.016838	-56.14432	0.0000
AR(5)	0.011757	0.024268	0.484477	0.6280
MA(1)	0.528429	0.009261	57.05715	0.0000
MA(2)	-0.014223	0.012679	-1.121828	0.2619
MA(3)	0.497395	0.010474	47.49029	0.0000
MA(4)	0.977594	0.007784	125.5842	0.0000
Variance Equation				
C	1.48E-06	3.06E-07	4.830706	0.0000
RESID(-1)^2	0.094684	0.006145	15.40768	0.0000
GARCH(-1)	0.901715	0.005435	165.9198	0.0000

R-squared	0.027660	Mean dependent var	7.93E-06
Adjusted R-squared	0.023423	S.D. dependent var	0.013965
S.E. of regression	0.013801	Akaike info criterion	-6.124669
Sum squared resid	0.349687	Schwarz criterion	-6.088765
Log likelihood	5662.007	Hannan-Quinn criter.	-6.111432
Durbin-Watson stat	1.960981		

Inverted AR Roots	.59+.79i	.59-.79i	.01	-.84-.52i
	-.84+.52i			
Inverted MA Roots	.59+.80i	.59-.80i	-.85-.52i	-.85+.52i

(a) China

Dependent Variable: US_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 09:37
Sample (adjusted): 1/09/2015 8/12/2022
Included observations: 1912 after adjustments
Convergence achieved after 16 iterations
MA Backcast: 1/07/2015 1/08/2015
Presample variance: backcast (parameter = 0.7)
GARCH = C(7) + C(8)*RESID(-1)^2 + C(9)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.232258	0.414557	-0.560256	0.5753
AR(2)	-0.262213	0.274610	-0.954858	0.3396
AR(3)	-0.021337	0.029400	-0.725761	0.4680
AR(4)	0.003068	0.023091	0.132873	0.8943
MA(1)	0.177393	0.414807	0.427653	0.6689
MA(2)	0.282053	0.268506	1.050453	0.2935
Variance Equation				
C	4.22E-06	4.53E-07	9.312955	0.0000
RESID(-1)^2	0.205822	0.017647	11.66313	0.0000
GARCH(-1)	0.763322	0.017705	43.11384	0.0000

R-squared	0.020291	Mean dependent var	0.000382
Adjusted R-squared	0.017721	S.D. dependent var	0.011724
S.E. of regression	0.011619	Akaike info criterion	-6.653000
Sum squared resid	0.257322	Schwarz criterion	-6.626848
Log likelihood	6369.268	Hannan-Quinn criter.	-6.643375
Durbin-Watson stat	2.209264		

Inverted AR Roots	.07	-.07+.51i	-.07-.51i	-.16
Inverted MA Roots	-.09-.52i	-.09+.52i		

(b) USA

Dependent Variable: JAPAN_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 10:02
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1878 after adjustments
Convergence achieved after 12 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.030061	0.025355	-1.185597	0.2358
Variance Equation				
C	8.32E-06	1.27E-06	6.573551	0.0000
RESID(-1)^2	0.129988	0.012977	10.01702	0.0000
GARCH(-1)	0.819401	0.017526	46.75239	0.0000

R-squared	-0.000006	Mean dependent var	0.000280
Adjusted R-squared	-0.000006	S.D. dependent var	0.012805
S.E. of regression	0.012805	Akaike info criterion	-6.084550
Sum squared resid	0.307758	Schwarz criterion	-6.072754
Log likelihood	5717.392	Hannan-Quinn criter.	-6.080205
Durbin-Watson stat	1.981306		
Inverted AR Roots	-.03		

(c) Japan

Dependent Variable: KOREA_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 10:08
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1869 after adjustments
Convergence achieved after 9 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.019835	0.025809	0.768536	0.4422
AR(2)	0.046843	0.024812	1.887935	0.0590
Variance Equation				
C	4.42E-06	8.56E-07	5.161748	0.0000
RESID(-1)^2	0.127011	0.014310	8.875891	0.0000
GARCH(-1)	0.827349	0.019176	43.14606	0.0000

R-squared	0.006516	Mean dependent var	0.000158
Adjusted R-squared	0.005984	S.D. dependent var	0.010344
S.E. of regression	0.010313	Akaike info criterion	-6.596964
Sum squared resid	0.198559	Schwarz criterion	-6.582162
Log likelihood	6169.863	Hannan-Quinn criter.	-6.591510
Durbin-Watson stat	2.048851		
Inverted AR Roots	.23	-.21	

(d) South Korea

Dependent Variable: HK_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 10:12
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1876 after adjustments
Convergence achieved after 12 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.022431	0.023975	0.935607	0.3495
Variance Equation				
C	3.04E-06	6.44E-07	4.725202	0.0000
RESID(-1)^2	0.067766	0.007606	8.909497	0.0000
GARCH(-1)	0.914315	0.009154	99.88105	0.0000

R-squared	-0.000218	Mean dependent var	-8.63E-05
Adjusted R-squared	-0.000218	S.D. dependent var	0.012712
S.E. of regression	0.012713	Akaike info criterion	-6.036053
Sum squared resid	0.303054	Schwarz criterion	-6.024247
Log likelihood	5665.817	Hannan-Quinn criter.	-6.031704
Durbin-Watson stat	2.029022		
Inverted AR Roots	.02		

(e) Hong Kong

Dependent Variable: TAIWAN_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 10:20
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1858 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.020013	0.024457	0.818296	0.4132
Variance Equation				
C	5.50E-06	1.03E-06	5.331691	0.0000
RESID(-1)^2	0.122670	0.010954	11.19851	0.0000
GARCH(-1)	0.822068	0.019338	42.51061	0.0000

R-squared	-0.000676	Mean dependent var	0.000282
Adjusted R-squared	-0.000676	S.D. dependent var	0.009822
S.E. of regression	0.009825	Akaike info criterion	-6.580822
Sum squared resid	0.179256	Schwarz criterion	-6.568923
Log likelihood	6117.584	Hannan-Quinn criter.	-6.576437
Durbin-Watson stat	2.013393		
Inverted AR Roots	.02		

(f) Taiwan

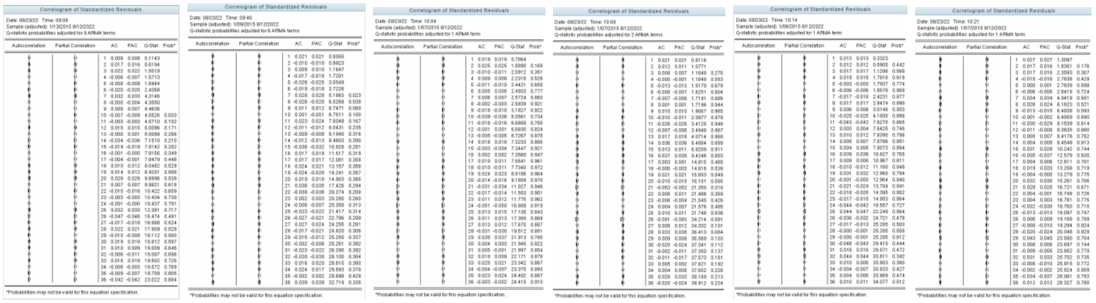
Figure 8. Eviews GARCH(1,1) full sample result

Table 13. Eviews GARCH(1,1) ARCH term and GARCH term result

Full Sample			**China**	**USA**	**Japan**	**South Korea**	**Hong Kong**	**Taiwan**
Full sample	ARCH term	stats	0.094684	0.205822	0.129988	0.127011	0.067766	0.122670
		prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	GARCH term	stats	0.901715	0.763322	0.819401	0.827349	0.914315	0.822068
		prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

4.3.2.1 Ljung-Box test in GARCH(1,1)

As described in section 2.4.3, the Ljung-Box test helps assess whether the time series of interest is autocorrelated. The null hypothesis of the test is that the autocorrelations of the given sample are all zero. If the p-value we get from the test is larger than 0.05, we fail to reject the null hypothesis, and the model is lack of fit. Figure 9 presents the Ljung Box test result.



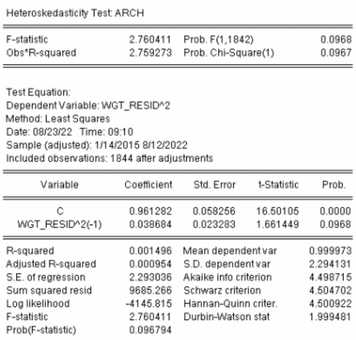
China USA Japan South Korea Hong Kong Taiwan

Figure 9. Eviews GARCH(1,1) full sample Ljung-Box test result

Except China at lag 10 yield 0.033, US at lag7 yield 0.023, lag8 yield 0.038, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.

4.3.2.2 ARCH-LM test

As described in section 2.4.3, the ARCH-LM test is a test for ARCH effects by regressing the squared errors on different specified lags. The null hypothesis is that the lagged regression coefficients are zero, there is no existing ARCH up to order q in the residuals, and there are no ARCH effects. If the p-value we get from the test is larger than 0.05, we reject the null hypothesis, and there are ARCH effects. We expect rejecting the null hypothesis to pass the ARCH LM diagnostic test in the section successfully. Figure 10 presents the ARCH LM test result, and table 14 summarizes the Prob. Chi-Square results.



Heteroskedasticity Test: ARCH

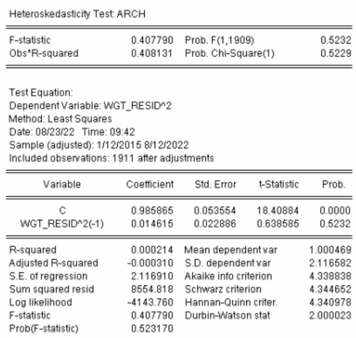
F-statistic	2.760411	Prob. F(1,1842)	0.0968
Obs*R-squared	2.759273	Prob. Chi-Square(1)	0.0967

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 09:10
Sample (adjusted): 1/14/2015 8/12/2022
Included observations: 1844 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.961282	0.058256	16.50105	0.0000
WGT_RESID^2(-1)	0.038684	0.023283	1.661449	0.0968

R-squared	0.001496	Mean dependent var	0.999973
Adjusted R-squared	0.000954	S.D. dependent var	2.294131
S.E. of regression	2.293036	Akaike info criterion	4.498715
Sum squared resid	9685.266	Schwarz criterion	4.504702
Log likelihood	-4145.815	Hannan-Quinn criter.	4.500922
F-statistic	2.760411	Durbin-Watson stat	1.999481
Prob(F-statistic)	0.096794		

(a) China



Heteroskedasticity Test: ARCH

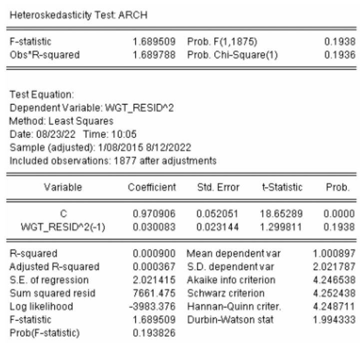
F-statistic	0.407790	Prob. F(1,1909)	0.5232
Obs*R-squared	0.408131	Prob. Chi-Square(1)	0.5229

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 09:42
Sample (adjusted): 1/12/2015 8/12/2022
Included observations: 1911 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.985865	0.053554	18.40884	0.0000
WGT_RESID^2(-1)	0.014615	0.022886	0.638585	0.5232

R-squared	0.000214	Mean dependent var	1.000469
Adjusted R-squared	-0.000310	S.D. dependent var	2.116582
S.E. of regression	2.116910	Akaike info criterion	4.338838
Sum squared resid	8554.818	Schwarz criterion	4.344652
Log likelihood	-4143.760	Hannan-Quinn criter.	4.340978
F-statistic	0.407790	Durbin-Watson stat	2.000023
Prob(F-statistic)	0.523170		

(b) USA



Heteroskedasticity Test: ARCH

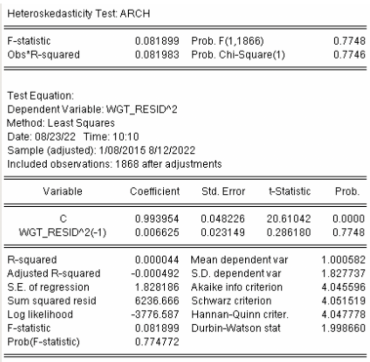
F-statistic	1.689509	Prob. F(1,1875)	0.1938
Obs*R-squared	1.689788	Prob. Chi-Square(1)	0.1936

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 10:05
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1877 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.970906	0.052051	18.65289	0.0000
WGT_RESID^2(-1)	0.030083	0.023144	1.299811	0.1938

R-squared	0.000900	Mean dependent var	1.000897
Adjusted R-squared	0.000367	S.D. dependent var	2.021787
S.E. of regression	2.021415	Akaike info criterion	4.246538
Sum squared resid	7661.475	Schwarz criterion	4.252438
Log likelihood	-3983.376	Hannan-Quinn criter.	4.248711
F-statistic	1.689509	Durbin-Watson stat	1.994333
Prob(F-statistic)	0.193826		

(c) Japan



Heteroskedasticity Test: ARCH

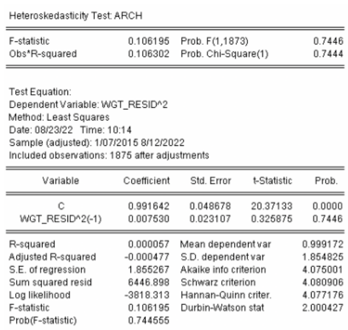
F-statistic	0.081899	Prob. F(1,1866)	0.7748
Obs*R-squared	0.081983	Prob. Chi-Square(1)	0.7746

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 10:10
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1868 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.993954	0.048226	20.61042	0.0000
WGT_RESID^2(-1)	0.006625	0.023149	0.286180	0.7748

R-squared	0.000044	Mean dependent var	1.000582
Adjusted R-squared	-0.000492	S.D. dependent var	1.827737
S.E. of regression	1.828186	Akaike info criterion	4.045596
Sum squared resid	6236.666	Schwarz criterion	4.051519
Log likelihood	-3776.587	Hannan-Quinn criter.	4.047778
F-statistic	0.081899	Durbin-Watson stat	1.998660
Prob(F-statistic)	0.774772		

(d) South Korea



Heteroskedasticity Test: ARCH

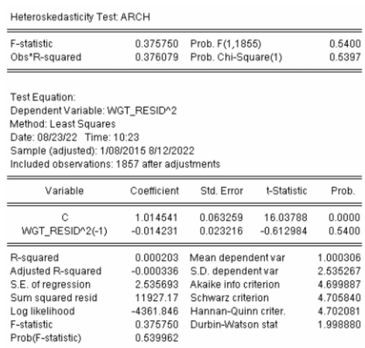
F-statistic	0.106195	Prob. F(1,1873)	0.7446
Obs*R-squared	0.106302	Prob. Chi-Square(1)	0.7444

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 10:14
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1875 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.991642	0.048678	20.37133	0.0000
WGT_RESID^2(-1)	0.007530	0.023107	0.325875	0.7446

R-squared	0.000057	Mean dependent var	0.999172
Adjusted R-squared	-0.000477	S.D. dependent var	1.854825
S.E. of regression	1.855267	Akaike info criterion	4.075001
Sum squared resid	6446.898	Schwarz criterion	4.080906
Log likelihood	-3818.313	Hannan-Quinn criter.	4.077176
F-statistic	0.106195	Durbin-Watson stat	2.000427
Prob(F-statistic)	0.744555		

(e) Hong Kong



Heteroskedasticity Test: ARCH

F-statistic	0.375750	Prob. F(1,1855)	0.5400
Obs*R-squared	0.376079	Prob. Chi-Square(1)	0.5397

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 10:23
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1857 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.014541	0.063259	16.03788	0.0000
WGT_RESID^2(-1)	-0.014231	0.023216	-0.612984	0.5400

R-squared	0.000203	Mean dependent var	1.000306
Adjusted R-squared	-0.000336	S.D. dependent var	2.535267
S.E. of regression	2.535693	Akaike info criterion	4.699887
Sum squared resid	11927.17	Schwarz criterion	4.705840
Log likelihood	-4361.846	Hannan-Quinn criter.	4.702081
F-statistic	0.375750	Durbin-Watson stat	1.998880
Prob(F-statistic)	0.539962		

(f) Taiwan

Figure 10. Eviews GARCH(1,1) full sample ARCH-LM test result

Table 14. Eviews GARCH(1,1) ARCH LM test Prob. Chi-Square(1) result

Prob. Chi-Square	China	USA	Japan	South Korea	Hong Kong	Taiwan
Full sample	0.0967	0.5229	0.1936	0.7746	0.7444	0.5397

From the ARCH-LM test, all the Prob. Chi-Square results are significantly larger than 0.05, successfully passing the ARCH-LM test.

4.4 Model estimation with EGARCH

In the EGARCH model, the GARCH models are improved to better capture negative shocks and tend to impact volatility more than positive shocks.

The conditional variance equation is as follows:

$$\left(\sigma_t^2\right) = \omega + \beta ln\left(\sigma_{t-1}^2\right) + \gamma\frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha\left[\frac{\left|u_{t-1}\right|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}}\right]$$

Section 4.4.1 presents the estimation output of the EGARCH with the result analysis focusing on the variance equation rather than the mean equation. Section 4.4.2 offers the Diagnostic tests following the result, comprising section 4.4.2.1, the Ljung-Box test, and section 4.4.2.1, the ARCH-LM test.

4.4.1 Model estimation and general characteristic on leverage effect

In Eviews implementation, this study employs EGARCH, the order ARCH 1, GARCH 1, Threshold Order 1, and Eviews legacy as the optimization method. The mean equation uses the ARMA specification determined in 4.2.1. Figure 11-13 illustrates the Eviews EGARCH results, and Table 15 highlights the ARCH term and GARCH term in the GARCH(1,1) result.

The result shows that before and during covid, the ARCH term has probabilities of 0.0000 or close to 0.0000, indicating that shock size significantly impacts the volatility of returns. The ARCH term is positive for all markets and sample periods covered in this study, so there is a positive relationship between the past and current variance. In modeling the E-Garch for the United States during the covid sample, there was a negative number log error so the study couldn't deduce the contrast relationship. This positive relationship has strengthened after the pandemic in China, Japan, South Korea, Hong Kong, and Taiwan's stock market. Throughout all samples studied, the GARCH term has a p-value of 0.0000, which is smaller than 0.05 and thus indicates that past volatility does help to predict future volatility.

The leverage effect terms' probabilities are all below 0.05 and thus significant for all the countries and regions considered in this study, suggesting the shock's sign does impact the volatility of returns. The leverage effect comes with a negative leverage term indicating bad news will increase volatility more than the good news of the same size, and a positive term assumes no such effect. From the EGARCH estimation, only the leverage effect of Japan has dropped from before covid to during the covid. In contrast, the leverage effect of China, South Korea, Hong Kong, and Taiwan have all increased with covid. US's stock market's case cannot be decided regarding change before and after covid, as the latter has no data because of model error, which is the log of non-positive numbers. Thus EGARCH is not enough, and this study will apply another GJR-Garch model to supplement the missing leverage effect in the US's case.

Dependent Variable: CHINA_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 11:46
Sample (adjusted): 1/13/2015 8/12/2022
Included observations: 1845 after adjustments
Convergence achieved after 8 iterations
MA Backcast: 1/07/2015 1/12/2015
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(10) + C(11)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(12)*RESID(-1)/@SQRT(GARCH(-1)) + C(13)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.895789	0.107039	-8.368821	0.0000
AR(2)	-0.646547	0.028619	-22.59123	0.0000
AR(3)	-0.804321	0.101756	-7.904431	0.0000
AR(4)	-0.084085	0.027727	-3.032589	0.0024
AR(5)	0.002651	0.021128	0.125489	0.9001
MA(1)	0.902133	0.102177	8.829143	0.0000
MA(2)	0.663482	0.001524	435.4505	0.0000
MA(3)	0.837203	0.100889	8.298297	0.0000
MA(4)	0.091963	0.005464	16.83077	0.0000
Variance Equation				
C(10)	-0.254015	0.021592	-11.76432	0.0000
C(11)	0.185197	0.011049	16.76148	0.0000
C(12)	-0.018376	0.006211	-2.958729	0.0031
C(13)	0.987141	0.002418	408.2272	0.0000

R-squared	0.006744	Mean dependent var	7.93E-06
Adjusted R-squared	0.002416	S.D. dependent var	0.013965
S.E. of regression	0.013948	Akaike info criterion	-6.110478
Sum squared resid	0.357209	Schwarz criterion	-6.071582
Log likelihood	5649.916	Hannan-Quinn criter.	-6.096138
Durbin-Watson stat	1.921281		

Inverted AR Roots	.10+.86i	.10-.86i	.03	-.14
	-.98			
Inverted MA Roots	.10+.87i	.10-.87i	-.12	-.99

(a) China

Dependent Variable: US_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 13:22
Sample (adjusted): 1/09/2015 8/12/2022
Included observations: 1912 after adjustments
Convergence achieved after 22 iterations
MA Backcast: 1/07/2015 1/08/2015
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(7) + C(8)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(9)*RESID(-1)/@SQRT(GARCH(-1)) + C(10)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.257382	0.022926	11.22670	0.0000
AR(2)	0.701100	0.018505	37.88752	0.0000
AR(3)	0.047857	0.022555	2.121817	0.0339
AR(4)	-0.006062	0.017297	-0.350475	0.7260
MA(1)	-0.329319	0.008695	-37.87556	0.0000
MA(2)	-0.667522	0.008627	-77.37183	0.0000
Variance Equation				
C(7)	-0.700277	0.059381	-11.79286	0.0000
C(8)	0.257322	0.017133	15.01938	0.0000
C(9)	-0.160369	0.010911	-14.69783	0.0000
C(10)	0.946959	0.005328	177.7467	0.0000

R-squared	0.019380	Mean dependent var	0.000382
Adjusted R-squared	0.016807	S.D. dependent var	0.011724
S.E. of regression	0.011625	Akaike info criterion	-6.692370
Sum squared resid	0.257561	Schwarz criterion	-6.663312
Log likelihood	6407.906	Hannan-Quinn criter.	-6.681677
Durbin-Watson stat	2.175188		

Inverted AR Roots	1.00	.06	-.14	-.67
	Estimated AR process is nonstationary			
Inverted MA Roots	1.00	-.67		

(b) USA

Dependent Variable: JAPAN_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 14:04
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1878 after adjustments
Convergence achieved after 13 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.005203	0.024425	-0.213014	0.8313
Variance Equation				
C(2)	-0.676244	0.056146	-12.04430	0.0000
C(3)	0.169583	0.015666	10.82487	0.0000
C(4)	-0.164972	0.012132	-13.59865	0.0000
C(5)	0.938472	0.005585	168.0265	0.0000

R-squared	-0.000266	Mean dependent var	0.000280
Adjusted R-squared	-0.000266	S.D. dependent var	0.012805
S.E. of regression	0.012806	Akaike info criterion	-6.143358
Sum squared resid	0.307838	Schwarz criterion	-6.128613
Log likelihood	5773.613	Hannan-Quinn criter.	-6.137927
Durbin-Watson stat	2.032808		
Inverted AR Roots	-.01		

(c) Japan

Dependent Variable: KOREA_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 14:12
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1869 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.023394	0.025127	0.931031	0.3518
AR(2)	0.054891	0.023995	2.287600	0.0222
Variance Equation				
C(3)	-0.760784	0.096283	-7.901501	0.0000
C(4)	0.220433	0.019404	11.36016	0.0000
C(5)	-0.108931	0.012822	-8.495748	0.0000
C(6)	0.937159	0.009396	99.73901	0.0000

R-squared	0.007147	Mean dependent var	0.000158
Adjusted R-squared	0.006616	S.D. dependent var	0.010344
S.E. of regression	0.010309	Akaike info criterion	-6.620316
Sum squared resid	0.198433	Schwarz criterion	-6.602553
Log likelihood	6192.685	Hannan-Quinn criter.	-6.613771
Durbin-Watson stat	2.056215		
Inverted AR Roots	.25	-.22	

(d) South Korea

Dependent Variable: HK_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 14:25
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1876 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.017700	0.024344	0.727054	0.4672
Variance Equation				
C(2)	-0.444338	0.056577	-7.853712	0.0000
C(3)	0.136175	0.016015	8.502870	0.0000
C(4)	-0.075145	0.010206	-7.362594	0.0000
C(5)	0.961620	0.006017	159.8241	0.0000

R-squared	-0.000098	Mean dependent var	-8.63E-05
Adjusted R-squared	-0.000098	S.D. dependent var	0.012712
S.E. of regression	0.012713	Akaike info criterion	-6.052046
Sum squared resid	0.303018	Schwarz criterion	-6.037289
Log likelihood	5681.820	Hannan-Quinn criter.	-6.046610
Durbin-Watson stat	2.019700		
Inverted AR Roots	.02		

(e) Hong Kong

Dependent Variable: TAIWAN_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 14:37
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1858 after adjustments
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.038396	0.024348	1.576954	0.1148
Variance Equation				
C(2)	-0.769523	0.092231	-8.343438	0.0000
C(3)	0.173173	0.019621	8.825878	0.0000
C(4)	-0.147877	0.011663	-12.67958	0.0000
C(5)	0.931997	0.009120	102.1885	0.0000

R-squared	-0.001246	Mean dependent var	0.000282
Adjusted R-squared	-0.001246	S.D. dependent var	0.009822
S.E. of regression	0.009828	Akaike info criterion	-6.629732
Sum squared resid	0.179358	Schwarz criterion	-6.614858
Log likelihood	6164.021	Hannan-Quinn criter.	-6.624251
Durbin-Watson stat	2.052148		
Inverted AR Roots	.04		

(f) Taiwan

Figure 11. Eviews EGARCH full sample result

Dependent Variable: CHINA_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 09/07/22 Time: 11:55
Sample (adjusted): 1/09/2015 2/10/2020
Included observations: 1235 after adjustments
Convergence achieved after 10 iterations
MA Backcast: 1/07/2015 1/08/2015
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(6) + C(7)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(8)*RESID(-1)/@SQRT(GARCH(-1)) + C(9)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.756106	0.029713	25.44734	0.0000
AR(2)	0.232649	0.031591	7.364450	0.0000
AR(3)	-0.004644	0.019727	-0.235412	0.8139
MA(1)	-0.673517	6.64E-13	-1.01E+12	0.0000
MA(2)	-0.315601	6.91E-13	-4.57E+11	0.0000
Variance Equation				
C(6)	-0.365615	0.030906	-11.82982	0.0000
C(7)	0.247125	0.014330	17.24560	0.0000
C(8)	-0.057278	0.008847	-6.473932	0.0000
C(9)	0.979120	0.003506	279.2679	0.0000

R-squared	0.006189	Mean dependent var	-0.000106
Adjusted R-squared	0.002957	S.D. dependent var	0.015202
S.E. of regression	0.015179	Akaike info criterion	-6.021923
Sum squared resid	0.283402	Schwarz criterion	-5.984620
Log likelihood	3727.538	Hannan-Quinn criter.	-6.007891
Durbin-Watson stat	2.051514		
Inverted AR Roots	.99	.02	-.25
Inverted MA Roots	.99	-.32	

(a) China

Dependent Variable: US_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 15:59
Sample (adjusted): 1/06/2015 2/10/2020
Included observations: 1283 after adjustments
Convergence achieved after 13 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.057090	0.025503	-2.238548	0.0252
Variance Equation				
C(2)	-0.867843	0.075954	-11.42589	0.0000
C(3)	0.184555	0.021393	8.627089	0.0000
C(4)	-0.231639	0.014804	-15.64717	0.0000
C(5)	0.925104	0.006737	137.3200	0.0000

R-squared	-0.003206	Mean dependent var	0.000395
Adjusted R-squared	-0.003206	S.D. dependent var	0.008451
S.E. of regression	0.008465	Akaike info criterion	-7.062992
Sum squared resid	0.091864	Schwarz criterion	-7.042895
Log likelihood	4535.910	Hannan-Quinn criter.	-7.055447
Durbin-Watson stat	1.933414		
Inverted AR Roots	-.06		

(b) USA

Dependent Variable: JAPAN_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 16:14
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1267 after adjustments
Convergence achieved after 18 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.002125	0.030718	0.069181	0.9448
Variance Equation				
C(2)	-0.849203	0.063900	-13.28959	0.0000
C(3)	0.142266	0.018675	7.617955	0.0000
C(4)	-0.220643	0.016176	-13.64013	0.0000
C(5)	0.917979	0.006439	142.5648	0.0000

R-squared	-0.000758	Mean dependent var	0.000267
Adjusted R-squared	-0.000758	S.D. dependent var	0.012119
S.E. of regression	0.012124	Akaike info criterion	-6.284822
Sum squared resid	0.186078	Schwarz criterion	-6.264520
Log likelihood	3986.435	Hannan-Quinn criter.	-6.277195
Durbin-Watson stat	2.129670		
Inverted AR Roots	.00		

(c) Japan

Dependent Variable: KOREA_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 16:21
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1249 after adjustments
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.007983	0.031270	0.255278	0.7985
AR(2)	0.055878	0.029017	1.925718	0.0541
Variance Equation				
C(3)	-0.678428	0.124049	-5.469040	0.0000
C(4)	0.079311	0.021362	3.712650	0.0002
C(5)	-0.113920	0.014195	-8.025185	0.0000
C(6)	0.936364	0.012161	76.99741	0.0000

R-squared	0.003676	Mean dependent var	0.000125
Adjusted R-squared	0.002877	S.D. dependent var	0.007917
S.E. of regression	0.007906	Akaike info criterion	-6.914894
Sum squared resid	0.077946	Schwarz criterion	-6.890250
Log likelihood	4324.351	Hannan-Quinn criter.	-6.905629
Durbin-Watson stat	1.980355		
Inverted AR Roots	.24	-.23	

(d) South Korea

Dependent Variable: HK_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 16:32
Sample (adjusted): 1/05/2015 2/10/2020
Included observations: 1258 after adjustments
Convergence achieved after 21 iterations
MA Backcast: 1/02/2015
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.038882	0.029676	1.310199	0.1901
Variance Equation				
C(2)	-0.475884	0.091969	-5.174387	0.0000
C(3)	0.114651	0.018434	6.219445	0.0000
C(4)	-0.069926	0.012343	-5.665431	0.0000
C(5)	0.957000	0.009697	98.69317	0.0000

R-squared	0.000548	Mean dependent var	0.000110
Adjusted R-squared	0.000548	S.D. dependent var	0.011155
S.E. of regression	0.011152	Akaike info criterion	-6.249171
Sum squared resid	0.156336	Schwarz criterion	-6.228753
Log likelihood	3935.729	Hannan-Quinn criter.	-6.241498
Durbin-Watson stat	2.022050		
Inverted MA Roots	-.04		

(e) Hong Kong

Dependent Variable: TAIWAN_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 16:38
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1243 after adjustments
Convergence achieved after 20 iterations
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.025185	0.030127	0.835963	0.4032
Variance Equation				
C(2)	-0.767328	0.097239	-7.891176	0.0000
C(3)	0.088588	0.023425	3.781835	0.0002
C(4)	-0.161941	0.013485	-12.00920	0.0000
C(5)	0.927066	0.010103	91.75722	0.0000

R-squared	-0.001738	Mean dependent var	0.000198
Adjusted R-squared	-0.001738	S.D. dependent var	0.008426
S.E. of regression	0.008434	Akaike info criterion	-6.837954
Sum squared resid	0.088342	Schwarz criterion	-6.817337
Log likelihood	4254.788	Hannan-Quinn criter.	-6.830201
Durbin-Watson stat	2.071327		
Inverted AR Roots	.03		

(f) Taiwan

Figure 12. Eviews EGARCH before covid sample result

Dependent Variable: CHINA_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 17:11
Sample: 2/11/2020 8/12/2022
Included observations: 612
Convergence achieved after 21 iterations
MA Backcast: 2/10/2020
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.011085	0.050324	-0.220282	0.8257
Variance Equation				
C(2)	-1.091881	0.291760	-3.742401	0.0002
C(3)	0.269247	0.040191	6.699263	0.0000
C(4)	-0.073068	0.025476	-2.868075	0.0041
C(5)	0.902495	0.030539	29.55186	0.0000

R-squared	-0.000491	Mean dependent var	0.000205
Adjusted R-squared	-0.000491	S.D. dependent var	0.011059
S.E. of regression	0.011062	Akaike info criterion	-6.271645
Sum squared resid	0.074767	Schwarz criterion	-6.235560
Log likelihood	1924.123	Hannan-Quinn criter.	-6.257610
Durbin-Watson stat	1.975432		
Inverted MA Roots	.01		

(a) China

Error: log of non-positive number

(b) USA

Dependent Variable: JAPAN_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 17:38
Sample: 2/12/2020 8/12/2022
Included observations: 611
Convergence achieved after 16 iterations
MA Backcast: 2/11/2020
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.004073	0.042644	0.095516	0.9239
Variance Equation				
C(2)	-0.635875	0.146546	-4.339076	0.0000
C(3)	0.167176	0.039555	4.226373	0.0000
C(4)	-0.125409	0.024362	-5.147708	0.0000
C(5)	0.941583	0.014700	64.05237	0.0000

R-squared	-0.000174	Mean dependent var	0.000306
Adjusted R-squared	-0.000174	S.D. dependent var	0.014132
S.E. of regression	0.014133	Akaike info criterion	-5.861164
Sum squared resid	0.121840	Schwarz criterion	-5.825034
Log likelihood	1795.586	Hannan-Quinn criter.	-5.847111
Durbin-Watson stat	1.925999		
Inverted MA Roots	-.00		

(c) Japan

Dependent Variable: KOREA_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 17:46
Sample: 2/11/2020 8/12/2022
Included observations: 620
Convergence achieved after 19 iterations
MA Backcast: 2/07/2020 2/10/2020
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.071653	0.043198	1.658697	0.0972
MA(2)	0.055652	0.043226	1.287446	0.1979
Variance Equation				
C(3)	-1.381986	0.259465	-5.326302	0.0000
C(4)	0.389411	0.058973	6.603195	0.0000
C(5)	-0.185884	0.032989	-5.634700	0.0000
C(6)	0.880129	0.026866	32.75981	0.0000

R-squared	0.002564	Mean dependent var	0.000223
Adjusted R-squared	0.000950	S.D. dependent var	0.014017
S.E. of regression	0.014011	Akaike info criterion	-6.081741
Sum squared resid	0.121312	Schwarz criterion	-6.038872
Log likelihood	1891.340	Hannan-Quinn criter.	-6.065077
Durbin-Watson stat	2.185326		
Inverted MA Roots	-.04+.23i	-.04-.23i	

(d) South Korea

Dependent Variable: HK_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 17:53
Sample: 2/11/2020 8/12/2022
Included observations: 619
Convergence achieved after 13 iterations
MA Backcast: 2/07/2020 2/10/2020
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.016711	0.043917	-0.380505	0.7036
MA(2)	0.019328	0.038956	0.496150	0.6198
Variance Equation				
C(3)	-0.652304	0.174819	-3.731298	0.0002
C(4)	0.153077	0.039297	3.895397	0.0001
C(5)	-0.106009	0.026825	-3.951936	0.0001
C(6)	0.937544	0.019722	47.53907	0.0000

R-squared	-0.002503	Mean dependent var	-0.000485
Adjusted R-squared	-0.004128	S.D. dependent var	0.015392
S.E. of regression	0.015424	Akaike info criterion	-5.654940
Sum squared resid	0.146786	Schwarz criterion	-5.612018
Log likelihood	1756.204	Hannan-Quinn criter.	-5.638255
Durbin-Watson stat	1.991356		
Inverted MA Roots	.01-.14i	.01+.14i	

(e) Hong Kong

Dependent Variable: TAIWAN_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/23/22 Time: 18:00
Sample: 2/11/2020 8/12/2022
Included observations: 615
Convergence achieved after 14 iterations
MA Backcast: 2/10/2020
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.073140	0.042390	1.725413	0.0845
Variance Equation				
C(2)	-1.203153	0.305770	-3.934826	0.0001
C(3)	0.225212	0.063028	3.573226	0.0004
C(4)	-0.207943	0.037442	-5.553717	0.0000
C(5)	0.885994	0.030803	28.76338	0.0000

R-squared	-0.001999	Mean dependent var	0.000453
Adjusted R-squared	-0.001999	S.D. dependent var	0.012169
S.E. of regression	0.012181	Akaike info criterion	-6.242927
Sum squared resid	0.091101	Schwarz criterion	-6.206979
Log likelihood	1924.700	Hannan-Quinn criter.	-6.228949
Durbin-Watson stat	2.080680		
Inverted MA Roots	-.07		

(f) Taiwan

Figure 13. Eviews EGARCH after covid sample result

Table 15. Eviews EGARCH ARCH term, leverage term and GARCH term result

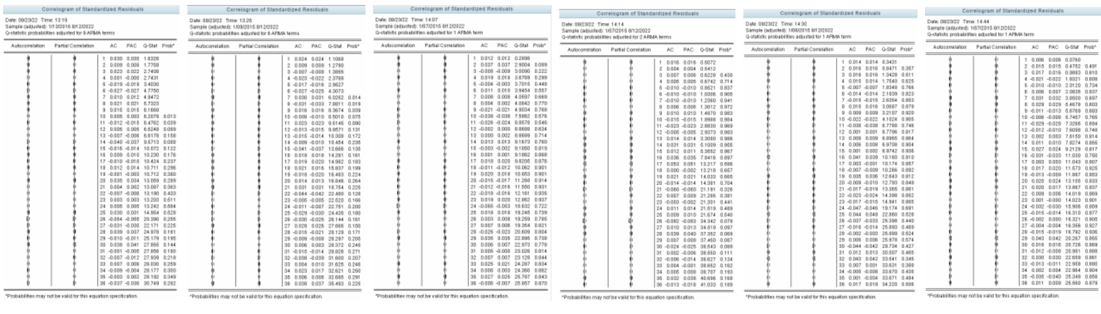
Full Sample			**China**	**USA**	**Japan**	**South Korea**	**Hong Kong**	**Taiwan**
Full sample	ARCH term	stats	0.185196	0.257322	0.169583	0.220433	0.136175	0.173173
		prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	leverage term	stats	-0.018376	-0.160369	-0.164972	-0.108931	-0.075145	-0.147877
		prob	0.0031	0.0000	0.0000	0.0000	0.0000	0.0000

	GARCH term	stats	0.987141	0.946956	0.938472	0.937159	0.961620	0.931997
		prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Before covid	ARCH term	stats	0.247125	0.184555	0.142266	0.079311	0.114651	0.088588
		prob	0.0000	0.0000	0.0000	0.0002	0.0000	0.0002
	leverage term	stats	-0.057278 leverage	-0.231639 leverage	-0.220643 leverage	-0.113920 leverage	-0.069926 leverage	-0.161941 leverage
		prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	GARCH term	stats	0.979120	0.925104	0.917979	0.936364	0.957000	0.927066
		prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
During covid	ARCH term	stats	0.269247	Error: log of non-positive number	0.767179	0.389411	0.153077	0.225212
		prob	0.0000		0.0000	0.0000	0.0001	0.0004
	leverage term	stats	-0.073068 Leverage Leverage+		-0.125409 Leverage Leverage-	-0.185884 Leverage Leverage+	-0.106009 Leverage Leverage+	-0.207983 Leverage Leverage+
		prob	0.0041		0.0000	0.0000	0.0001	0.0000
	GARCH term	stats	0.902495		0.941583	0.880129	0.937544	0.885994
		prob	0.0000		0.0000	0.0000	0.0000	0.0000

Note: in the eviews output, take China full sample for example, C10 stands for constant, C11 stands for arch term, C12 stands for term beginning with gama-egarch term/leverage effect term, C13 stands for garch term.

4.4.2.1 Ljung-Box test

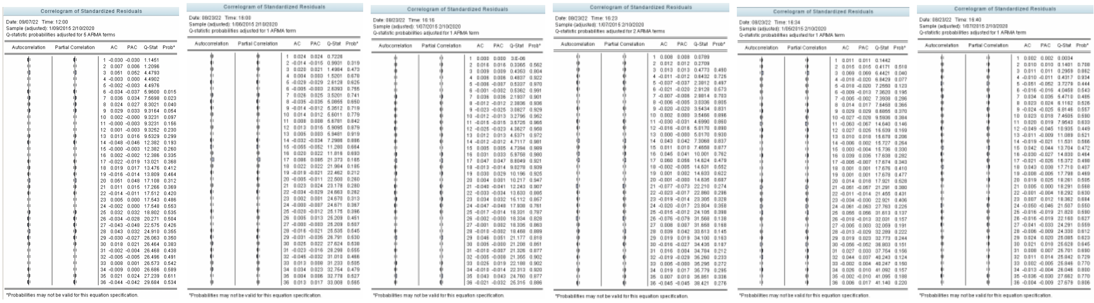
As described in section 2.4.3, the Ljung-Box test helps assess whether the time series of interest is autocorrelated. The null hypothesis of the test is that the autocorrelations of the given sample are all zero. If the p-value we get from test is larger than 0.05, we fail to reject the null hypothesis, and the model is lack of fit. Figure 14-16 presents the Ljung Box test result for EGARCH.



China USA Japan South Korea Hong Kong Taiwan

Figure 14. Eviews EGARCH full sample Ljung-Box test result

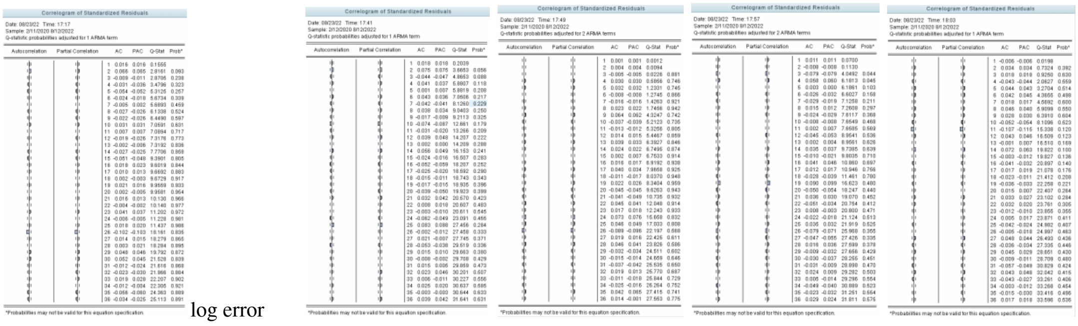
Except China at lag10 yields 0.013, lag 11 yields 0.039, USA at lag7 yields 0.014, lag8 yields 0.019, lag9 yields 0.039, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.



China USA Japan South Korea Hong Kong Taiwan

Figure 15. Eviews EGARCH before covid sample Ljung-Box test result

Except China at at lag6 yields 0.015, lag7 yields 0.023, lag8 yields 0.04, Hong Kong's lag3 yields 0.04, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.



log error

China USA Japan South Korea Hong Kong Taiwan

Figure 16. Eviews EGARCH during covid sample Ljung-Box test result

Except Hong Kong at lag3 yields 0.044, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.

4.4.2.2 ARCH-LM test

As described in section 2.4.3, the ARCH-LM test is a test for ARCH effects by regressing the squared errors on different specified lags. The null hypothesis is that the lagged regression coefficients are zero, there is no existing ARCH up to order q in the residuals, and there are no ARCH effects. If the p-value we get from the test is larger than 0.05, we reject the null hypothesis, and there are ARCH effects. We expect rejecting the null hypothesis to pass the ARCH LM diagnostic test in the section successfully. Figure 17-19 presents the ARCH LM test result, and table 16 summarizes the Prob. Chi-Square results.

Heteroskedasticity Test: ARCH

F-statistic	2.566251	Prob. F(1,1842)	0.1093
Obs*R-squared	2.565463	Prob. Chi-Square(1)	0.1092

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 13:19
Sample (adjusted): 1/14/2015 8/12/2022
Included observations: 1844 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.999574	0.063459	15.75140	0.0000
WGT_RESID^2(-1)	0.037301	0.023285	1.601952	0.1093

R-squared	0.001391	Mean dependent var	1.038320
Adjusted R-squared	0.000849	S.D. dependent var	2.520442
S.E. of regression	2.519372	Akaike info criterion	4.686980
Sum squared resid	11691.61	Schwarz criterion	4.692967
Log likelihood	-4319.396	Hannan-Quinn criter.	4.689188
F-statistic	2.566251	Durbin-Watson stat	2.000105
Prob(F-statistic)	0.109338		

Heteroskedasticity Test: ARCH

F-statistic	1.583254	Prob. F(1,1909)	0.2084
Obs*R-squared	1.583600	Prob. Chi-Square(1)	0.2082

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 13:26
Sample (adjusted): 1/12/2015 8/12/2022
Included observations: 1911 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.974127	0.058257	16.72123	0.0000
WGT_RESID^2(-1)	0.028805	0.022893	1.258274	0.2084

R-squared	0.000829	Mean dependent var	1.002958
Adjusted R-squared	0.000305	S.D. dependent var	2.341806
S.E. of regression	2.341448	Akaike info criterion	4.540462
Sum squared resid	10465.86	Schwarz criterion	4.546276
Log likelihood	-4336.412	Hannan-Quinn criter.	4.542602
F-statistic	1.583254	Durbin-Watson stat	1.998966
Prob(F-statistic)	0.208446		

Heteroskedasticity Test: ARCH

F-statistic	0.587192	Prob. F(1,1875)	0.4436
Obs*R-squared	0.587634	Prob. Chi-Square(1)	0.4433

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 14:08
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1877 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.983237	0.051106	19.23927	0.0000
WGT_RESID^2(-1)	0.017726	0.023133	0.766284	0.4436

R-squared	0.000313	Mean dependent var	1.000920
Adjusted R-squared	-0.000220	S.D. dependent var	1.975326
S.E. of regression	1.975544	Akaike info criterion	4.200629
Sum squared resid	7317.699	Schwarz criterion	4.206530
Log likelihood	-3940.291	Hannan-Quinn criter.	4.202803
F-statistic	0.587192	Durbin-Watson stat	1.995641
Prob(F-statistic)	0.443604		

(a) China (b) USA (c) Japan

Heteroskedasticity Test: ARCH

F-statistic	0.378850	Prob. F(1,1866)	0.5383
Obs*R-squared	0.379179	Prob. Chi-Square(1)	0.5380

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 14:16
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1868 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.986277	0.047261	20.86857	0.0000
WGT_RESID^2(-1)	0.014247	0.023147	0.615508	0.5383

R-squared	0.000203	Mean dependent var	1.000532
Adjusted R-squared	-0.000333	S.D. dependent var	1.780298
S.E. of regression	1.780594	Akaike info criterion	3.992841
Sum squared resid	5916.182	Schwarz criterion	3.998765
Log likelihood	-3727.314	Hannan-Quinn criter.	3.995024
F-statistic	0.378850	Durbin-Watson stat	1.998260
Prob(F-statistic)	0.538295		

(d) South Korea

Heteroskedasticity Test: ARCH

F-statistic	0.052287	Prob. F(1,1873)	0.8192
Obs*R-squared	0.052342	Prob. Chi-Square(1)	0.8190

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 14:31
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1875 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.993498	0.048279	20.57832	0.0000
WGT_RESID^2(-1)	0.005284	0.023107	0.228664	0.8192

R-squared	0.000028	Mean dependent var	0.998779
Adjusted R-squared	-0.000506	S.D. dependent var	1.835346
S.E. of regression	1.835810	Akaike info criterion	4.053915
Sum squared resid	6312.382	Schwarz criterion	4.059820
Log likelihood	-3798.545	Hannan-Quinn criter.	4.056090
F-statistic	0.052287	Durbin-Watson stat	2.000108
Prob(F-statistic)	0.819155		

(e) Hong Kong

Heteroskedasticity Test: ARCH

F-statistic	1.294823	Prob. F(1,1855)	0.2553
Obs*R-squared	1.295315	Prob. Chi-Square(1)	0.2551

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 14:45
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1857 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.026212	0.058600	17.51223	0.0000
WGT_RESID^2(-1)	-0.026411	0.023210	-1.137903	0.2553

R-squared	0.000698	Mean dependent var	0.999808
Adjusted R-squared	0.000159	S.D. dependent var	2.319004
S.E. of regression	2.318820	Akaike info criterion	4.521070
Sum squared resid	9974.199	Schwarz criterion	4.527023
Log likelihood	-4195.814	Hannan-Quinn criter.	4.523264
F-statistic	1.294823	Durbin-Watson stat	1.998699
Prob(F-statistic)	0.255308		

(f) Taiwan

Figure 17. ARCH-LM EGarch full sample

Heteroskedasticity Test: ARCH

F-statistic	0.042502	Prob. F(1,1232)	0.8367
Obs*R-squared	0.042570	Prob. Chi-Square(1)	0.8365

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 09/07/22 Time: 12:02
Sample (adjusted): 1/12/2015 2/10/2020
Included observations: 1234 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.026249	0.076089	13.48748	0.0000
WGT_RESID^2(-1)	-0.005873	0.028490	-0.206160	0.8367

R-squared	0.000034	Mean dependent var	1.020257
Adjusted R-squared	-0.000777	S.D. dependent var	2.469218
S.E. of regression	2.470178	Akaike info criterion	4.648077
Sum squared resid	7517.390	Schwarz criterion	4.656372
Log likelihood	-2865.863	Hannan-Quinn criter.	4.651197
F-statistic	0.042502	Durbin-Watson stat	2.000111
Prob(F-statistic)	0.836700		

(a) China

Heteroskedasticity Test: ARCH

F-statistic	1.120261	Prob. F(1,1280)	0.2901
Obs*R-squared	1.121030	Prob. Chi-Square(1)	0.2897

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 16:09
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1282 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.970664	0.065541	14.81013	0.0000
WGT_RESID^2(-1)	0.029571	0.027939	1.058424	0.2901

R-squared	0.000874	Mean dependent var	1.000245
Adjusted R-squared	0.000094	S.D. dependent var	2.122737
S.E. of regression	2.122637	Akaike info criterion	4.344754
Sum squared resid	5767.152	Schwarz criterion	4.352798
Log likelihood	-2782.987	Hannan-Quinn criter.	4.347774
F-statistic	1.120261	Durbin-Watson stat	1.998579
Prob(F-statistic)	0.290062		

(b) USA

Heteroskedasticity Test: ARCH

F-statistic	0.003005	Prob. F(1,1264)	0.9563
Obs*R-squared	0.003010	Prob. Chi-Square(1)	0.9563

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 16:17
Sample (adjusted): 1/08/2015 2/10/2020
Included observations: 1266 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.003151	0.067712	14.81501	0.0000
WGT_RESID^2(-1)	-0.001542	0.028126	-0.054816	0.9563

R-squared	0.000002	Mean dependent var	1.001607
Adjusted R-squared	-0.000789	S.D. dependent var	2.190091
S.E. of regression	2.190955	Akaike info criterion	4.408130
Sum squared resid	6067.556	Schwarz criterion	4.416256
Log likelihood	-2788.346	Hannan-Quinn criter.	4.411183
F-statistic	0.003005	Durbin-Watson stat	1.999064
Prob(F-statistic)	0.956294		

(c) Japan

Heteroskedasticity Test: ARCH

F-statistic	0.556794	Prob. F(1,1246)	0.4557
Obs*R-squared	0.557438	Prob. Chi-Square(1)	0.4553

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 16:24
Sample (adjusted): 1/08/2015 2/10/2020
Included observations: 1248 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.021005	0.061337	16.64572	0.0000
WGT_RESID^2(-1)	-0.021133	0.028321	-0.746186	0.4557

R-squared	0.000447	Mean dependent var	0.999882
Adjusted R-squared	-0.000356	S.D. dependent var	1.921960
S.E. of regression	1.922301	Akaike info criterion	4.146524
Sum squared resid	4604.272	Schwarz criterion	4.154744
Log likelihood	-2585.431	Hannan-Quinn criter.	4.149615
F-statistic	0.556794	Durbin-Watson stat	1.998927
Prob(F-statistic)	0.455696		

(d) South Korea

Heteroskedasticity Test: ARCH

F-statistic	0.127474	Prob. F(1,1255)	0.7211
Obs*R-squared	0.127665	Prob. Chi-Square(1)	0.7209

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 16:36
Sample (adjusted): 1/06/2015 2/10/2020
Included observations: 1257 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.990304	0.060797	16.28881	0.0000
WGT_RESID^2(-1)	0.010077	0.028225	0.357036	0.7211

R-squared	0.000102	Mean dependent var	1.000384
Adjusted R-squared	-0.000695	S.D. dependent var	1.908340
S.E. of regression	1.909003	Akaike info criterion	4.132630
Sum squared resid	4573.589	Schwarz criterion	4.140802
Log likelihood	-2595.358	Hannan-Quinn criter.	4.135701
F-statistic	0.127474	Durbin-Watson stat	1.999134
Prob(F-statistic)	0.721125		

(e) Hong Kong

Heteroskedasticity Test: ARCH

F-statistic	0.258084	Prob. F(1,1240)	0.6115
Obs*R-squared	0.258446	Prob. Chi-Square(1)	0.6112

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 16:49
Sample (adjusted): 1/08/2015 2/10/2020
Included observations: 1242 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.013923	0.082985	12.21818	0.0000
WGT_RESID^2(-1)	-0.014426	0.028396	-0.508019	0.6115

R-squared	0.000208	Mean dependent var	0.999502
Adjusted R-squared	-0.000598	S.D. dependent var	2.747319
S.E. of regression	2.748140	Akaike info criterion	4.861335
Sum squared resid	9364.822	Schwarz criterion	4.869587
Log likelihood	-3016.889	Hannan-Quinn criter.	4.864438
F-statistic	0.258084	Durbin-Watson stat	1.998131
Prob(F-statistic)	0.611530		

(f) Taiwan

Figure 18. ARCH-LM EGarch before covid sample

Heteroskedasticity Test: ARCH

F-statistic	0.002790	Prob. F(1,609)	0.9579
Obs*R-squared	0.002799	Prob. Chi-Square(1)	0.9578

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 17:18
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 611 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.001430	0.088552	11.30891	0.0000
WGT_RESID^2(-1)	0.002140	0.040524	0.052819	0.9579

R-squared	0.000005	Mean dependent var	1.003578
Adjusted R-squared	-0.001637	S.D. dependent var	1.942643
S.E. of regression	1.944233	Akaike info criterion	4.170880
Sum squared resid	2302.044	Schwarz criterion	4.185332
Log likelihood	-1272.204	Hannan-Quinn criter.	4.176501
F-statistic	0.002790	Durbin-Watson stat	1.999842
Prob(F-statistic)	0.957894		

(a) China

Error: log of non-positive number

(b) USA

Heteroskedasticity Test: ARCH

F-statistic	2.541558	Prob. F(1,608)	0.1114
Obs*R-squared	2.539304	Prob. Chi-Square(1)	0.1110

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 17:43
Sample (adjusted): 2/13/2020 8/12/2022
Included observations: 610 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.937694	0.076749	12.21769	0.0000
WGT_RESID^2(-1)	0.064991	0.040766	1.594226	0.1114

R-squared	0.004163	Mean dependent var	1.002282
Adjusted R-squared	0.002525	S.D. dependent var	1.611984
S.E. of regression	1.609947	Akaike info criterion	3.793553
Sum squared resid	1575.894	Schwarz criterion	3.808024
Log likelihood	-1155.034	Hannan-Quinn criter.	3.799182
F-statistic	2.541558	Durbin-Watson stat	1.988367
Prob(F-statistic)	0.111405		

(c) Japan

Heteroskedasticity Test: ARCH

F-statistic	0.550731	Prob. F(1,617)	0.4583
Obs*R-squared	0.552024	Prob. Chi-Square(1)	0.4575

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 17:50
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 619 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.969460	0.070380	13.77465	0.0000
WGT_RESID^2(-1)	0.029874	0.040256	0.742113	0.4583

R-squared	0.000892	Mean dependent var	0.999368
Adjusted R-squared	-0.000728	S.D. dependent var	1.435002
S.E. of regression	1.435524	Akaike info criterion	3.564162
Sum squared resid	1271.469	Schwarz criterion	3.578470
Log likelihood	-1101.108	Hannan-Quinn criter.	3.569724
F-statistic	0.550731	Durbin-Watson stat	1.998070
Prob(F-statistic)	0.458301		

(d) South Korea

Heteroskedasticity Test: ARCH

F-statistic	0.362751	Prob. F(1,616)	0.5472
Obs*R-squared	0.363714	Prob. Chi-Square(1)	0.5465

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 17:58
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 618 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.023279	0.078546	13.02778	0.0000
WGT_RESID^2(-1)	-0.024262	0.040284	-0.602288	0.5472

R-squared	0.000589	Mean dependent var	0.998982
Adjusted R-squared	-0.001034	S.D. dependent var	1.674540
S.E. of regression	1.675405	Akaike info criterion	3.873218
Sum squared resid	1729.101	Schwarz criterion	3.887543
Log likelihood	-1194.824	Hannan-Quinn criter.	3.878787
F-statistic	0.362751	Durbin-Watson stat	1.996820
Prob(F-statistic)	0.547204		

(e) Hong Kong

Heteroskedasticity Test: ARCH

F-statistic	2.711131	Prob. F(1,612)	0.1002
Obs*R-squared	2.707994	Prob. Chi-Square(1)	0.0998

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/23/22 Time: 18:04
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 614 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.064804	0.072981	14.59024	0.0000
WGT_RESID^2(-1)	-0.066425	0.040342	-1.646551	0.1002

R-squared	0.004410	Mean dependent var	0.998395
Adjusted R-squared	0.002784	S.D. dependent var	1.509249
S.E. of regression	1.507147	Akaike info criterion	3.661566
Sum squared resid	1390.153	Schwarz criterion	3.675963
Log likelihood	-1122.101	Hannan-Quinn criter.	3.667165
F-statistic	2.711131	Durbin-Watson stat	2.001717
Prob(F-statistic)	0.100164		

(f) Taiwan

Figure 19. ARCH-LM EGarch during covid sample

Table 16. Eviews GARCH(1,1) ARCH LM test Prob. Chi-Square(1) result

Prob. Chi-Square	China	USA	Japan	South Korea	Hong Kong	Taiwan
Full sample	0.1092	0.2082	0.4433	0.5380	0.8190	0.2551
Before covid	0.8365	0.2897	0.9563	0.4553	0.7209	0.6112
After covid	0.9579	-	0.1110	0.4575	0.5465	0.0998

From the ARCH-LM test, all the Prob. Chi-Square results are significantly larger than 0.05, successfully passing the ARCH-LM test.

4.5 Model estimation result - GJR-GARCH

In the GJRGARCH model, the model acts as another asymmetric model like EGARCH to describe financial markets with changing volatility, and can be pretty useful in capturing and making conclusions regarding the leverage effect.

The conditional variance equation is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta\sigma_{t-1}^2 + \gamma u_{t-1}^2 I_{t-1}$$

Section 4.5.1 presents the estimation output of the GJRGARCH with the result analysis focusing on the variance equation rather than the mean equation. Section 4.5.2 offers the Diagnostic tests following the result, comprising section 4.5.2.1, the Ljung-Box test, and section 4.5.2.1, the ARCH-LM test.

4.5.1 Model estimation and general characteristic on leverage effect

In Eviews implementation, this study employs GJRGARCH, the order ARCH 1, GARCH 1, Threshold Order 1, and Eviews legacy as the optimization method. The mean equation uses the ARMA specification determined in 4.2.1. Figure 20-22 illustrates the Eviews EGARCH total sample result, and Table 17 highlights the ARCH term and GARCH term in the GARCH(1,1) result.

By applying the GJR-GARCH model, all six countries demonstrate leverage effect in full, before, or after covid sample due to positivity in the leverage effect term. The US and Japan stock market's leverage effect dropped in the period of covid. China, South Korea, Hong Kong, and Taiwan's leverage effect increased with covid. China's before covid leverage effect statistics is insignificant at the 5% level, yet its leverage effect strengthened and later became significant.

This GJRGARCH result supplements the EGARCH result since the leverage effects are the same conclusion, except that we couldn't model the US change due to the model log of non-positive numbers error in EGARCH. So far, the study has successfully modeled the leverage effect by combining the two GARCH approaches.

Dependent Variable: CHINA_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/19/22 Time: 19:02
Sample (adjusted): 1/13/2015 8/12/2022
Included observations: 1845 after adjustments
Convergence achieved after 24 iterations
MA Backcast: 1/07/2015 1/12/2015
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-1)^2*(RESID(-1)<0) + C(13)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.088535	1.215932	-0.072812	0.9420
AR(2)	0.235153	0.219659	1.070538	0.2844
AR(3)	-0.875218	0.247814	-3.531753	0.0004
AR(4)	-0.227248	1.133636	-0.200459	0.8411
AR(5)	-0.013595	0.037160	-0.365845	0.7145
MA(1)	0.114236	1.215590	0.093976	0.9251
MA(2)	-0.235084	0.182181	-1.290397	0.1969
MA(3)	0.896871	0.236347	3.794712	0.0001
MA(4)	0.251214	1.151909	0.218085	0.8274
Variance Equation				
C	1.54E-06	2.97E-07	5.172165	0.0000
RESID(-1)^2	0.082031	0.007706	10.64572	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.022288	0.009673	2.304120	0.0212
GARCH(-1)	0.902329	0.005320	169.6105	0.0000
R-squared	0.011340	Mean dependent var		7.93E-06
Adjusted R-squared	0.007032	S.D. dependent var		0.013965
S.E. of regression	0.013916	Akaike info criterion		-6.112482
Sum squared resid	0.355556	Schwarz criterion		-6.073586
Log likelihood	5651.764	Hannan-Quinn criter.		-6.098142
Durbin-Watson stat	1.966477			
Inverted AR Roots	.58-.78i	.58+.78i	-.10	-.15
	-.99			
Inverted MA Roots	.57+.79i	.57-.79i	-.26	-1.00

(a) China

Dependent Variable: US_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/19/22 Time: 23:44
Sample (adjusted): 1/09/2015 8/12/2022
Included observations: 1912 after adjustments
Convergence achieved after 15 iterations
MA Backcast: 1/07/2015 1/08/2015
Presample variance: backcast (parameter = 0.7)
GARCH = C(7) + C(8)*RESID(-1)^2 + C(9)*RESID(-1)^2*(RESID(-1)<0) + C(10)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.191931	0.401958	-0.477490	0.6330
AR(2)	-0.279127	0.287412	-0.971172	0.3315
AR(3)	-0.007678	0.037441	-0.205060	0.8375
AR(4)	0.015360	0.027081	0.567193	0.5706
MA(1)	0.134800	0.402113	0.335230	0.7375
MA(2)	0.327854	0.287417	1.140693	0.2540
Variance Equation				
C	4.46E-06	4.43E-07	10.05521	0.0000
RESID(-1)^2	0.084572	0.010535	8.027772	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.291157	0.033921	8.583269	0.0000
GARCH(-1)	0.751915	0.017138	43.87467	0.0000
R-squared	0.023877	Mean dependent var		0.000382
Adjusted R-squared	0.021316	S.D. dependent var		0.011724
S.E. of regression	0.011598	Akaike info criterion		-6.687435
Sum squared resid	0.256380	Schwarz criterion		-6.658377
Log likelihood	6403.188	Hannan-Quinn criter.		-6.676741
Durbin-Watson stat	2.200776			
Inverted AR Roots	.20	-.07+.56i	-.07-.56i	-.24
Inverted MA Roots	-.07+.57i	-.07-.57i		

(b) USA

Dependent Variable: JAPAN_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/20/22 Time: 10:02
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1878 after adjustments
Convergence achieved after 11 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.003950	0.025434	0.155310	0.8766
Variance Equation				
C	8.56E-06	9.26E-07	9.238287	0.0000
RESID(-1)^2	-0.014048	0.009415	-1.492074	0.1357
RESID(-1)^2*(RESID(-1)<0)	0.251796	0.025058	10.04867	0.0000
GARCH(-1)	0.835352	0.013782	60.61224	0.0000
R-squared	-0.000674	Mean dependent var		0.000280
Adjusted R-squared	-0.000674	S.D. dependent var		0.012805
S.E. of regression	0.012809	Akaike info criterion		-6.139853
Sum squared resid	0.307963	Schwarz criterion		-6.125108
Log likelihood	5770.322	Hannan-Quinn criter.		-6.134421
Durbin-Watson stat	2.051762			
Inverted AR Roots	.00			

(c) Japan

Dependent Variable: KOREA_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/20/22 Time: 01:50
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1869 after adjustments
Convergence achieved after 10 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-1)^2*(RESID(-1)<0) + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.042869	0.026662	1.607909	0.1079
AR(2)	0.062191	0.025055	2.482164	0.0131
Variance Equation				
C	6.75E-06	1.07E-06	6.332904	0.0000
RESID(-1)^2	0.039986	0.012655	3.159646	0.0016
RESID(-1)^2*(RESID(-1)<0)	0.202791	0.025269	8.025253	0.0000
GARCH(-1)	0.783904	0.021848	35.88014	0.0000
R-squared	0.006367	Mean dependent var		0.000158
Adjusted R-squared	0.005835	S.D. dependent var		0.010344
S.E. of regression	0.010313	Akaike info criterion		-6.620781
Sum squared resid	0.198589	Schwarz criterion		-6.603018
Log likelihood	6193.120	Hannan-Quinn criter.		-6.614236
Durbin-Watson stat	2.096484			
Inverted AR Roots	.27	-.23		

(d) South Korea

Dependent Variable: HK_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/20/22 Time: 11:32
Sample (adjusted): 1/06/2015 8/12/2022
Included observations: 1876 after adjustments
Convergence achieved after 14 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.023089	0.024600	0.938601	0.3479
Variance Equation				
C	4.96E-06	7.39E-07	6.706696	0.0000
RESID(-1)^2	0.017029	0.008655	1.967435	0.0491
RESID(-1)^2*(RESID(-1)<0)	0.091842	0.013870	6.621669	0.0000
GARCH(-1)	0.902260	0.009911	91.03680	0.0000
R-squared	-0.000238	Mean dependent var		-8.63E-05
Adjusted R-squared	-0.000238	S.D. dependent var		0.012712
S.E. of regression	0.012713	Akaike info criterion		-6.052695
Sum squared resid	0.303060	Schwarz criterion		-6.037937
Log likelihood	5682.428	Hannan-Quinn criter.		-6.047258
Durbin-Watson stat	2.030318			
Inverted AR Roots	.02			

(e) Hong Kong

Dependent Variable: TAIWAN_RETURN_FULL
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/20/22 Time: 20:32
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1858 after adjustments
Convergence achieved after 17 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.039656	0.025570	1.550914	0.1209
Variance Equation				
C	7.52E-06	9.45E-07	7.951508	0.0000
RESID(-1)^2	0.004103	0.012234	0.335396	0.7373
RESID(-1)^2*(RESID(-1)<0)	0.217104	0.020481	10.60025	0.0000
GARCH(-1)	0.805267	0.019275	41.77795	0.0000
R-squared	-0.001309	Mean dependent var		0.000282
Adjusted R-squared	-0.001309	S.D. dependent var		0.009822
S.E. of regression	0.009828	Akaike info criterion		-6.615741
Sum squared resid	0.179370	Schwarz criterion		-6.600867
Log likelihood	6151.023	Hannan-Quinn criter.		-6.610259
Durbin-Watson stat	2.054803			
Inverted AR Roots	.04			

(f) Taiwan

Figure 20. Eviews GJRGARCH full sample result

Dependent Variable: CHINA_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 09/07/22 Time: 12:04
Sample (adjusted): 1/09/2015 2/10/2020
Included observations: 1235 after adjustments
Convergence achieved after 68 iterations
MA Backcast: 1/07/2015 1/08/2015
Presample variance: backcast (parameter = 0.7)
GARCH = C(6) + C(7)*RESID(-1)^2 + C(8)*RESID(-1)^2*(RESID(-1)<0) + C(9)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.387376	0.066599	-5.816546	0.0000
AR(2)	-0.891410	0.041866	-21.29215	0.0000
AR(3)	0.055641	0.032207	1.727573	0.0841
MA(1)	0.437366	0.060789	7.194761	0.0000
MA(2)	0.910183	0.041479	21.94303	0.0000
Variance Equation				
C	9.14E-07	2.32E-07	3.935696	0.0001
RESID(-1)^2	0.075439	0.009887	7.630394	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.017236	0.011482	1.501158	0.1333
GARCH(-1)	0.917572	0.005056	181.4789	0.0000
R-squared	0.011318	Mean dependent var		-0.000106
Adjusted R-squared	0.008103	S.D. dependent var		0.015202
S.E. of regression	0.015140	Akaike info criterion		-6.036474
Sum squared resid	0.281939	Schwarz criterion		-5.999171
Log likelihood	3736.523	Hannan-Quinn criter.		-6.022442
Durbin-Watson stat	1.980535			
Inverted AR Roots	.06	-.22-.93i	-.22+.93i	
Inverted MA Roots	-.22-.93i	-.22+.93i		

(a) China

Dependent Variable: US_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/21/22 Time: 18:11
Sample (adjusted): 1/06/2015 2/10/2020
Included observations: 1283 after adjustments
Convergence achieved after 19 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.070656	0.029546	-2.391390	0.0168
Variance Equation				
C	4.01E-06	4.44E-07	9.035133	0.0000
RESID(-1)^2	0.002163	0.012517	0.172839	0.8628
RESID(-1)^2*(RESID(-1)<0)	0.322925	0.035629	9.063649	0.0000
GARCH(-1)	0.788807	0.021940	35.95287	0.0000
R-squared	-0.004413	Mean dependent var		0.000395
Adjusted R-squared	-0.004413	S.D. dependent var		0.008451
S.E. of regression	0.008470	Akaike info criterion		-7.042714
Sum squared resid	0.091974	Schwarz criterion		-7.022617
Log likelihood	4522.901	Hannan-Quinn criter.		-7.035169
Durbin-Watson stat	1.907884			
Inverted AR Roots	-.07			

(b) USA

Dependent Variable: JAPAN_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/21/22 Time: 19:18
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1267 after adjustments
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.011670	0.031612	0.369169	0.7120
Variance Equation				
C	7.66E-06	8.10E-07	9.458360	0.0000
RESID(-1)^2	-0.040889	0.006765	-6.043870	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.289123	0.026334	10.97912	0.0000
GARCH(-1)	0.840847	0.013474	62.40589	0.0000
R-squared	-0.002091	Mean dependent var		0.000267
Adjusted R-squared	-0.002091	S.D. dependent var		0.012119
S.E. of regression	0.012132	Akaike info criterion		-6.282946
Sum squared resid	0.186326	Schwarz criterion		-6.262644
Log likelihood	3985.246	Hannan-Quinn criter.		-6.275319
Durbin-Watson stat	2.148663			
Inverted AR Roots	.01			

(c) Japan

Dependent Variable: KOREA_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/22/22 Time: 09:38
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1249 after adjustments
Convergence achieved after 11 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-1)^2*(RESID(-1)<0) + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.017724	0.031524	0.562232	0.5740
AR(2)	0.058152	0.029547	1.968146	0.0491
Variance Equation				
C	5.72E-06	1.17E-06	4.906780	0.0000
RESID(-1)^2	-0.019728	0.013936	-1.415616	0.1569
RESID(-1)^2*(RESID(-1)<0)	0.156916	0.024361	6.441267	0.0000
GARCH(-1)	0.845697	0.026506	31.90625	0.0000
R-squared	0.003786	Mean dependent var		0.000125
Adjusted R-squared	0.002987	S.D. dependent var		0.007917
S.E. of regression	0.007906	Akaike info criterion		-6.904290
Sum squared resid	0.077937	Schwarz criterion		-6.879646
Log likelihood	4317.729	Hannan-Quinn criter.		-6.895025
Durbin-Watson stat	1.999952			
Inverted AR Roots	.25	-.23		

(d) South Korea

Dependent Variable: HK_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/22/22 Time: 10:43
Sample (adjusted): 1/05/2015 2/10/2020
Included observations: 1258 after adjustments
Convergence achieved after 16 iterations
MA Backcast: 1/02/2015
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.045951	0.030432	1.509994	0.1310
Variance Equation				
C	5.01E-06	1.14E-06	4.402614	0.0000
RESID(-1)^2	0.014710	0.009385	1.567416	0.1170
RESID(-1)^2*(RESID(-1)<0)	0.082764	0.017125	4.832941	0.0000
GARCH(-1)	0.902020	0.016214	55.63305	0.0000
R-squared	0.000342	Mean dependent var		0.000110
Adjusted R-squared	0.000342	S.D. dependent var		0.011155
S.E. of regression	0.011153	Akaike info criterion		-6.246846
Sum squared resid	0.156368	Schwarz criterion		-6.226427
Log likelihood	3934.266	Hannan-Quinn criter.		-6.239172
Durbin-Watson stat	2.036169			
Inverted MA Roots	-.05			

(e) Hong Kong

Dependent Variable: TAIWAN_RETURN_BEFORE
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/22/22 Time: 11:39
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1243 after adjustments
Convergence achieved after 13 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.030887	0.030332	1.018275	0.3085
Variance Equation				
C	6.71E-06	1.03E-06	6.514110	0.0000
RESID(-1)^2	-0.034370	0.012283	-2.798122	0.0051
RESID(-1)^2*(RESID(-1)<0)	0.207237	0.019260	10.76017	0.0000
GARCH(-1)	0.832882	0.021981	37.89094	0.0000
R-squared	-0.002184	Mean dependent var		0.000198
Adjusted R-squared	-0.002184	S.D. dependent var		0.008426
S.E. of regression	0.008436	Akaike info criterion		-6.827532
Sum squared resid	0.088381	Schwarz criterion		-6.806916
Log likelihood	4248.311	Hannan-Quinn criter.		-6.819780
Durbin-Watson stat	2.083040			
Inverted AR Roots	.03			

(f) Taiwan

Figure 21. Eviews GJRGARCH before covid sample result

Dependent Variable: CHINA_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/30/22 Time: 23:12
Sample: 2/11/2020 8/12/2022
Included observations: 612
Convergence achieved after 19 iterations
MA Backcast: 2/10/2020
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.019755	0.049534	-0.398811	0.6900
Variance Equation				
C	1.31E-05	4.12E-06	3.190280	0.0014
RESID(-1)^2	0.090465	0.017112	5.286673	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.103840	0.042376	2.450439	0.0143
GARCH(-1)	0.749819	0.051864	14.45743	0.0000

R-squared	-0.000790	Mean dependent var	0.000205
Adjusted R-squared	-0.000790	S.D. dependent var	0.011059
S.E. of regression	0.011064	Akaike info criterion	-6.274960
Sum squared resid	0.074790	Schwarz criterion	-6.238875
Log likelihood	1925.138	Hannan-Quinn criter.	-6.260925
Durbin-Watson stat	1.957494		
Inverted MA Roots	.02		

（a） China

Dependent Variable: US_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/21/22 Time: 17:03
Sample (adjusted): 2/18/2020 8/12/2022
Included observations: 628 after adjustments
Convergence achieved after 48 iterations
MA Backcast: 2/11/2020 2/14/2020
Presample variance: backcast (parameter = 0.7)
GARCH = C(9) + C(10)*RESID(-1)^2 + C(11)*RESID(-1)^2*(RESID(-1)<0) + C(12)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.541961	0.005460	-99.26680	0.0000
AR(2)	0.482414	0.005814	82.97084	0.0000
AR(3)	-0.534867	0.006255	-85.51635	0.0000
AR(4)	-0.970181	0.004200	-231.0154	0.0000
MA(1)	0.544875	0.002039	267.2185	0.0000
MA(2)	-0.473925	0.002759	-171.7826	0.0000
MA(3)	0.540751	0.002089	258.9177	0.0000
MA(4)	0.990326	0.001566	632.4784	0.0000
Variance Equation				
C	4.20E-06	1.28E-06	3.278803	0.0010
RESID(-1)^2	0.032946	0.030525	1.079338	0.2804
RESID(-1)^2*(RESID(-1)<0)	0.181677	0.048375	3.755631	0.0002
GARCH(-1)	0.849738	0.033632	25.26608	0.0000

R-squared	0.110881	Mean dependent var		0.000376
Adjusted R-squared	0.100843	S.D. dependent var		0.016541
S.E. of regression	0.015685	Akaike info criterion		-6.078605
Sum squared resid	0.152528	Schwarz criterion		-5.993715
Log likelihood	1920.682	Hannan-Quinn criter.		-6.045627
Durbin-Watson stat	2.383084			
Inverted AR Roots	.66+.74i	.66-.74i	-.93+.35i	-.93-.35i
Inverted MA Roots	.66-.75i	.66+.75i	-.93-.35i	-.93+.35i

（b）USA

Dependent Variable: JAPAN_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/21/22 Time: 20:02
Sample: 2/12/2020 8/12/2022
Included observations: 611
Convergence achieved after 13 iterations
MA Backcast: 2/11/2020
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.004573	0.043041	0.106240	0.9154
Variance Equation				
C	1.27E-05	3.51E-06	3.625003	0.0003
RESID(-1)^2	-0.003130	0.023153	-0.135185	0.8925
RESID(-1)^2*(RESID(-1)<0)	0.192381	0.048049	4.003856	0.0001
GARCH(-1)	0.839280	0.041306	20.31867	0.0000

R-squared	-0.000141	Mean dependent var	0.000306
Adjusted R-squared	-0.000141	S.D. dependent var	0.014132
S.E. of regression	0.014133	Akaike info criterion	-5.874418
Sum squared resid	0.121836	Schwarz criterion	-5.838288
Log likelihood	1799.635	Hannan-Quinn criter.	-5.860365
Durbin-Watson stat	1.927080		
Inverted MA Roots	-.00		

（c）Japan

Dependent Variable: KOREA_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/22/22 Time: 10:08
Sample: 2/11/2020 8/12/2022
Included observations: 620
Convergence achieved after 14 iterations
MA Backcast: 2/07/2020 2/10/2020
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-1)^2*(RESID(-1)<0) + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.080532	0.045488	1.770389	0.0767
MA(2)	0.062964	0.044363	1.419292	0.1558
Variance Equation				
C	1.70E-05	4.61E-06	3.688867	0.0002
RESID(-1)^2	0.065876	0.034694	1.898769	0.0576
RESID(-1)^2*(RESID(-1)<0)	0.375675	0.076484	4.911785	0.0000
GARCH(-1)	0.648278	0.055199	11.74438	0.0000

R-squared	0.001805	Mean dependent var	0.000223
Adjusted R-squared	0.000189	S.D. dependent var	0.014017
S.E. of regression	0.014016	Akaike info criterion	-6.094094
Sum squared resid	0.121404	Schwarz criterion	-6.051225
Log likelihood	1895.169	Hannan-Quinn criter.	-6.077431
Durbin-Watson stat	2.203076		
Inverted MA Roots	-.04-.25i	-.04+.25i	

（d）South Korea

Dependent Variable: HK_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/22/22 Time: 11:09
Sample: 2/11/2020 8/12/2022
Included observations: 619
Convergence achieved after 10 iterations
MA Backcast: 2/10/2020
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.014535	0.043874	-0.331295	0.7404
Variance Equation				
C	1.06E-05	3.10E-06	3.417197	0.0006
RESID(-1)^2	-0.001066	0.021495	-0.049605	0.9604
RESID(-1)^2*(RESID(-1)<0)	0.132216	0.031782	4.160060	0.0000
GARCH(-1)	0.880899	0.021908	40.20950	0.0000

R-squared	-0.000791	Mean dependent var	-0.000485
Adjusted R-squared	-0.000791	S.D. dependent var	0.015392
S.E. of regression	0.015398	Akaike info criterion	-5.663293
Sum squared resid	0.146535	Schwarz criterion	-5.627525
Log likelihood	1757.789	Hannan-Quinn criter.	-5.649388
Durbin-Watson stat	1.998220		
Inverted MA Roots	.01		

（e）Hong Kong

Dependent Variable: TAIWAN_RETURN_AFTER
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 08/22/22 Time: 12:07
Sample: 2/11/2020 8/12/2022
Included observations: 615
Convergence achieved after 15 iterations
MA Backcast: 2/10/2020
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	0.058440	0.044627	1.309532	0.1904
Variance Equation				
C	1.65E-05	4.18E-06	3.958768	0.0001
RESID(-1)^2	-0.013631	0.025861	-0.527085	0.5981
RESID(-1)^2*(RESID(-1)<0)	0.307629	0.071065	4.328867	0.0000
GARCH(-1)	0.738243	0.055664	13.26256	0.0000

R-squared	-0.000884	Mean dependent var	0.000453
Adjusted R-squared	-0.000884	S.D. dependent var	0.012169
S.E. of regression	0.012174	Akaike info criterion	-6.222518
Sum squared resid	0.091000	Schwarz criterion	-6.186570
Log likelihood	1918.424	Hannan-Quinn criter.	-6.208539
Durbin-Watson stat	2.049001		
Inverted MA Roots	-.06		

（f）Taiwan

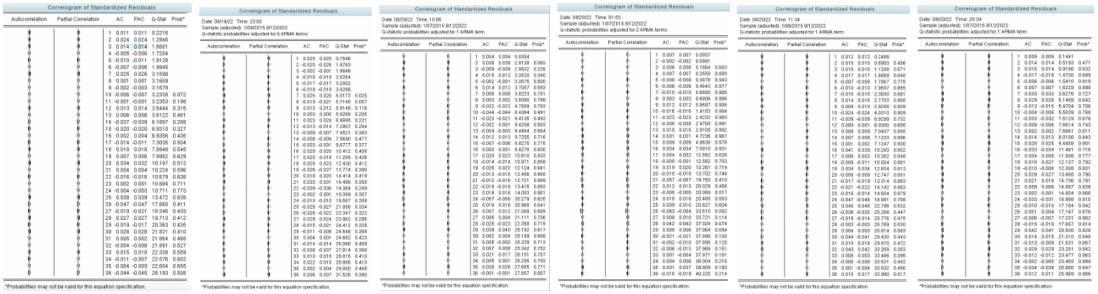
Figure 22. Eviews GJRGARCH during covid sample result

Table 17. Eviews leverage effect term from GJR-Garch.

Full Sample		China	USA	Japan	South Korea	Hong Kong	Taiwan
Full sample	stats	0.022288	0.291157	0.251796	0.202791	0.091842	0.217104
	prob	0.0212	0.0000	0.0000	0.0000	0.0000	0.0000
Before covid	stats	0.017236 leverage	0.322925 leverage	0.289123 leverage	0.156916 leverage	0.082764 leverage	0.207237 leverage
	prob	0.1333	0.0000	0.0000	0.0000	0.0000	0.0000
After covid	stats	0.103840 leverage+	0.181677 leverage-	0.192381 leverage-	0.375675 leverage+	0.132276 leverage+	0.307629 leverage+
	prob	0.0143	0.0002	0.0001	0.0000	0.0000	0.0000

4.5.2.1 Ljung-Box test for serial correlation

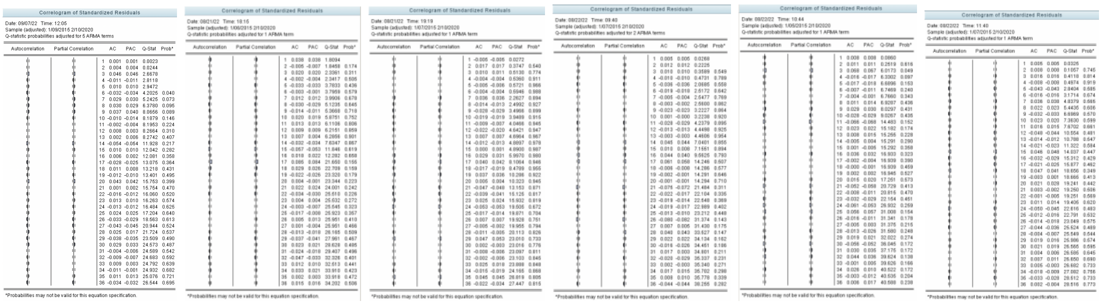
As described in section 2.4.3, the Ljung-Box test helps assess whether the time series of interest is autocorrelated. The null hypothesis of the test is that the autocorrelations of the given sample are all zero. If the p-value we get from the test is larger than 0.05, we fail to reject the null hypothesis, and the model is lack of fit. Figure 20-22 presents the Ljung Box test result for GJRGARCH.



China USA Japan South Korea Hong Kong Taiwan

Figure 23. Ljung-Box test for serial correlation for GJR Garch full sample

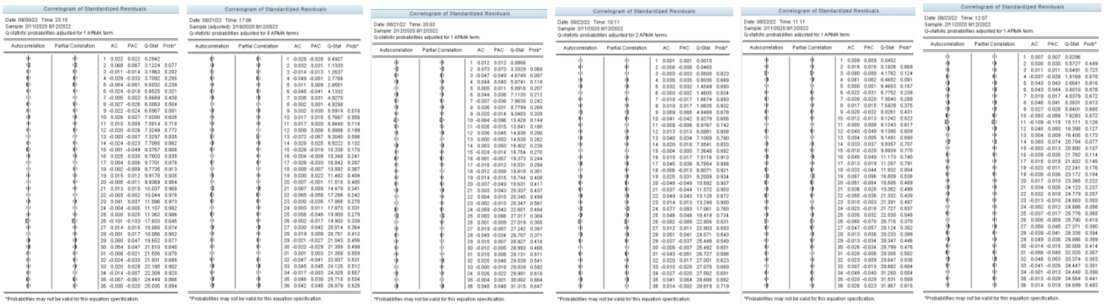
Except US at lag7 yields 0.025, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.



China USA Japan South Korea Hong Kong Taiwan

Figure 24. Ljung-Box test for serial correlation for GJR Garch before covid sample

Except China at lag5 yields 0.040, Hong Kong at lag 3 yields 0.049, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.



China USA Japan South Korea Hong Kong Taiwan

Figure 25. Ljung-Box test for serial correlation for GJR Garch after covid sample

Except US at lag9 yields 0.018, all probabilities satisfy the Ljung Box test with probabilities larger than 0.05. Thus we conclude that in general, the models are good fit and pass the Ljung-Box test.

4.5.2.2 ARCH-LM test

As described in section 2.4.3, the ARCH-LM test is a test for ARCH effects by regressing the squared errors on different specified lags. The null hypothesis is that the lagged regression coefficients are zero, there is no existing ARCH up to order q in the residuals, and there are no ARCH effects. If the p-value we get from the test is larger than 0.05, we reject the null hypothesis, and there are ARCH effects. We expect rejecting the null hypothesis to pass the ARCH LM diagnostic test in the section successfully. Figure 26-28 presents the ARCH LM test result, and table 18 summarizes the Prob. Chi-Square results.

Heteroskedasticity Test: ARCH

F-statistic	1.885892	Prob. F(1,1842)	0.1698
Obs*R-squared	1.886009	Prob. Chi-Square(1)	0.1697

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/19/22 Time: 20:07
Sample (adjusted): 1/14/2015 8/12/2022
Included observations: 1844 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.968939	0.059057	16.40693	0.0000
WGT_RESID^2(-1)	0.031981	0.023288	1.373278	0.1698

R-squared	0.001023	Mean dependent var	1.000953
Adjusted R-squared	0.000480	S.D. dependent var	2.330614
S.E. of regression	2.330054	Akaike info criterion	4.530744
Sum squared resid	10000.50	Schwarz criterion	4.536730
Log likelihood	-4175.346	Hannan-Quinn criter.	4.532951
F-statistic	1.885892	Durbin-Watson stat	1.999588
Prob(F-statistic)	0.169833		

(a) China

Heteroskedasticity Test: ARCH

F-statistic	0.005821	Prob. F(1,1909)	0.9392
Obs*R-squared	0.005827	Prob. Chi-Square(1)	0.9392

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/19/22 Time: 23:59
Sample (adjusted): 1/12/2015 8/12/2022
Included observations: 1911 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.998244	0.055382	18.02468	0.0000
WGT_RESID^2(-1)	0.001747	0.022897	0.076293	0.9392

R-squared	0.000003	Mean dependent var	0.999988
Adjusted R-squared	-0.000521	S.D. dependent var	2.204777
S.E. of regression	2.205351	Akaike info criterion	4.420696
Sum squared resid	9284.558	Schwarz criterion	4.426510
Log likelihood	-4221.975	Hannan-Quinn criter.	4.422836
F-statistic	0.005821	Durbin-Watson stat	1.999091
Prob(F-statistic)	0.939194		

(b) USA

Heteroskedasticity Test: ARCH

F-statistic	0.011919	Prob. F(1,1875)	0.9131
Obs*R-squared	0.011932	Prob. Chi-Square(1)	0.9130

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/20/22 Time: 10:14
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1877 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.003607	0.050576	19.84356	0.0000
WGT_RESID^2(-1)	-0.002527	0.023148	-0.109174	0.9131

R-squared	0.000006	Mean dependent var	1.001086
Adjusted R-squared	-0.000527	S.D. dependent var	1.949006
S.E. of regression	1.949520	Akaike info criterion	4.174108
Sum squared resid	7126.175	Schwarz criterion	4.180008
Log likelihood	-3915.400	Hannan-Quinn criter.	4.176281
F-statistic	0.011919	Durbin-Watson stat	1.994417
Prob(F-statistic)	0.913076		

(c) Japan

Heteroskedasticity Test: ARCH

F-statistic	0.147234	Prob. F(1,1866)	0.7012
Obs*R-squared	0.147380	Prob. Chi-Square(1)	0.7011

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/20/22 Time: 02:00
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1868 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.009658	0.047374	21.31233	0.0000
WGT_RESID^2(-1)	-0.008882	0.023149	-0.383711	0.7012

R-squared	0.000079	Mean dependent var	1.000768
Adjusted R-squared	-0.000457	S.D. dependent var	1.785603
S.E. of regression	1.786011	Akaike info criterion	3.998917
Sum squared resid	5952.235	Schwarz criterion	4.004840
Log likelihood	-3732.988	Hannan-Quinn criter.	4.001099
F-statistic	0.147234	Durbin-Watson stat	1.999008
Prob(F-statistic)	0.701237		

(d) South Korea

Heteroskedasticity Test: ARCH

F-statistic	0.074018	Prob. F(1,1873)	0.7856
Obs*R-squared	0.074094	Prob. Chi-Square(1)	0.7855

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/20/22 Time: 11:40
Sample (adjusted): 1/07/2015 8/12/2022
Included observations: 1875 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.005392	0.048316	20.80880	0.0000
WGT_RESID^2(-1)	-0.006287	0.023107	-0.272062	0.7856

R-squared	0.000040	Mean dependent var	0.999106
Adjusted R-squared	-0.000494	S.D. dependent var	1.836986
S.E. of regression	1.837440	Akaike info criterion	4.055689
Sum squared resid	6323.594	Schwarz criterion	4.061595
Log likelihood	-3800.209	Hannan-Quinn criter.	4.057865
F-statistic	0.074018	Durbin-Watson stat	1.999605
Prob(F-statistic)	0.785604		

(e) Hong Kong

Heteroskedasticity Test: ARCH

F-statistic	2.298105	Prob. F(1,1855)	0.1297
Obs*R-squared	2.297736	Prob. Chi-Square(1)	0.1296

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/20/22 Time: 20:44
Sample (adjusted): 1/08/2015 8/12/2022
Included observations: 1857 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.035456	0.059799	17.31554	0.0000
WGT_RESID^2(-1)	-0.035175	0.023204	-1.515950	0.1297

R-squared	0.001237	Mean dependent var	1.000274
Adjusted R-squared	0.000699	S.D. dependent var	2.375766
S.E. of regression	2.374936	Akaike info criterion	4.568894
Sum squared resid	10462.80	Schwarz criterion	4.574847
Log likelihood	-4240.219	Hannan-Quinn criter.	4.571088
F-statistic	2.298105	Durbin-Watson stat	1.998799
Prob(F-statistic)	0.129702		

(f) Taiwan

Figure 26. ARCH-LM test for GJR Garch full sample

Heteroskedasticity Test: ARCH

F-statistic	1.422341	Prob. F(1,1232)	0.2332
Obs*R-squared	1.423007	Prob. Chi-Square(1)	0.2329

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 09/07/22 Time: 12:11
Sample (adjusted): 1/12/2015 2/10/2020
Included observations: 1234 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.967274	0.076386	12.66306	0.0000
WGT_RESID^2(-1)	0.033959	0.028474	1.192619	0.2332

R-squared	0.001153	Mean dependent var	1.001279
Adjusted R-squared	0.000342	S.D. dependent var	2.489779
S.E. of regression	2.489352	Akaike info criterion	4.663542
Sum squared resid	7634.549	Schwarz criterion	4.671837
Log likelihood	-2875.405	Hannan-Quinn criter.	4.666662
F-statistic	1.422341	Durbin-Watson stat	1.997518
Prob(F-statistic)	0.233248		

(a) China

Heteroskedasticity Test: ARCH

F-statistic	0.432956	Prob. F(1,1280)	0.5107
Obs*R-squared	0.433486	Prob. Chi-Square(1)	0.5103

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/21/22 Time: 18:21
Sample (adjusted): 1/07/2015 2/10/2020
Included observations: 1282 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.982217	0.068830	14.27015	0.0000
WGT_RESID^2(-1)	0.018389	0.027946	0.657994	0.5107

R-squared	0.000338	Mean dependent var	1.000620
Adjusted R-squared	-0.000443	S.D. dependent var	2.251362
S.E. of regression	2.251860	Akaike info criterion	4.462949
Sum squared resid	6490.720	Schwarz criterion	4.470993
Log likelihood	-2858.750	Hannan-Quinn criter.	4.465969
F-statistic	0.432956	Durbin-Watson stat	1.998787
Prob(F-statistic)	0.510660		

(b) USA

Heteroskedasticity Test: ARCH

F-statistic	9.89E-05	Prob. F(1,1264)	0.9921
Obs*R-squared	9.91E-05	Prob. Chi-Square(1)	0.9921

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/21/22 Time: 19:26
Sample (adjusted): 1/08/2015 2/10/2020
Included observations: 1266 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.001763	0.065718	15.24338	0.0000
WGT_RESID^2(-1)	0.000280	0.028126	0.009945	0.9921

R-squared	0.000000	Mean dependent var	1.002043
Adjusted R-squared	-0.000791	S.D. dependent var	2.111666
S.E. of regression	2.112501	Akaike info criterion	4.335201
Sum squared resid	5640.805	Schwarz criterion	4.343327
Log likelihood	-2742.182	Hannan-Quinn criter.	4.338254
F-statistic	9.89E-05	Durbin-Watson stat	1.998974
Prob(F-statistic)	0.992067		

(c) Japan

Heteroskedasticity Test: ARCH

F-statistic	1.002456	Prob. F(1,1246)	0.3169
Obs*R-squared	1.003258	Prob. Chi-Square(1)	0.3165

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/22/22 Time: 09:45
Sample (adjusted): 1/08/2015 2/10/2020
Included observations: 1248 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.029258	0.062284	16.52520	0.0000
WGT_RESID^2(-1)	-0.028351	0.028316	-1.001227	0.3169

R-squared	0.000804	Mean dependent var	1.000891
Adjusted R-squared	0.000002	S.D. dependent var	1.959491
S.E. of regression	1.959489	Akaike info criterion	4.184846
Sum squared resid	4784.139	Schwarz criterion	4.193066
Log likelihood	-2609.344	Hannan-Quinn criter.	4.187936
F-statistic	1.002456	Durbin-Watson stat	1.999524
Prob(F-statistic)	0.316911		

(d) South Korea

Heteroskedasticity Test: ARCH

F-statistic	0.022556	Prob. F(1,1255)	0.8806
Obs*R-squared	0.022592	Prob. Chi-Square(1)	0.8805

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/22/22 Time: 10:49
Sample (adjusted): 1/06/2015 2/10/2020
Included observations: 1257 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.004654	0.061227	16.40854	0.0000
WGT_RESID^2(-1)	-0.004239	0.028227	-0.150188	0.8806

R-squared	0.000018	Mean dependent var	1.000413
Adjusted R-squared	-0.000779	S.D. dependent var	1.925441
S.E. of regression	1.926190	Akaike info criterion	4.150555
Sum squared resid	4656.313	Schwarz criterion	4.158728
Log likelihood	-2606.624	Hannan-Quinn criter.	4.153627
F-statistic	0.022556	Durbin-Watson stat	1.999170
Prob(F-statistic)	0.880641		

(e) Hong Kong

Heteroskedasticity Test: ARCH

F-statistic	0.595012	Prob. F(1,1240)	0.4406
Obs*R-squared	0.595685	Prob. Chi-Square(1)	0.4402

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/22/22 Time: 11:45
Sample (adjusted): 1/08/2015 2/10/2020
Included observations: 1242 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.021919	0.084299	12.12249	0.0000
WGT_RESID^2(-1)	-0.021901	0.028392	-0.771370	0.4406

R-squared	0.000480	Mean dependent var	1.000015
Adjusted R-squared	-0.000326	S.D. dependent var	2.796796
S.E. of regression	2.797253	Akaike info criterion	4.896762
Sum squared resid	9702.532	Schwarz criterion	4.905014
Log likelihood	-3038.889	Hannan-Quinn criter.	4.899865
F-statistic	0.595012	Durbin-Watson stat	1.998142
Prob(F-statistic)	0.440635		

(f) Taiwan

Figure 27. ARCH-LM test for GJR Garch before covid sample

Heteroskedasticity Test: ARCH

F-statistic	0.032031	Prob. F(1,609)	0.8580
Obs*R-squared	0.032135	Prob. Chi-Square(1)	0.8577

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/30/22 Time: 23:20
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 611 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.010049	0.087649	11.52379	0.0000
WGT_RESID^2(-1)	-0.007253	0.040524	-0.178973	0.8580

R-squared	0.000053	Mean dependent var	1.002774
Adjusted R-squared	-0.001589	S.D. dependent var	1.917962
S.E. of regression	1.919486	Akaike info criterion	4.145260
Sum squared resid	2243.815	Schwarz criterion	4.159712
Log likelihood	-1264.377	Hannan-Quinn criter.	4.150881
F-statistic	0.032031	Durbin-Watson stat	1.998875
Prob(F-statistic)	0.858018		

(a) China

Heteroskedasticity Test: ARCH

F-statistic	0.582599	Prob. F(1,625)	0.4456
Obs*R-squared	0.583919	Prob. Chi-Square(1)	0.4448

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/21/22 Time: 17:11
Sample (adjusted): 2/19/2020 8/12/2022
Included observations: 627 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.034072	0.077989	13.25923	0.0000
WGT_RESID^2(-1)	-0.030538	0.040009	-0.763282	0.4456

R-squared	0.000931	Mean dependent var	1.003542
Adjusted R-squared	-0.000667	S.D. dependent var	1.675884
S.E. of regression	1.676443	Akaike info criterion	3.874410
Sum squared resid	1756.538	Schwarz criterion	3.888576
Log likelihood	-1212.628	Hannan-Quinn criter.	3.879914
F-statistic	0.582599	Durbin-Watson stat	1.995141
Prob(F-statistic)	0.445584		

(b) USA

Heteroskedasticity Test: ARCH

F-statistic	0.481593	Prob. F(1,608)	0.4880
Obs*R-squared	0.482795	Prob. Chi-Square(1)	0.4872

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/21/22 Time: 20:09
Sample (adjusted): 2/13/2020 8/12/2022
Included observations: 610 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.972318	0.075371	12.90046	0.0000
WGT_RESID^2(-1)	0.028340	0.040838	0.693969	0.4880

R-squared	0.000791	Mean dependent var	1.000436
Adjusted R-squared	-0.000852	S.D. dependent var	1.568979
S.E. of regression	1.569647	Akaike info criterion	3.742852
Sum squared resid	1497.985	Schwarz criterion	3.757322
Log likelihood	-1139.570	Hannan-Quinn criter.	3.748481
F-statistic	0.481593	Durbin-Watson stat	1.986081
Prob(F-statistic)	0.487966		

(c) Japan

Heteroskedasticity Test: ARCH

F-statistic	0.059671	Prob. F(1,617)	0.8071
Obs*R-squared	0.059859	Prob. Chi-Square(1)	0.8067

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/22/22 Time: 10:15
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 619 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.988970	0.070026	14.12288	0.0000
WGT_RESID^2(-1)	0.009837	0.040272	0.244276	0.8071

R-squared	0.000097	Mean dependent var	0.998814
Adjusted R-squared	-0.001524	S.D. dependent var	1.423725
S.E. of regression	1.424809	Akaike info criterion	3.549178
Sum squared resid	1252.560	Schwarz criterion	3.563486
Log likelihood	-1096.471	Hannan-Quinn criter.	3.554740
F-statistic	0.059671	Durbin-Watson stat	1.998463
Prob(F-statistic)	0.807098		

(d) South Korea

Heteroskedasticity Test: ARCH

F-statistic	0.584818	Prob. F(1,616)	0.4447
Obs*R-squared	0.586161	Prob. Chi-Square(1)	0.4439

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/22/22 Time: 11:15
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 618 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.029415	0.078083	13.18353	0.0000
WGT_RESID^2(-1)	-0.030800	0.040275	-0.764734	0.4447

R-squared	0.000948	Mean dependent var	0.998579
Adjusted R-squared	-0.000673	S.D. dependent var	1.661705
S.E. of regression	1.662265	Akaike info criterion	3.857470
Sum squared resid	1702.084	Schwarz criterion	3.871795
Log likelihood	-1189.958	Hannan-Quinn criter.	3.863039
F-statistic	0.584818	Durbin-Watson stat	1.995984
Prob(F-statistic)	0.444723		

(e) Hong Kong

Heteroskedasticity Test: ARCH

F-statistic	2.783534	Prob. F(1,612)	0.0957
Obs*R-squared	2.779987	Prob. Chi-Square(1)	0.0954

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 08/22/22 Time: 12:11
Sample (adjusted): 2/12/2020 8/12/2022
Included observations: 614 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.066254	0.075286	14.16273	0.0000
WGT_RESID^2(-1)	-0.067298	0.040337	-1.668393	0.0957

R-squared	0.004528	Mean dependent var	0.998932
Adjusted R-squared	0.002901	S.D. dependent var	1.577218
S.E. of regression	1.574929	Akaike info criterion	3.749549
Sum squared resid	1518.005	Schwarz criterion	3.763947
Log likelihood	-1149.112	Hannan-Quinn criter.	3.755148
F-statistic	2.783534	Durbin-Watson stat	1.999902
Prob(F-statistic)	0.095749		

(f) Taiwan

Figure 28. ARCH-LM test for GJR Garch after covid sample

Table 18. ARCH-LM result GJR-Garch

Prob. Chi-Square	China	USA	Japan	South Korea	Hong Kong	Taiwan
Full sample	0.1697	0.9392	0.9130	0.7011	0.7855	0.1296
Before covid	0.2329	0.5103	0.9921	0.3165	0.8805	0.4402
After covid	0.8577	0.4448	0.4872	0.8067	0.4439	0.0954

From the ARCH-LM test, all the Prob. Chi-Square results are significantly larger than 0.05, successfully pass the ARCH-LM test.

4.6 Forecasting conditional variance of the series

After modeling the characteristics of volatilities of different countries and regions, this study predicted the volatility. The study first trains the data using the 2015-2021 data, then employs the derived models to forecast volatility in 2021. The study chooses the best model based on four criteria: the model that yields the lowest Root Mean Square Error, the lowest Mean Absolute Error, the Lowest Mean Absolute Percent Error, and finally, the highest Theil's Inequality Coefficient.

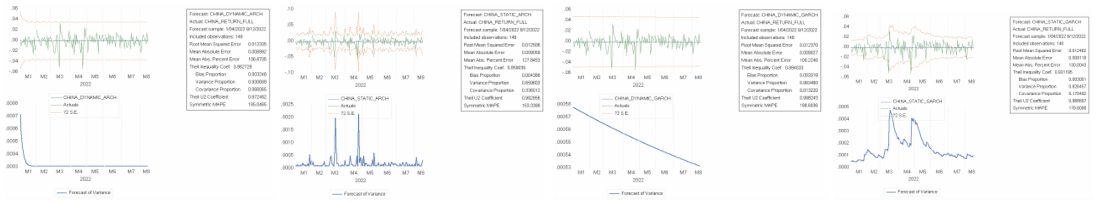
$$\text{Mean Absolute Error}: (\frac{1}{N}) \sum_{i=1}^{N} \left|(y_i - \hat{y}_i)\right|$$

$$\text{Mean Absolute Percent Error}: \left(\frac{1}{N}\right)\sum_{i=1}^{N} \left|\left(y_i - \hat{y}_i\right)/y_i\right|. 100$$

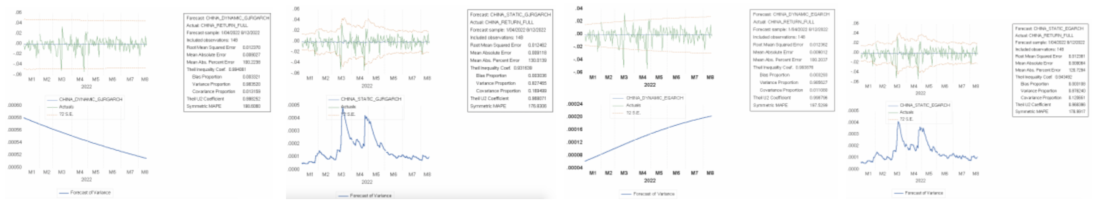
$$\text{Root Mean Square Error}: \sqrt{(\frac{1}{N}) \sum_{i=1}^{N} (y_i - \hat{y}_i)^2}$$

$$\text{Theil's Inequality Coefficient: } \frac{\sqrt{\left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(y_i-\hat{y}_i\right)^2}}{\left[\sqrt{\left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(y_i\right)^2}+\sqrt{\left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(\hat{y}_i\right)^2}\right]}$$

As all our previous models exist ARCH effects through, we estimate ARCH, GARCH(1,1), EGARCH, GJRGARCH models in dynamic, and static forms. Figure 29-34 presents our estimating results.

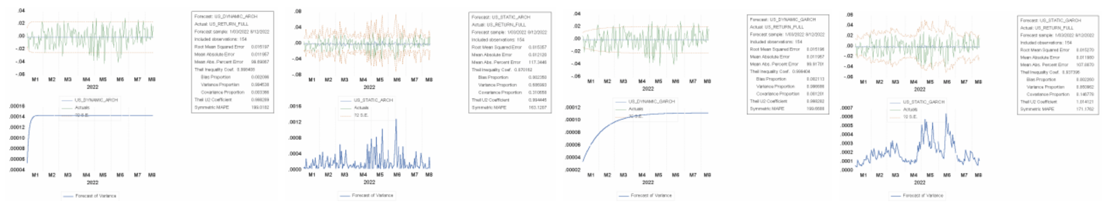


China Dynamic ARCH | China Static ARCH | China Dynamic GARCH(1,1) | China Static GARCH(1,1)

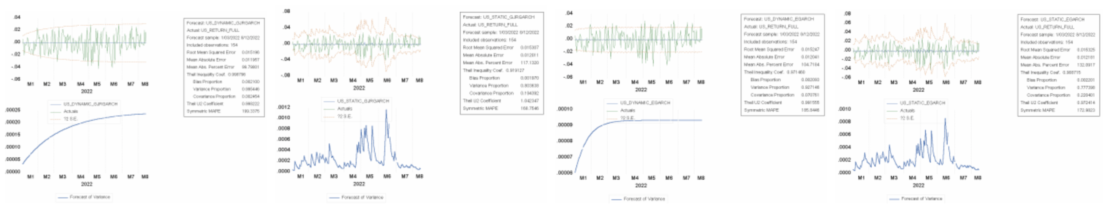


China Dynamic GJR-GARCH | China Static GJR-GARCH | China Dynamic EGARCH | China Static EGARCH

Figure 29. In-sample Forecast result for China 2022's volatility using 2015-2021 volatility

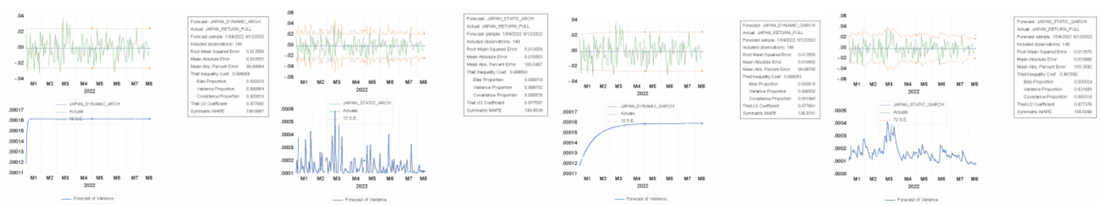


US Dynamic ARCH | US Static ARCH | US Dyamic GARCH(1,1) | US Static GARCH(1,1)

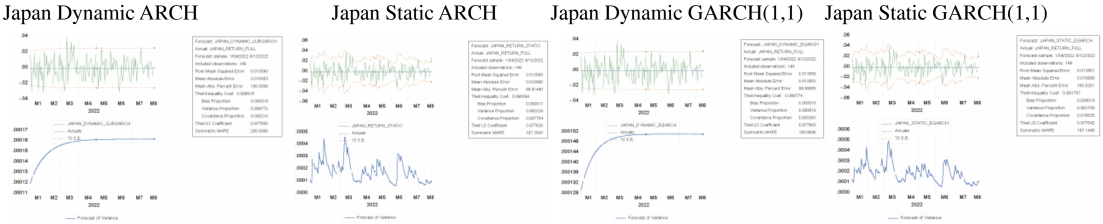


US Dynamic GJR-GARCH | US Static GJR-GARCH | US Dynamic EGARCH | US Static EGARCH

Figure 30. In-sample Forecast result for US 2022's volatility using 2015-2021 volatility

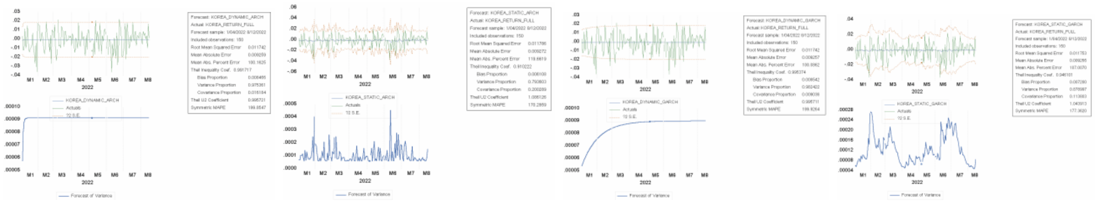


Japan Dynamic ARCH | Japan Static ARCH | Japan Dynamic GARCH(1,1) | Japan Static GARCH(1,1)

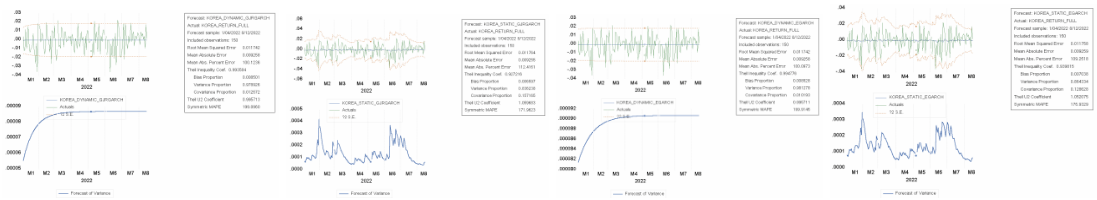


Japan Dynamic GJR-GARCH Japan Static GJR-GARCH Japan Dynamic EGARCH Japan Static EGARCH

Figure 31. In-sample Forecast result for Japan 2022's volatility using 2015-2021 volatility

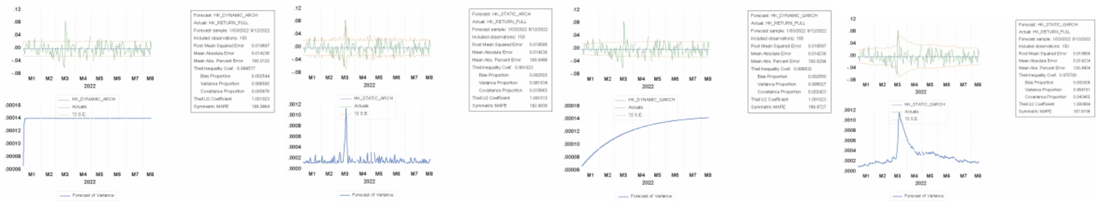


Korea Dynamic ARCH Korea Static ARCH Korea Dynamic GARCH(1,1) Korea Static GARCH(1,1)

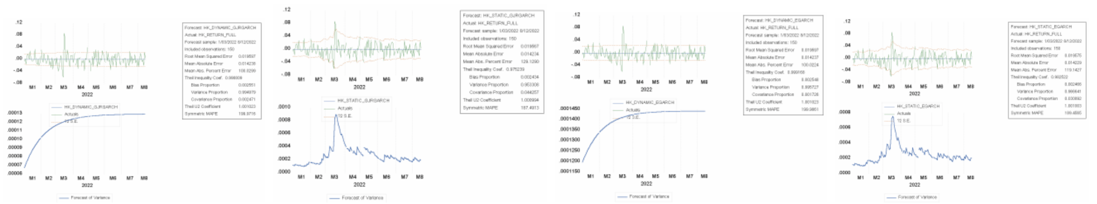


Korea Dynamic GJR-GARCH Korea Static GJR-GARCH Korea Dynamic EGARCH Korea Static EGARCH

Figure 32. In-sample Forecast result for Korea 2022's volatility using 2015-2021 volatility

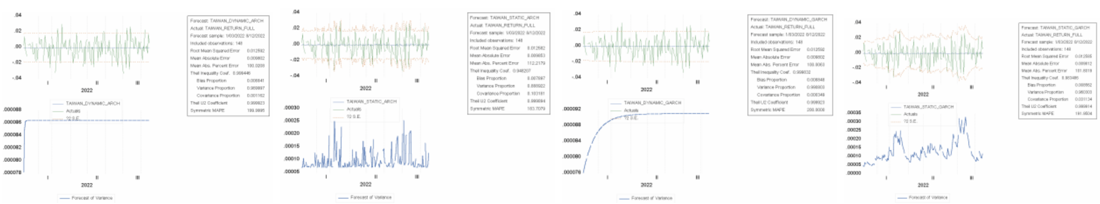


HK Dynamic ARCH HK Static ARCH HK Dynamic GARCH(1,1) HK Static GARCH(1,1)

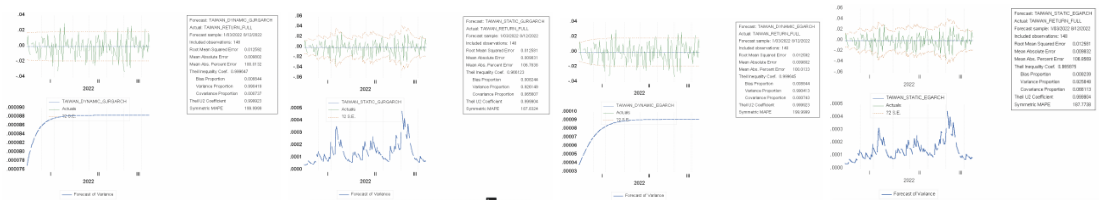


HK Dynamic GJR-GARCH HK Static GJR-GARCH HK Dynamic EGARCH HK Static EGARCH

Figure 33. In-sample Forecast result for Hong Kong 2022's volatility using 2015-2021 volatility



Taiwan Dynamic ARCH Taiwan Static ARCH Taiwan Dynamic GARCH(1,1) Taiwan Static GARCH(1,1)



Taiwan Dynamic GJR-GARCH Taiwan Static GJR-GARCH Taiwan Dynamic EGARCH Taiwan Static EGARCH

Figure 34. In-sample Forecast result for Taiwan 2022's volatility using 2015-2021 volatility

Table 19. Comparison of Root Mean Square Error

Forecast result/RMSE	China	USA	Japan	South Korea	Hong Kong	Taiwan
Dynamic ARCH	0.012335	0.015196	0.013559	0.011742	0.019597	0.012592
Static ARCH	0.012506	0.015357	0.013559	0.011786	0.019585	0.012582
Dynamic GARCH(1,1)	0.012370	0.015196	0.013558	0.011742	0.019597	0.012592

Static GARCH(1,1)	0.012462	0.015270	0.013570	0.011753	0.019568	0.012585
Dynamic GJR-GARCH	0.012370	0.015196	0.013560	0.011742	0.019597	0.012592
Static GJR-GARCH	0.012462	0.015307	0.013559	0.011764	0.019567	0.012581
Dynamic E-GARCH	0.012362	0.015247	0.013559	0.001742	0.019597	0.012592
Static E-GARCH	0.012381	0.015325	0.013561	0.011758	0.019575	0.012581

For China, using the criterion of minimizing the root mean square error, the best estimating model is Dynamic ARCH, followed by Dynamic E-GARCH, and then by Dynamic GARCH(1,1) and Dynamic GJR-GARCH. For the US, the best estimating models are Dynamic ARCH, Dynamic GARCH(1,1) and Dynamic GJR-GARCH. For Japan, the best forecasting models are Dynamic GARCH(1,1), followed by Dynamic ARCH, Static ARCH, Static GJR-GARCH, Dynamic EGARCH. For South Korea, the best forecasting models are Dynamic ARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH and Dynamic EGARCH. For Hong Kong, the best forecasting models are Static GJR-GRACH, followed by Static GARCH(1,1) and Static E-GARCH. For Taiwan, the best forecasting models are Static GJR-GARCH and Static E-GARCH, followed by Static ARCH and then by Static GARCH(1,1).

Table 20. Comparison of Mean Absolute Error

Forecast result/MAE	China	USA	Japan	South Korea	Hong Kong	Taiwan
Dynamic ARCH	0.008992	0.011957	0.010883	0.009259	0.014236	0.009802
Static ARCH	0.009059	0.012120	0.010883	0.009272	0.014230	0.009853
Dynamic GARCH(1,1)	0.009027	0.011957	0.010882	0.009257	0.014238	0.009802
Static GARCH(1,1)	0.009118	0.011980	0.010906	0.009255	0.014234	0.009812
Dynamic GJR-GARCH	0.009027	0.011957	0.010883	0.009258	0.014238	0.009802
Static GJR-GARCH	0.009118	0.012011	0.010880	0.009255	0.014234	0.009831
Dynamic E-GARCH	0.009012	0.012041	0.010883	0.009258	0.014237	0.009802
Static E-GARCH	0.009064	0.012181	0.010888	0.009259	0.014229	0.009832

For China, using the criterion of minimizing the mean absolute error, the best estimating model is Dynamic ARCH, followed by Dynamic E-GARCH, and then by Dynamic GARCH(1,1) and Dynamic GJR-GARCH. For the US, the best estimating models are Dynamic ARCH, Dynamic GARCH(1,1) and Dynamic GJR-GARCH. For Japan, the best forecasting models are Static GJR-GARCH, followed by Dynamic GARCH(1,1). For South Korea, the best forecasting models are Static GARCH(1,1) and Static GJR-GARCH, followed by Dynamic GARCH(1,1). For Hong Kong, the best forecasting model is Static E-GARCH, followed by Static ARCH, and then by Static GARCH(1,1) and Static GJR-GARCH. For Taiwan, the best forecasting models are Dynamic ARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH and Dynamic E-GARCH.

Table 21. Comparison of Mean Absolute Percent Error

Forecast result/MAPE	China	USA	Japan	South Korea	Hong Kong	Taiwan
Dynamic ARCH	106.8705	99.69867	99.99994	100.1625	100.0122	100.0208

Static ARCH	127.8453	117.2446	100.0407	119.6619	108.9498	112.2179
Dynamic GARCH(1,1)	100.2248	99.91701	99.99780	100.0862	100.0294	100.0063
Static GARCH(1,1)	130.0043	107.8870	103.3592	107.0070	128.4904	101.8019
Dynamic GJR-GARCH	100.2238	99.79801	100.0006	100.1236	100.0299	100.0132
Static GJR-GARCH	130.0139	117.1320	99.61440	112.4161	129.1290	106.7838
Dynamic E-GARCH	100.2037	104.7184	99.99889	100.0973	100.0224	100.0133
Static E-GARCH	120.7294	132.0917	100.8261	109.2518	119.1427	106.8569

For China, using the criterion of minimizing the mean absolute percent error, the best estimating model is Dynamic E-GARCH, followed by Dynamic GJR-GARCH, and then by Dynamic GARCH(1,1). For the US, the best estimating model is Dynamic ARCH, followed by Dynamic GJR-GARCH, and then by Dynamic GARCH(1,1). For Japan, the best forecasting model is Static GJR-GARCH, followed by Dynamic GARCH(1,1). For South Korea, the best forecasting model is Dynamic GARCH(1,1), followed by Dynamic E-GARCH. For Hong Kong, the best forecasting model is Dynamic ARCH, followed by Dynamic E-GARCH. For Taiwan, the best forecasting model is Dynamic GARCH(1,1), followed by Dynamic GJR-GARCH.

Table 22. Comparison of Theil's Inequality Coefficient

Forecast result/TIC	China	USA	Japan	South Korea	Hong Kong	Taiwan
Dynamic ARCH	0.962729	0.998408	0.999989	0.991717	0.999577	0.999446
Static ARCH	0.859039	0.870162	0.999591	0.910222	0.991023	0.948207
Dynamic GARCH(1,1)	0.994033	0.999404	0.999083	0.995347	0.998832	0.999832
Static GARCH(1,1)	0.931185	0.937396	0.967892	0.946101	0.975700	0.983486
Dynamic GJR-GARCH	0.994061	0.998796	0.999915	0.993584	0.998809	0.999647
Static GJR-GARCH	0.931639	0.919127	0.996094	0.927216	0.975239	0.966123
Dynamic E-GARCH	0.993876	0.971460	0.999774	0.994776	0.999168	0.999645
Static E-GARCH	0.943492	0.908715	0.991797	0.939815	0.982522	0.965875

For China, using the criterion of maximizing the Theil's Inequality Coefficient, the best estimating model is Dynamic GJR-GARCH, followed by Dynamic GARCH(1,1), and then by Dynamic E-GARCH. For the US, the best estimating models are Dynamic ARCH and Dynamic GJR-GARCH. For Japan, the best estimating model is Dynamic ARCH, followed by Dynamic GJR-GARCH. For South Korea, the best estimating model is Dynamic GARCH(1,1), followed by Dynamic E-GARCH. For Hong Kong, the best estimating model is Dynamic ARCH, followed by Dynamic E-GARCH. For Taiwan, the best estimating model is Dynamic GARCH(1,1), followed by Dynamic GJR-GARCH.

Table 23. Summary of Best Estimating Models

	minimize RMSE	minimize MAE	minimize MAPE	maximize TIC

China	Dynamic ARCH, Dynamic E-GARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH	Dynamic ARCH, Dynamic E-GARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH	Dynamic E-GARCH, Dynamic GJR-GARCH, Dynamic GARCH(1,1)	Dynamic GJR-GARCH, Dynamic GARCH(1,1), Dynamic E-GARCH
USA	Dynamic ARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH	Dynamic ARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH	Dynamic ARCH, Dynamic GJR-GARCH, Dynamic GARCH(1,1)	Dynamic ARCH, Dynamic GJR-GARCH
Japan	Dynamic GARCH(1,1), Dynamic ARCH, Static ARCH, Static GJR-GARCH, Dynamic EGARCH	Static GJR-GARCH, Dynamic GARCH(1,1)	Static GJR-GARCH, Dynamic GARCH(1,1)	Dynamic ARCH, Dynamic GJR-GARCH
South Korea	Dynamic ARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH, Dynamic EGARCH	Static GARCH(1,1), Static GJR-GARCH	Dynamic GARCH(1,1), Dynamic E-GARCH	Dynamic GARCH(1,1)
Hong Kong	Static GJR-GARCH, Static GARCH(1,1), Static E-GARCH	Static E-GARCH, Static ARCH, Static GARCH(1,1), Static GJR-GARCH	Dynamic ARCH, Dynamic E-GARCH, Dynamic GARCH(1,1)	Dynamic ARCH, Dynamic E-GARCH, Dynamic GARCH(1,1)
Taiwan	Static GJR-GARCH, Static E-GARCH	Dynamic ARCH, Dynamic GARCH(1,1), Dynamic GJR-GARCH, Dynamic E-GARCH	Dynamic GARCH(1,1), Dynamic GJR-GARCH	Dynamic GARCH(1,1)

After estimating each type of model in both its dynamic and static form, the GARCH(1,1) dynamic model is the one that minimizes the RMSE, MAE, MAPE, and has the highest Theil's Inequality Coefficient. On the scale of individual country or region, Dynamic E-GARCH performs the best in estimating China stock market. Dynamic ARCH is best for estimating the US stock market. For Japan, the model that best estimate its stock market is the Static GJR-GARCH. For South Korea, the best estimating model is Dynamic GARCH(1,1). For Hong Kong, the models' performance are average and not enough to support which one is the best. For Taiwan, it is also the Dynamic GARCH(1,1) model that best forecast its stock market. In summary, Dynamic GARCH(1,1) model performs the best in estimating stock markets across the studied countries.

4.7 Volatility spill-over effect

The ARCH and GARCH models in the previous sections of this study are univariate and conditional, and extensions into multivariate cases can model dynamics of both covariances and correlations between different countries' stock markets. The volatility spill-over effect holds great significance in this study since initially the study chooses countries and regions that are China's top trading partners. Measuring the co-movement in volatility can support our hypothesis that they are also profoundly connected regarding stock market volatility. The study adopts the straightforward diagonal BEKK method suggested by *Essentials of Time Series For Financial*

Applications. For the conditional mean, the study employs MA(1) for China's returns and AR(1) for other countries' or regions' returns. For the conditional variance, the study employs a simple Gaussian GARCH(1,1) model for both series.

System: BEKK
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal BEKK
Date: 09/04/22 Time: 14:48
Sample: 1/06/2015 8/12/2022
Included observations: 1985
Total system (balanced) observations 3970
Disturbance assumption: Student's t distribution
Presample covariance: backcast (parameter =0.7)
Failure to improve likelihood (non-zero gradients) after 0 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-8.01E-05	0.000191	-0.420275	0.6743
C(2)	0.191378	0.018715	10.22601	0.0000
C(3)	0.000436	0.000148	2.941469	0.0033
C(4)	-0.159610	0.024009	-6.647813	0.0000
Variance Equation Coefficients				
C(5)	9.81E-07	3.01E-07	3.259711	0.0011
C(6)	3.80E-07	2.91E-07	1.306746	0.1913
C(7)	4.11E-06	6.64E-07	6.183784	0.0000
C(8)	0.265501	0.016405	16.18445	0.0000
C(9)	0.464248	0.026997	17.19630	0.0000
C(10)	0.962802	0.003845	250.3946	0.0000
C(11)	0.869600	0.013186	65.94885	0.0000
t-Distribution (Degree of Freedom)				
C(12)	7.000000	0.603629	11.59653	0.0000

Log likelihood	12962.09	Schwarz criterion	-13.01414
Avg. log likelihood	3.265011	Hannan-Quinn criter.	-13.03553
Akaike info criterion	-13.04795		

Equation: CHINA_RETURN_FULL = C(1)+C(2)*US_RETURN_FULL(-1)

R-squared	0.026740	Mean dependent var	-1.12E-05
Adjusted R-squared	0.026249	S.D. dependent var	0.013481
S.E. of regression	0.013303	Sum squared resid	0.350923
Durbin-Watson stat	1.993504		

Equation: US_RETURN_FULL=C(3)+C(4)*US_RETURN_FULL(-1)

R-squared	0.025482	Mean dependent var	0.000378
Adjusted R-squared	0.024991	S.D. dependent var	0.011517
S.E. of regression	0.011372	Sum squared resid	0.256468
Durbin-Watson stat	1.975702		

Covariance specification: Diagonal BEKK
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1
M is an indefinite matrix
A1 is a diagonal matrix
B1 is a diagonal matrix

Transformed Variance Coefficients

	Coefficient	Std. Error	z-Statistic	Prob.
M(1,1)	9.81E-07	3.01E-07	3.259711	0.0011
M(1,2)	3.80E-07	2.91E-07	1.306746	0.1913
M(2,2)	4.11E-06	6.64E-07	6.183784	0.0000
A1(1,1)	0.265501	0.016405	16.18445	0.0000
A1(2,2)	0.464248	0.026997	17.19630	0.0000
B1(1,1)	0.962802	0.003845	250.3946	0.0000
B1(2,2)	0.869600	0.013186	65.94885	0.0000

Figure 35. Spillover effect between China and US output

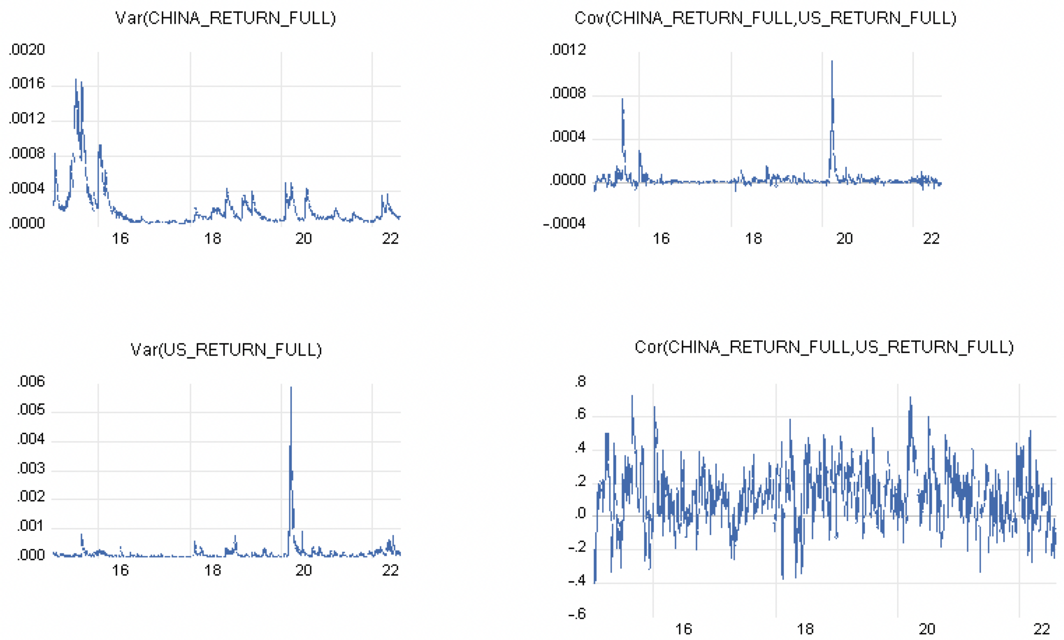


Figure 36. Covariance and correlation between China and US output

System: BEKK
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal BEKK
Date: 09/04/22 Time: 15:08
Sample: 1/06/2015 8/12/2022
Included observations: 1985
Total system (balanced) observations 3970
Disturbance assumption: Student's t distribution
Presample covariance: backcast (parameter =0.7)
Convergence achieved after 38 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.000511	0.000181	2.828020	0.0047
C(2)	0.001326	0.016135	0.082185	0.9345
C(3)	0.000734	0.000207	3.551865	0.0004
C(4)	-0.033321	0.021166	-1.574265	0.1154
Variance Equation Coefficients				
C(5)	1.53E-06	3.92E-07	3.894052	0.0001
C(6)	6.02E-07	3.10E-07	1.937539	0.0527
C(7)	5.65E-06	1.38E-06	4.092182	0.0000
C(8)	0.240846	0.017344	13.88643	0.0000
C(9)	0.302870	0.022779	13.29597	0.0000
C(10)	0.966051	0.004157	232.3732	0.0000
C(11)	0.937976	0.009054	103.6005	0.0000
t-Distribution (Degree of Freedom)				
C(12)	4.338004	0.341694	12.69559	0.0000

Log likelihood	12516.64	Schwarz criterion	-12.56532
Avg. log likelihood	3.152805	Hannan-Quinn criter.	-12.58671
Akaike info criterion	-12.59913		

Equation: CHINA_RETURN_FULL = C(1)+C(2)*JAPAN_RETURN_FULL(-1)

R-squared	-0.001391	Mean dependent var	-1.12E-05
Adjusted R-squared	-0.001896	S.D. dependent var	0.013481
S.E. of regression	0.013494	Sum squared resid	0.361066
Durbin-Watson stat	1.921222		

Equation: JAPAN_RETURN_FULL=C(3)+C(4)*JAPAN_RETURN_FULL(-1)

R-squared	-0.000473	Mean dependent var	0.000249
Adjusted R-squared	-0.000978	S.D. dependent var	0.012474
S.E. of regression	0.012480	Sum squared resid	0.308865
Durbin-Watson stat	1.985190		

Covariance specification: Diagonal BEKK
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1
M is an indefinite matrix
A1 is a diagonal matrix
B1 is a diagonal matrix

Transformed Variance Coefficients

	Coefficient	Std. Error	z-Statistic	Prob.
M(1,1)	1.53E-06	3.92E-07	3.894052	0.0001
M(1,2)	6.02E-07	3.10E-07	1.937539	0.0527
M(2,2)	5.65E-06	1.38E-06	4.092182	0.0000
A1(1,1)	0.240846	0.017344	13.88643	0.0000
A1(2,2)	0.302870	0.022779	13.29597	0.0000
B1(1,1)	0.966051	0.004157	232.3732	0.0000
B1(2,2)	0.937976	0.009054	103.6005	0.0000

Figure 37. Spillover effect between China and Japan output

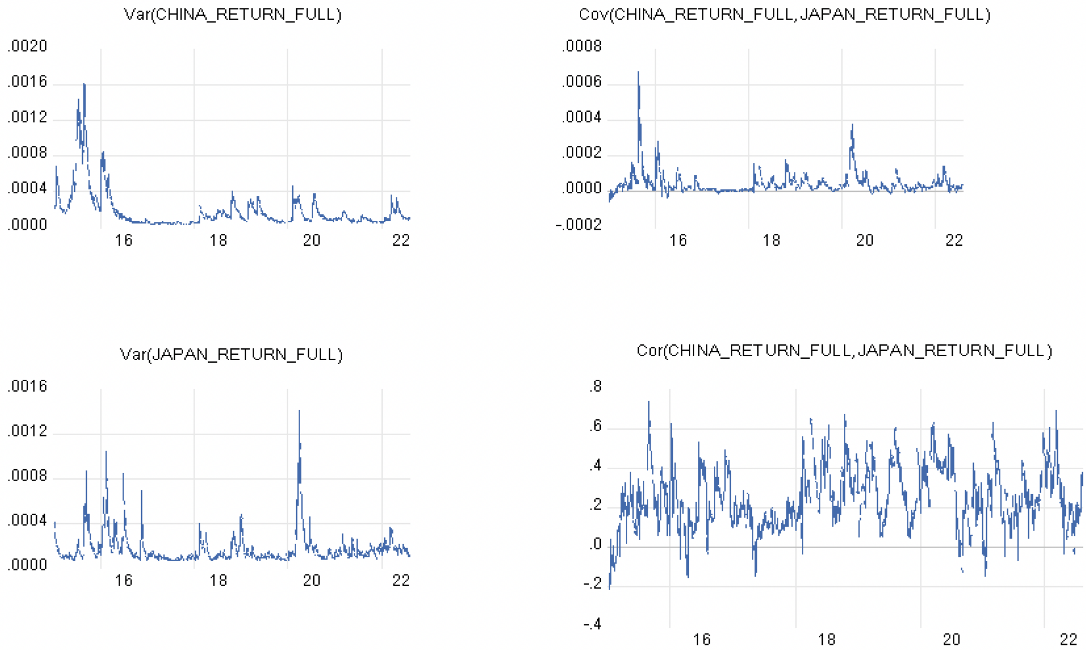


Figure 38. Covariance and correlation between China and Japan output

System: BEKK
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal BEKK
Date: 09/04/22 Time: 15:40
Sample: 1/06/2015 8/12/2022
Included observations: 1985
Total system (balanced) observations 3970
Disturbance assumption: Student's t distribution
Presample covariance: backcast (parameter =0.7)
Convergence achieved after 33 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.000480	0.000181	2.652319	0.0080
C(2)	-0.029661	0.020487	-1.447776	0.1477
C(3)	0.000599	0.000165	3.640973	0.0003
C(4)	-0.017975	0.021896	-0.820935	0.4117
Variance Equation Coefficients				
C(5)	1.41E-06	3.61E-07	3.891643	0.0001
C(6)	5.99E-07	2.42E-07	2.473280	0.0134
C(7)	3.66E-06	8.61E-07	4.248747	0.0000
C(8)	0.243209	0.016576	14.67242	0.0000
C(9)	0.294488	0.023296	12.64136	0.0000
C(10)	0.964955	0.004092	235.8111	0.0000
C(11)	0.938323	0.009268	101.2479	0.0000
t-Distribution (Degree of Freedom)				
C(12)	4.625734	0.374962	12.33654	0.0000

Log likelihood	13046.76	Schwarz criterion	-13.09945
Avg. log likelihood	3.286338	Hannan-Quinn criter.	-13.12084
Akaike info criterion	-13.13326		

Equation: CHINA_RETURN_FULL = C(1)+C(2)*KOREA_RETURN_FULL(-1)

R-squared	-0.003229	Mean dependent var	-1.12E-05
Adjusted R-squared	-0.003735	S.D. dependent var	0.013481
S.E. of regression	0.013506	Sum squared resid	0.361729
Durbin-Watson stat	1.904132		

Equation: KOREA_RETURN_FULL=C(3)+C(4)*KOREA_RETURN_FULL(-1)

R-squared	-0.001923	Mean dependent var	0.000140
Adjusted R-squared	-0.002428	S.D. dependent var	0.010045
S.E. of regression	0.010057	Sum squared resid	0.200561
Durbin-Watson stat	1.981894		

Covariance specification: Diagonal BEKK
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1
M is an indefinite matrix
A1 is a diagonal matrix
B1 is a diagonal matrix

Transformed Variance Coefficients

	Coefficient	Std. Error	z-Statistic	Prob.
M(1,1)	1.41E-06	3.61E-07	3.891643	0.0001
M(1,2)	5.99E-07	2.42E-07	2.473280	0.0134
M(2,2)	3.66E-06	8.61E-07	4.248747	0.0000
A1(1,1)	0.243209	0.016576	14.67242	0.0000
A1(2,2)	0.294488	0.023296	12.64136	0.0000
B1(1,1)	0.964955	0.004092	235.8111	0.0000
B1(2,2)	0.938323	0.009268	101.2479	0.0000

Figure 39. Spillover effect between China and Korea output

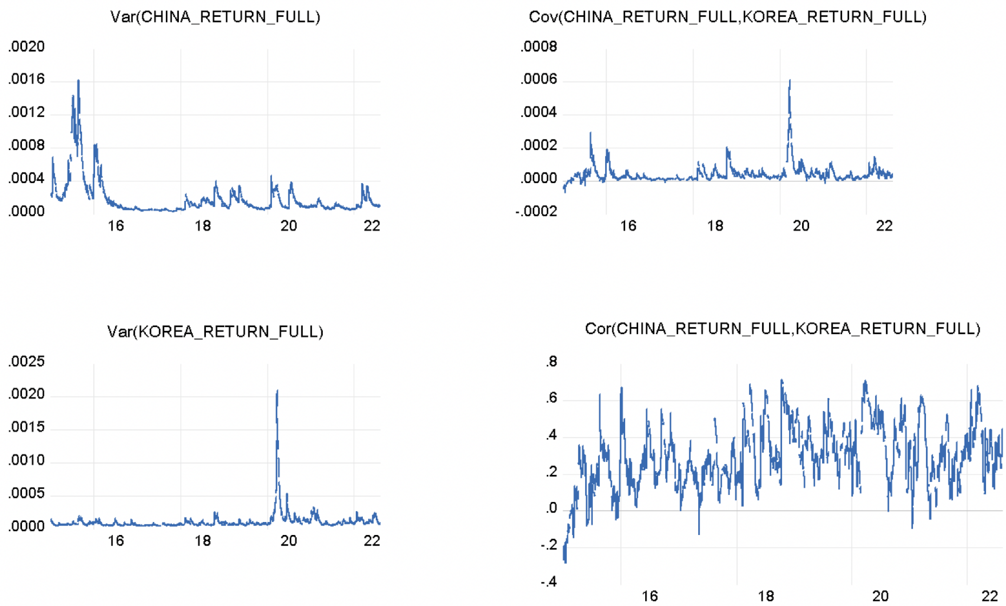


Figure 40. Covariance and correlation between China and Korea output

System: BEKK
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal BEKK
Date: 09/04/22 Time: 15:46
Sample: 1/06/2015 8/12/2022
Included observations: 1985
Total system (balanced) observations 3970
Disturbance assumption: Student's t distribution
Presample covariance: backcast (parameter =0.7)
Convergence achieved after 41 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.000488	0.000179	2.729305	0.0063
C(2)	0.008463	0.016298	0.519280	0.6036
C(3)	0.000487	0.000213	2.288953	0.0221
C(4)	-0.007887	0.020206	-0.390336	0.6963
Variance Equation Coefficients				
C(5)	1.25E-06	3.24E-07	3.847797	0.0001
C(6)	6.51E-07	2.09E-07	3.123848	0.0018
C(7)	1.60E-06	5.30E-07	3.020691	0.0025
C(8)	0.238691	0.015907	15.00584	0.0000
C(9)	0.196466	0.015249	12.88382	0.0000
C(10)	0.966417	0.003777	255.8361	0.0000
C(11)	0.976702	0.003797	257.2248	0.0000
t-Distribution (Degree of Freedom)				
C(12)	4.624447	0.370228	12.49081	0.0000

Log likelihood	12759.26	Schwarz criterion	-12.80977
Avg. log likelihood	3.213918	Hannan-Quinn criter.	-12.83116
Akaike info criterion	-12.84358		

Equation: CHINA_RETURN_FULL = C(1)+C(2)*HK_RETURN_FULL(-1)

R-squared	-0.000489	Mean dependent var	-1.12E-05
Adjusted R-squared	-0.000993	S.D. dependent var	0.013481
S.E. of regression	0.013488	Sum squared resid	0.360741
Durbin-Watson stat	1.929811		

Equation: HK_RETURN_FULL=C(3)+C(4)*HK_RETURN_FULL(-1)

R-squared	-0.002277	Mean dependent var	-8.16E-05
Adjusted R-squared	-0.002782	S.D. dependent var	0.012358
S.E. of regression	0.012375	Sum squared resid	0.303679
Durbin-Watson stat	1.968350		

Covariance specification: Diagonal BEKK
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1
M is an indefinite matrix
A1 is a diagonal matrix
B1 is a diagonal matrix

Transformed Variance Coefficients

	Coefficient	Std. Error	z-Statistic	Prob.
M(1,1)	1.25E-06	3.24E-07	3.847797	0.0001
M(1,2)	6.51E-07	2.09E-07	3.123848	0.0018
M(2,2)	1.60E-06	5.30E-07	3.020691	0.0025
A1(1,1)	0.238691	0.015907	15.00584	0.0000
A1(2,2)	0.196466	0.015249	12.88382	0.0000
B1(1,1)	0.966417	0.003777	255.8361	0.0000
B1(2,2)	0.976702	0.003797	257.2248	0.0000

Figure 41. Spillover effect between China and Hong Kong output

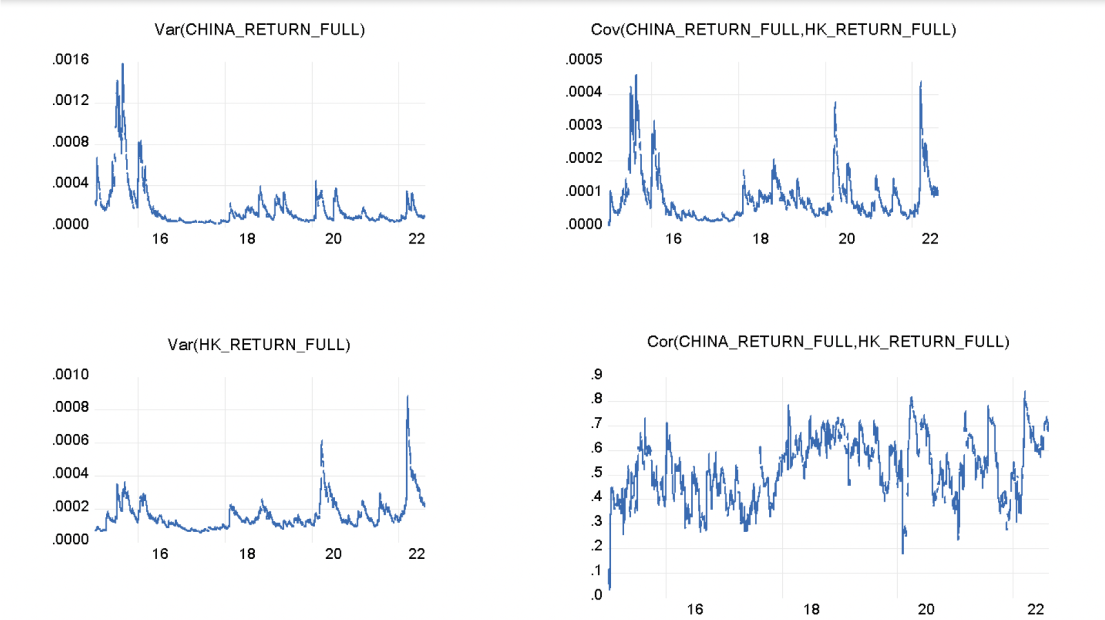


Figure 42. Covariance and correlation between China and Hong Kong output

System: BEKK
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal BEKK
Date: 09/04/22 Time: 15:52
Sample: 1/06/2015 8/12/2022
Included observations: 1985
Total system (balanced) observations 3970
Disturbance assumption: Student's t distribution
Presample covariance: backcast (parameter =0.7)
Convergence achieved after 29 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.000464	0.000181	2.566716	0.0103
C(2)	0.008610	0.021563	0.399294	0.6897
C(3)	0.000728	0.000159	4.594385	0.0000
C(4)	0.015450	0.021023	0.734942	0.4624
Variance Equation Coefficients				
C(5)	1.46E-06	3.89E-07	3.759602	0.0002
C(6)	6.30E-07	2.35E-07	2.685842	0.0072
C(7)	3.39E-06	8.30E-07	4.084913	0.0000
C(8)	0.239968	0.017180	13.96824	0.0000
C(9)	0.272099	0.022646	12.01559	0.0000
C(10)	0.966234	0.004118	234.6337	0.0000
C(11)	0.945262	0.008643	109.3687	0.0000
t-Distribution (Degree of Freedom)				
C(12)	4.281145	0.315405	13.57350	0.0000

Log likelihood	13102.30	Schwarz criterion	-13.15541
Avg. log likelihood	3.300329	Hannan-Quinn criter.	-13.17680
Akaike info criterion	-13.18922		

Equation: CHINA_RETURN_FULL = C(1)+C(2)*TAIWAN_RETURN_FULL(-1)

R-squared	-0.000989	Mean dependent var	-1.12E-05
Adjusted R-squared	-0.001494	S.D. dependent var	0.013481
S.E. of regression	0.013491	Sum squared resid	0.360921
Durbin-Watson stat	1.926060		

Equation: TAIWAN_RETURN_FULL=C(3)+C(4)*TAIWAN_RETURN_FULL(-1)

R-squared	-0.002294	Mean dependent var	0.000252
Adjusted R-squared	-0.002800	S.D. dependent var	0.009519
S.E. of regression	0.009532	Sum squared resid	0.180177
Durbin-Watson stat	1.992342		

Covariance specification: Diagonal BEKK
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1
M is an indefinite matrix
A1 is a diagonal matrix
B1 is a diagonal matrix

Transformed Variance Coefficients

	Coefficient	Std. Error	z-Statistic	Prob.
M(1,1)	1.46E-06	3.89E-07	3.759602	0.0002
M(1,2)	6.30E-07	2.35E-07	2.685842	0.0072
M(2,2)	3.39E-06	8.30E-07	4.084913	0.0000
A1(1,1)	0.239968	0.017180	13.96824	0.0000
A1(2,2)	0.272099	0.022646	12.01559	0.0000
B1(1,1)	0.966234	0.004118	234.6337	0.0000
B1(2,2)	0.945262	0.008643	109.3687	0.0000

Figure 43. Spillover effect between China and Taiwan output

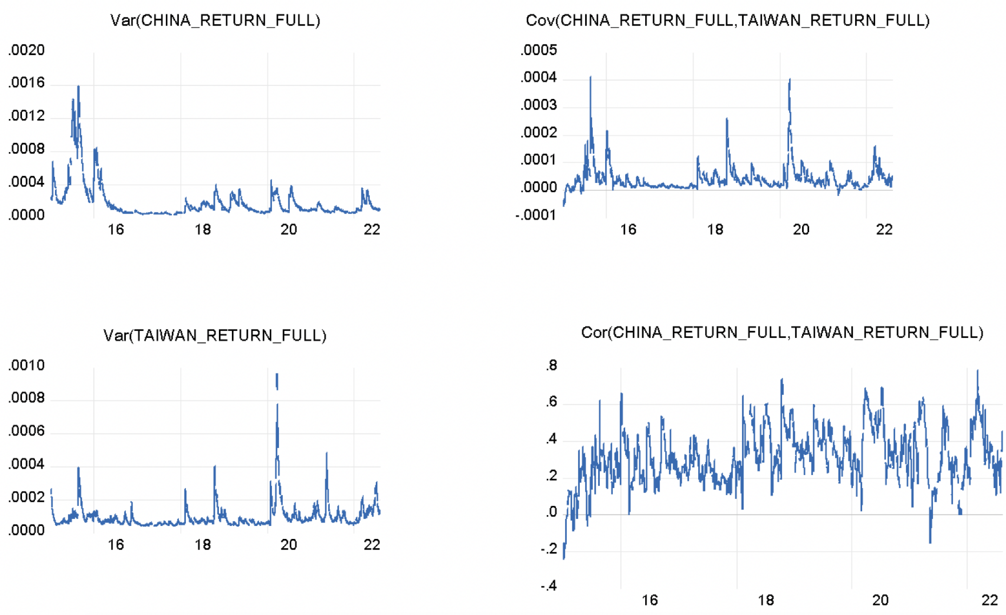


Figure 44. Covariance and correlation between China and Taiwan output

The spillover effect occurs if shocks from one market/asset increase the volatility in another market/asset. According to the covariance and correlation, China's stock market is most correlated with the Hong Kong stock market, followed by Japan, Korea, and Taiwan, which exhibit similar extent, while least correlated with the US stock market. The difference may be not only related to covid-19 but more complex geopolitical backgrounds like trade tension between China and the US, also the intense impact of the Hong Kong stock market under China's stock market influence. It can also be observed that each market's stock variance increases with major events like China's stock market crash in 2015 and Hong Kong's round of covid pandemic in 2022. There is also an overall huge volatility increase in 2020, where all countries and regions experienced a sharp rise in volatility level except China, where there are state efforts to control the risk rise in the face of the pandemic.

5. conclusion

Findings reveal several results in volatility characteristics, forecast and spillover effect. In terms of characteristics, shocks experienced by conditional variance will be highly consistent, indicating that shocks persist with the ongoing COVID-19 pandemic. All countries and regions illustrate the leverage effect, which means bad news will increase volatility more than the good news of the same size. The US and Japan stock market's leverage effect dropped in the period of covid. China, South Korea, Hong Kong, and Taiwan's leverage increased with covid. In terms of forecast, the Dynamic GARCH(1,1) model performs the best in estimating stock markets across the studied countries in minimizing the RMSE, MAE, MAPE, and having the highest Theil's Inequality Coefficient. In terms of individual countries or regions, Dynamic E-GARCH performs the best in estimating China's stock market. Dynamic ARCH is best for evaluating the US stock market. For Japan, the best forecasting model is the Static GJR-GARCH. For South Korea, it becomes Dynamic GARCH(1,1). Different models' performances are around average for Hong Kong. The Dynamic GARCH(1,1) model best forecasts Taiwan's stock market. In terms of volatility spillover, covariance and correlation indicate that China's stock market is most correlated with the Hong Kong stock market, followed by Japan, Korea, and Taiwan, which exhibit similar extent, while least correlated with the US stock market.

Our study can provide helpful information and enlightenment for the government, economic enterprises and stock markets research scholars. The study reveals that government agencies and individual stockholders should be aware of the persisting risk covid-19 entail, and should work towards prosperity together since our result revealed that there is a mostly positive correlation between the return of the Chinese stock market and the returns of stock markets in countries and regions involved in this study. The forecasting model can also achieve a generally small error rate in volatility forecasting compared to the real volatility in 2022 so far. Thus using Garch families to conduct volatility forecasting can be beneficial to predict and forecast the stock market's future volatility. As this study tried in-sample forecasting, it should be probably even more precise when it comes to forecasting just a couple of business days, and forecasting volatility can be a potential future area besides just forecasting stock prices using machine learning algorithms.

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Appendix

1.

The missing values that we make adjustments are listed below. Japan has 21 missing value on 2017/7/17, 2017/8/11, 2017/9/18, 2017/10/9, 2017/11/3, 2017/11/23, 2018/1/1, 2018/1/2, 2018/1/3, 2018/1/8, 2018/2/12, 2018/3/21, 2018/4/30, 2018/5/3, 2018/5/4, 2018/9/17, 2018/9/24, 2018/10/8, 2018/11/23, 2018/12/24, and 2018/12/31. Korea has 2 missing value on 2015/8/13 and 2015/8/14. Hong Kong has 3 missing value, 2016/8/2, 2016/10/21, and 2017/8/23. Taiwan has 9 missing value, 2015/7/10, 2015/9/29, 2016/1/30, 2016/6/4, 2016/9/10, 2016/9/27, 2016/9/28, 2017/2/18, and 2017/6/3.

2. full sample ARMA specification

CHN	MA0	1	2	3	4	5
AR0	N/A	-5.703028	-5.696152	-5.696361	-5.693316	-5.68927
1	-5.702341	-5.702717	-5.699138	-5.692101	-5.688704	-5.690093
2	-5.699243	-5.707825	-5.700625	-5.691176	-5.711509	-5.690482
3	-5.696654	-5.693052	-5.697240	-5.705436	-5.713620	-5.710415
4	-5.693338	-5.689264	-5.714334	-5.713875	-5.710026	-5.706982
5	-5.68964	-5.692442	-5.711151	-5.707207	**-5.719201**	-5.717230

USA	MA0	1	2	3	4	5
AR0	N/A	-6.072319	-6.080747	-6.077870	-6.075716	-6.071922
1	-6.077606	-6.077670	-6.078390	-6.075950	-6.097309	-6.094002
2	-6.080871	-6.076962	-6.076037	-6.074233	-6.119721	-6.117714
3	-6.077234	-6.106152	-6.074406	-6.070633	-6.116651	-6.087440
4	-6.080000	-6.110057	-6.120698	-6.117153	-6.117902	-6.113951
5	-6.076939	-6.107860	-6.101644	-6.112853	-6.114241	-6.114099

JPN	MA0	1	2	3	4	5
AR0	N/A	-5.872017	-5.869406	-5.866321	-5.862447	-5.858823
1	-5.874566	-5.872682	-5.868259	-5.864945	-5.861041	-5.857513
2	-5.871515	-5.869693	-5.865731	-5.863779	-5.860895	-5.855745
3	-5.868871	-5.865495	-5.863795	-5.858035	-5.858119	-5.854224
4	-5.864420	-5.861331	-5.861149	-5.857713	-5.854080	-5.851990
5	-5.860355	-5.857473	-5.857236	-5.856192	-5.852629	-5.850252

KOR	MA0	1	2	3	4	5
AR0	N/A	-6.300538	-6.307145	-6.303495	-6.299536	-6.295562
1	-6.300157	-6.298415	-6.303348	-6.299444	-6.296005	-6.292256
2	-6.307342	-6.303451	-6.300733	-6.298119	-6.298659	-6.295651
3	-6.303084	-6.299819	-6.298179	-6.294589	-6.295045	-6.293423
4	-6.300049	-6.296672	-6.296305	-6.291308	-6.290868	-6.286533
5	-6.296156	-6.292234	-6.290079	-6.291174	-6.287204	-6.280949

HKG	MA0	1	2	3	4	5
AR0	N/A	-5.885593	-5.885792	-5.881914	-5.878249	-5.874262
1	-5.889072	-5.885355	-5.881298	-5.877754	-5.873712	-5.870957
2	-5.885061	-5.881055	-5.881169	-5.883925	-5.873150	-5.875365
3	-5.880849	-5.877808	-5.873787	-5.879995	-5.875026	-5.871109
4	-5.876831	-5.872791	-5.874921	-5.875526	-5.875558	-5.872373
5	-5.872322	-5.869574	-5.865581	-5.864994	-5.871986	-5.866599

TWN	MA0	1	2	3	4	5
AR0	N/A	-6.401445	-6.400675	-6.397736	-6.394867	-6.391444
1	-6.404306	-6.400267	-6.399919	-6.397093	-6.393970	-6.390468
2	-6.402888	-6.399485	-6.400593	-6.395502	-6.391938	-6.389968
3	-6.401015	-6.397306	-6.397631	-6.391283	-6.389762	-6.386378
4	-6.397873	-6.394122	-6.393442	-6.389651	-6.386655	-6.382751
5	-6.393920	-6.389883	-6.385891	-6.385261	-6.379213	-6.382879

3. before covid sample ARMA specification

CHN	MA0	1	2	3	4	5
AR0	N/A	-5.533268	-5.530426	-5.525220	-5.521944	-5.516407
1	-5.532089	-5.533944	-5.528389	-5.519821	-5.515406	-5.518960
2	-5.528948	-5.527701	-5.546561	-5.550660	-5.545096	-5.539554
3	-5.525510	-5.521057	-5.553764	-5.547001	-5.542243	-5.542748
4	-5.522234	-5.516467	-5.548746	-5.544324	-5.542267	-5.546658
5	-5.516871	-5.521183	-5.543677	-5.544086	-5.544801	-5.542881

USA	MA0	1	2	3	4	5
AR0	N/A	-6.699488	-6.696926	-6.697412	-6.688408	-6.683151
1	-6.702360	-6.697800	-6.694161	-6.688788	-6.686490	-6.681002
2	-6.699747	-6.696254	-6.692882	-6.687402	-6.689957	-6.684381
3	-6.694722	-6.690164	-6.685107	-6.688265	-6.688294	-6.683716
4	-6.694056	-6.688512	-6.694455	-6.690314	-6.677466	-6.671878
5	-6.688939	-6.684222	-6.678810	-6.683617	-6.672804	-6.668815

JPN	MA0	1	2	3	4	5
AR0	N/A	-5.982453	-5.976821	-5.971801	-5.966319	-5.960984
1	-5.986689	-5.981055	-5.975427	-5.970397	-5.964948	-5.959692
2	-5.980271	-5.976350	-5.969790	-5.965975	-5.960365	-5.956608
3	-5.975831	-5.970273	-5.965009	-5.961887	-5.954738	-5.949159
4	-5.969573	-5.966881	-5.965737	-5.964469	-5.950852	-5.946098
5	-5.963595	-5.958713	-5.955248	-5.954517	-5.945953	-5.945911

KOR	MA0	1	2	3	4	5
AR0	N/A	-6.831972	-6.830206	-6.824798	-6.819646	-6.816677
1	-6.831605	-6.828150	-6.825010	-6.819904	-6.817270	-6.813261
2	-6.832666	-6.826958	-6.827551	-6.822631	-6.816929	-6.811298
3	-6.826208	-6.823889	-6.822180	-6.817630	-6.811026	-6.805725
4	-6.822684	-6.820023	-6.815844	-6.810774	-6.806699	-6.801246
5	-6.820431	-6.815061	-6.809763	-6.804368	-6.809231	-6.799438

HKG	MA0	1	2	3	4	5
AR0	N/A	-6.149598	-6.143925	-6.140274	-6.134819	-6.130650
1	-6.148799	-6.143302	-6.137625	-6.133912	-6.129172	-6.124334
2	-6.142958	-6.137966	-6.132407	-6.132123	-6.135306	-6.121150
3	-6.138837	-6.133197	-6.131329	-6.128202	-6.123092	-6.117833
4	-6.132928	-6.128271	-6.128265	-6.120192	-6.119291	-6.117461
5	-6.127942	-6.122294	-6.122762	-6.122228	-6.116721	-6.111590

TWN	MA0	1	2	3	4	5
AR0	N/A	-6.703454	-6.698814	-6.693559	-6.688274	-6.689714
1	-6.709513	-6.703874	-6.699469	-6.694327	-6.688965	-6.690054
2	-6.704090	-6.699209	-6.700610	-6.696545	-6.692219	-6.688544
3	-6.701539	-6.695858	-6.697494	-6.691890	-6.685837	-6.683781
4	-6.695400	-6.691949	-6.689568	-6.686527	-6.684344	-6.679963
5	-6.696046	-6.690349	-6.688259	-6.683524	-6.680356	-6.675297

4. during covid sample ARMA specification

CHN	MA0	1	2	3	4	5
AR0	N/A	-6.161891	-6.152863	-6.142803	-6.135946	-6.126440
1	-6.160441	-6.152918	-6.140954	-6.137304	-6.127620	-6.117518
2	-6.150558	-6.140480	-6.157049	-6.150400	-6.115819	-6.105309
3	-6.139576	-6.135911	-6.148743	-6.137460	-6.130787	-6.126925
4	-6.131026	-6.126498	-6.117424	-6.129590	-6.123185	-6.115501
5	-6.126682	-6.116150	-6.130356	-6.125493	-6.115131	-6.105425

USA	MA0	1	2	3	4	5
AR0	N/A	-5.409013	-5.439485	-5.432076	-5.422281	-5.412510
1	-5.423310	-5.424748	-5.429918	-5.421181	-5.450433	-5.442391
2	-5.433161	-5.424012	-5.418852	-5.489982	-5.442201	-5.475873
3	-5.423920	-5.475883	-5.488640	-5.402437	-5.482595	-5.472796
4	-5.423374	-5.472943	-5.472464	-5.484379	-5.498162	-5.472747
5	-5.414883	-5.463838	-5.472375	-5.474605	-5.474129	-5.469743

JPN	MA0	1	2	3	4	5
AR0	N/A	-5.672732	-5.670577	-5.662565	-5.653907	-5.643557
1	-5.671758	-5.663484	-5.664729	-5.654892	-5.644379	-5.633956
2	-5.667773	-5.664062	-5.653600	-5.658048	-5.651638	-5.652871
3	-5.658816	-5.664496	-5.659945	-5.650376	-5.644727	-5.635226
4	-5.648792	-5.640879	-5.666186	-5.643997	-5.635874	-5.612390
5	-5.638853	-5.629562	-5.656050	-5.626444	-5.654733	-5.647013

KOR	MA0	1	2	3	4	5
AR0	N/A	-5.688254	-5.694815	-5.684703	-5.674341	-5.664368
1	-5.687497	-5.680029	-5.684053	-5.673775	-5.663391	-5.663601
2	-5.692170	-5.682148	-5.672161	-5.674031	-5.681148	-5.653570
3	-5.680814	-5.684344	-5.673956	-5.663553	-5.650357	-5.671864
4	-5.669483	-5.673964	-5.685510	-5.675673	-5.683172	-5.672970
5	-5.657625	-5.663143	-5.676431	-5.682793	-5.669938	-5.652784

HKG	MA0	1	2	3	4	5
AR0	N/A	-5.500332	-5.490964	-5.486033	-5.477902	-5.468577
1	-5.499754	-5.497457	-5.481506	-5.475732	-5.467464	-5.458346
2	-5.489227	-5.487529	-5.488825	-5.488986	-5.478747	-5.478585
3	-5.482446	-5.473315	-5.487355	-5.484752	-5.474765	-5.459380
4	-5.473348	-5.463134	-5.476561	-5.466725	-5.465049	-5.466958
5	-5.462115	-5.453728	-5.476956	-5.458253	-5.474864	-5.440923

TWN	MA0	1	2	3	4	5
AR0	N/A	-5.970947	-5.967364	-5.958629	-5.951039	-5.941987
1	-5.970160	-5.964158	-5.957046	-5.950409	-5.940602	-5.931156
2	-5.965264	-5.955379	-5.954935	-5.939801	-5.949357	-5.919352
3	-5.954520	-5.948000	-5.938492	-5.939726	-5.938238	-5.912146
4	-5.945916	-5.936798	-5.926306	-5.915807	-5.912588	-5.925378
5	-5.935383	-5.925497	-5.941533	-5.909980	-5.924909	-5.898919