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Analysis of the Relationship Between Stock Prices and Their Volatilities

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1. Introduction
2. Principles of Financial Markets
3. Volatility Forecasting Models
4. Analysis of Stock Prices and Their Volatilities at Selected Asian Markets
5. Conclusion

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1 Introduction

An important theme in asset valuation research is the trade-off between volatility and returns (usually log price changes). Some theoretical asset pricing models relate the return of an asset to its own variance or to the covariance between the return of a stock and a market portfolio. However, whether this relationship is positive or negative has been debated.

As summarized by R. T. Baillie and R. P. DeGennaro (1990) in "Stock Returns and Volatility"1, most asset pricing models suggest a positive trade-off between expected returns and volatility. On the other hand, there are many empirical studies that confirm the relationship between negative returns and volatility. Moreover, C. R. Harvey (1989)2 suggested that the relationship between risk and return may be time varying. These contradictory and empirical results in the literature need to be further tested using different and possibly more appropriate econometric techniques.

In this thesis, the main purpose is to test the relationship between the stock price index and their volatilities by using the returns from daily stock prices. Generally, the volatility of stock prices is shown by its standard deviation or variance, and the value of variance is chosen to represent volatility in this paper. Consequently, the relationship between the conditional variance, which is the volatility, and the stock price index is analyzed by applying different forecasting models to the log returns of the stock price indexes to perform correlation and regression tests and testing the conditional variance and residual terms from the models.

For the chapter 2 of this paper, the portfolio of basic financial markets will be introduced. And there are the basic information about the 8 stock price indexes selected in Asia stock markets and their exchanged market.

In the next section chapter 3, firstly there is the introduction the volatility of stock price index and the methodologies we used for analyzing the relationship between the indexes and volatilities. The main selected models are the time series models including the Exponentially Weighted Moving Average (EWMA), the Autoregressive conditional heteroskedasticity model (ARCH), Generalized Autoregressive Conditional

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[1] R. T. Baillie and R. P. DeGennaro, *Stock Returns and Volatility*, Journa1 of Financia1 and Quantitative Ana1ysis, Vol. 5, No. 2, June 1990, pp. 203-214.
[2] C. R. Harvey, *Time-Varying Conditional Covariances in Tests of Asset Pricing Models*, Journal of Financial Economics, Vol. 24, No. 2, 1989, pp. 289-317.

Heteroskedasticity model (GARCH), GARCH-in-mean model and the exponential general autoregressive conditional heteroskedastic model (EGARCH).

Furthermore, by using an econometrics Software which is Econometrics Views (EViews) to calculate the selected models, it is observed that the relationships mentioned in chapter 3 have asymmetry and leverage effect.

2 Principles of Financial Markets

Financial markets include any place or system that provides buyers and sellers with the ability to trade in financial instruments, including bonds, stocks, various international currencies and derivatives. Financial markets facilitate the interaction between those who need capital and those who have capital to invest. In addition to making it possible to raise capital, financial markets also allow participants to transfer risk (generally through derivatives) and facilitate commerce.

2.1 Types of Financial Markets

Under this subchapter, the classification of financial markets will be defined. There are several ways to differentiate shown following:

By maturity of claim, financial markets can be classified as money market which is for short-term debt instrument, and capital market which is for equity instruments, debt instruments that longer than one year.

By nature of claim, financial markets can be differed as debt market and equity market which also as known as stock market. In debt market, the bonds are issued and traded.

By seasoning of claim, financial markets can be described as primary market which issues new securities on an exchange, and secondary market which trades the securities already exist among investors.

By immediate or future delivery, financial markets can be discussed as cash or spot market which the delivery of assets is immediately, while the delivery is in the future in derivative market, such as options and futures.

2.1.1 Stock Markets

A stock market is a public market that exists for the issuance, purchase and sale of shares traded on a stock exchange or over-the-counter. Stocks, also known as shares, which represent partial ownership of a company, and the stock market is where investors can buy and sell ownership of such investable assets. An efficiently functioning stock market is considered essential to economic development because it allows companies to quickly obtain capital from the public.

2.1.2 Bond Markets

A bond is a kind of security in which an investor takes out a loan at a pre-determined interest rate for a specified period of time. You can think of a bond as an agreement between a lender and a borrower which contains details of the loan and its payments. Bonds are issued by corporations as well as municipalities, states and sovereign governments to finance projects and operations. The bond market is also known as the debt, credit or fixed income market.

2.1.3 Money Markets

The money market is an organized trading market in which participants can lend and borrow short-term, high-quality debt securities with an average maturity of one year or less. It is possible for governments, banks and other large institutions to sell short-term securities to meet their short-term cash flow needs in money markets. The money market also has the ability to allow individual investors to invest small amounts of money in a low-risk environment. At the wholesale level, money markets involve large transactions made among institutions and traders. At the retail level, there are money market mutual funds purchased by individual investors and money market accounts opened by bank customers. Individuals can also invest in the money market by purchasing short-term certificates of deposit, municipal notes, or U.S. Treasury bills.

2.1.4 Derivatives Markets

The derivatives market refers to the financial market for financial instruments such as futures contracts or options that are based on the values of their underlying assets. A derivative is a contract between two or more parties with a value based on an agreed-upon underlying financial asset such as a security or group of assets like an index. Derivatives are secondary securities that derive their value entirely from the value of the primary securities to which a derivative is related. Derivatives are inherently worthless. Instead of trading stocks directly, derivatives markets trade futures and options contracts and other advanced financial products that derive their value from underlying instruments such as bonds, commodities, currencies, interest rates, market indices and stocks.

2.1.5 Commodities Markets

Commodities are another class of assets, just like stocks and bonds. Most commodities are products from the earth, with uniform quality, produced in large quantities, and produced by many different producers. Major commodities include cotton, oil, natural gas, corn, wheat, oranges, gold and uranium. In essence, as raw materials, which are needed by large manufacturing companies to conduct their business. However, most of the trading in these commodities occurs in the derivatives markets that use the spot commodity as the underlying asset. Forwards, futures and options on commodities are traded over-the-counter and on listed exchanges around the world like the Chicago Mercantile Exchange and the Intercontinental Exchange.

2.2 Introduction of selected Stock indexes

A stock index, also known as a share index or stock market index, consists of constituent stocks that are used to provide economic, market or industry indicators. Stock indexes are commonly used as benchmarks by investors to measure the performance of their portfolios. Examples of stock indexes can include the Dow Jones Industrial Average, the Nikkei Stock Average, the S&P 500, the Nasdaq Composite and the Wilshire 5000.

In this subchapter, 8 stock indices in Asia stock markets are selected as simples to analysis how the indices performed in the past ten years from 2010 to 2020.

2.2.1 Shanghai Composite Index

Shanghai is Mainland China's first city to see the emergence of stocks, stock trading and stock exchanges. Stock trading started in Shanghai as early as the 1860s. In 1891, the Shanghai Share Brokers Association, an early form of stock exchange, was established in Shanghai. Later in the 1920s, with the founding of the Shanghai Securities Goods Exchange and the Shanghai Chinese Securities Exchange, Shanghai emerged as the financial centre of the Far East, where both Chinese and foreign investors could trade stocks, bonds, and futures. In 1946, the Shanghai Chinese Security Exchange was renamed the Shanghai Securities Exchange Co., Ltd. Later in 1949, all securities trading venues were closed down.

Since 1980, China's securities market has grown in tandem with the reform and opening up of the country and the development of the socialist market economy. In 1981, the offering of treasury bonds was resumed. In 1984, stocks and enterprise bonds were issued in Shanghai and other regions. On November 26, 1990, the Shanghai Stock Exchange was established, and on December 19 of the same year, it started formal operations.

SSE Composite Index(Shanghai Composite Index), published on July 15, 1991, is the first index to reflect the performance of the whole Shanghai securities market, which includes the whole listed A shares and B shares stocks on SSE and is calculated based on total market capitalization of these listed stocks. It represents the 20-year-history development of China Capital Markets, and which is the most widely used index in China's securities market. This index is designed to reflect to overall market performance of companies listed on Shanghai Stock Exchange. The base date is Dec 19, 1990. The base level is 100.

2.2.2 Hang Seng Index

Hong Kong Exchanges is one of the world’s major exchange groups, and operates a range of equity, commodity, fixed income and currency markets. Hong Kong Exchanges is the world’s leading IPO market and as Hong Kong’s only securities and derivatives exchange and sole operator of its clearing houses, it is uniquely placed to offer regional and international investors access to Asia’s most vibrant market.

The Hang Seng Index is one of the earliest stock market indices in Hong Kong. Since its launch on November 24, 1969, it has been widely quoted as an important indicator of the performance of the Hong Kong stock market. The HSI is a market capitalisation-weighted index (shares outstanding multiplied by stock price) of the constituent stocks. The influence of each stock on the index's performance is directly proportional to its relative market value. Constituent stocks with higher market capitalisation will have greater impact on the index's performance than those with lower market capitalisation. The constituent stocks are grouped under Commerce and Industry, Finance, Properties and Utilities sub-indices.

The Hang Seng Index is the most influential stock price index reflecting the price movement trend of Hong Kong stock market. The index was first publicly released on November 24, 1969, with a base period of July 31, 1964. The base period index is set at 100.

2.2.3 NIKKEI 225 Index

Tokyo Stock Exchange is a stock exchange located in Tokyo, Japan. It is the third largest stock exchange in the world by aggregate market capitalization of its listed companies, and the largest in Asia. The exchange is owned by the Japan Exchange Group.

The Nikkei Stock Average, the Nikkei 225 is used around the globe as the premier index of Japanese stocks. More than 70 years have passed since the commencement of its calculation, which represents the history of Japanese economy after the World War II. Because of the prominent nature of the index, many financial products linked to the Nikkei 225 have been created are traded worldwide while the index has been sufficiently used as the indicator of the movement of Japanese stock markets. The Nikkei 225 is a price-weighted equity index, which consists of 225 stocks in the 1st section of the Tokyo Stock Exchange. The Nikkei 225 is comprised of 225 stocks selected from domestic common stocks in the 1st section of the Tokyo Stock Exchange, excluding ETFs, REITs, preferred equity contribution securities, tracking stocks (on subsidiary dividend) etc other than common stocks. The commencement date of the calculation was September 7th, 1950, which had been retroactively calculated in the past on the end-of-day basis, to May 16th, 1949. The Nikkei 225 is currently calculated every 5 seconds while the Tokyo Stock Exchange opens.

2.2.4 KOSPI Composite Index

The Korea Exchange is the only stock exchange in South Korea, and is based in Busan, South Korea. 2005 was the year when the former Korea Stock Exchange, the Korea Futures Exchange and the Korea Venture Exchange were merged.

In 2010, the volume of derivatives contracts traded on the Korea Exchange was 3.752 billion lots, accounting for 16.8% of the world's trading volume. According to the World Federation of Exchanges in 2008, Korea's GEM market, the Korea Venture Exchange, was second only to the U.S. Nasdaq in terms of volume and turnover rate, and its total market capitalization of listed companies ranked fourth in the world. As of Dec 2020, Korea Exchange had 2,409 listed companies with a combined market capitalization of ₩2.3 quadrillion KRW ($2.1 trillion USD).

The Korea Composite Stock Price Index or KOSPI is an index of all common stocks traded on the Stock Market Division of the Korea Stock Exchange (formerly known as the Korea Stock Exchange). It is a representative stock market index in Korea, along with the U.S. Standard & Poor's 500 Index.

The KOSPI was launched in 1983 with a base value of 100 as of January 4, 1980, and is calculated based on market capitalization.

2.2.5 FTSE Straits Times Index

Singapore Exchange Limited is the first corporate stock exchange in the Asia Pacific region to integrate securities and financial derivatives trading, and was the first exchange in the Asia Pacific region to be listed through a public offering and private placement on November 23, 2000. The Exchange offers a wide range of services related to securities and derivatives trading. Singapore Exchange Limited is also a member of the World Federation of Exchanges and the Federation of Asian and Oceanian Stock Exchanges.

The Singapore Exchange, formerly known as the Singapore Exchange Securities Trading Limited, was established on May 24, 1973 and merged with the Singapore International Financial Exchange in December 1999 to form the current Singapore Exchange. On August 22, 2016 Singapore Exchange acquired Baltic Exchange for £87 million ($114 million) in cash. on March 28, 2019 Singapore Exchange acquired a 20% stake in forex trading platform BidFX for $25 million in cash.

The Straits Times Index (STI) is a market capitalization-weighted measure of the stock market and is considered the benchmark index for the Singapore stock market. It tracks the performance of the top 30 companies listed on the Singapore Exchange. In addition to SGX, it is also jointly calculated by Singapore Press Holdings and FTSE Group.

The history dates of STI back to its inception in 1966. Following a major sectoral reclassification of listed companies on the Singapore Exchange, the "Industrial" category was removed and STI replaced the former Straits Times Industrial Index (and began trading at 885.26 on August 31, 1998, continuing where STII had left off.

2.2.6 Thailand SET Index

The Stock Exchange of Thailand is the only stock exchange in Thailand. Established on April 30, 1975, it has a market capitalization of US$599,000,000,000 as of March 31, 2022, making it the 2nd largest in ASEAN and the 23rd largest in the world. From 2015 to June 2020, it is the largest IPO market in Southeast Asia. It has raised US$17.8 billion in cumulative capital. It is also the most active exchange in the region for 10 consecutive years, with daily trading volume typically exceeding US$2 billion.

In addition to common shares, investors can trade other types of securities, including warrants, derivative warrants, depository receipts, exchange-traded funds, real estate funds /real estate investment trusts and infrastructure funds. The exchange also operates a separate derivatives market.

The SET Index is the oldest and most cited stock index in Thailand. The SET Index is a composite stock market index of Thailand, calculated as the price of all common stocks (including property fund unit trusts) on the main board of the Stock Exchange of Thailand (SET), which has stricter price rules than some other exchanges and usually does not allow stock prices to rise or fall by more than 30% in one day. It is a market capitalization-weighted price index that compares the current market value of all listed common stocks to their value on a benchmark date of April 30, 1975, which was established and set at 100 points for the index.

The SET Index calculation is adjusted for changes in the value of shares due to changes in the number of shares resulting from various events, such as public offerings, warrants exercised or conversion of preferred shares into common shares, in order to eliminate all price changes that affect the index except for the index.

2.2.7 JSX Composite Index

The Indonesia Stock Exchange is a stock exchange based in Jakarta, Indonesia. It was formerly known as the Jakarta Stock Exchange before its name was changed in 2007 following a merger with the Surabaya Stock Exchange.

The Indonesia Stock Exchange (IDX) is actively innovating in its development by providing stock indices that can be used by all participants in the Indonesian capital market. The index brochure "IDX Stock Index Brochure" contains a brief overview of the indices offered by the IDX.

IDX Composite/ Index Harga Saham Gabungan (IHSG), is an index of all stocks listed on the IDX of the Indonesian Stock Exchange. It is an index that measures the performance of the share prices of all listed companies on the Main Board of the Indonesia Stock Exchange and the Development Board.

2.2.8 S&P BSE Sensex Index

The Bombay Stock Exchange is the oldest stock exchange in Asia, located in Mumbai, India. The Bombay Stock Exchange was established in 1875. The Bombay Stock Exchange was established in 1875. There are 3,500 Indian companies listed here and the trading volume is considerable.

The BSE SENSEX (also known as S&P Bombay Stock Exchange Sensitive Index or SENSEX) is a free-float market-weighted stock market index of 30 well-established and financially sound companies, of which the 30 constituent companies are some of the largest and most actively traded stocks, representing various industrial sectors of the Indian economy. The S&P BSE SENSEX Index is a benchmark for the Indian economy. Since its release on January 1, 1986, the S&P BSE SENSEX has been considered the heartbeat of the Indian domestic stock market. The index has a base value of 100 as of April 1, 1979 and a base year of 1978-79.

3 Volatility Forecasting Models

Volatility is a statistical measure of the dispersion of returns for a given security or market index. For the most part, the higher the volatility, the greater the risk of the security. Volatility is usually measured as the standard deviation or variance between the returns of the same security or market index.

Volatility is usually the amount of uncertainty or risk associated with the magnitude of change in the value of a security. Higher volatility means that the value of a security may be spread over a wider range of values. This means that the price of a security can change dramatically in either direction over a short period of time. Lower volatility means that the value of the security does not fluctuate significantly and tends to be more stable.

Market volatility can also be seen through the VIX or Volatility Index, created by the Chicago Board Options Exchange as a measure of the 30-day expected volatility of the U.S. stock market, which is derived from real-time quotes for S&P 500 call and put options. It is effectively a measure of future bets that investors and traders place on the direction of the market or individual securities. a high VIX index means that the market is risky.

According to the differences and uncertainty of stock indexes, we need to estimate the volatilities for making investment decisions.

3.1 Exponentially Weighted Moving Average model

The Exponentially Weighted Moving Average (EWMA) is a quantitative or statistical measure used to model or describe a time series. The moving average is designed as such that older observations are given lower weights. The weights fall exponentially as the data point gets older – hence the name exponentially weighted.

The EWMA model was introduced in 1993 by J.P. Morgan in his financial risk metrics system Risk Metrics, the exponentially weighted moving average model is the dynamic model the simplest of them all, formally a forecasting model for t-time volatility as following:

$$\sigma_{t+1,t}^2 = (1-\omega)\cdot \varepsilon_t^2 + \omega \cdot \sigma_{t,t-1}^2 \tag{3.1}$$

The $\sigma_{t+1,t}^2$ is the forecasted variance, while ε_t^2 is the observed variance of the model, the ω is usually called the decay factor. The moving average is designed as such that older observations are given lower weights. The weights fall exponentially as the data point gets older, hence the name exponentially weighted. And the ω meet the conditions of greater than or equal to one and less than or equal to zero. Then the parameters can be estimated by minimizing the criterion of the RMSE which is Root Mean Square Error as a mathematical programming problem:

$$RMSE = \sqrt{\frac{1}{T} \cdot \sum_t z_t} \tag{3.2}$$

$$z_t = \varepsilon_t^2 - \sigma_{t,t-1}^2 \tag{3.3}$$

where z_t is the error of the forecast (difference between the observed and forecast value).

In order to get the forecasted variance, the returns of stock price indexes were calculated by using the logarithmic difference method. Next step is to calculate the observed variance of returns by the square of returns. Then the weights in the equation (3.1) of the EWMA model were set randomly in advance, and the values of the actual weights are then obtained by minimizing the RMSE as an objective function, finally, the forecasting variance can be obtained.

3.2 Autoregressive Conditional Heteroskedasticity

In order to overcome this drawback and obtain more accurate error estimates, Robert F. Engle (1982) proposed the Autoregressive conditional heteroskedasticity model or ARCH model.

The ARCH model is used to describe and model observations. They can be used whenever there is reason to believe that the error term will have an characteristic size or variance at any point in the series. In particular, the ARCH model assumes that the variance of the current error term is a function of the actual size of the error term in the previous time period.

In addition, the variance is usually related to the square of the previous error term. ARCH models are often used to model financial time series to demonstrate the clustering of volatilities over time. ARCH-type models are sometimes considered part of the stochastic volatility model family, but this is not strictly true. This is because we can obtain fully predetermined volatilities at time t from a given prior value. Generally, the variance is related to the squares of the previous innovations. The ARCH model is appropriate when the error variance in a time series follows an autoregressive (AR) mode.

To model the time series using the ARCH process, let εt denote the error terms (return residuals, relative to the average process), for instance, the series terms. These εt are divided into a random piece z_t and the time-dependent standard deviation σ characterizing the terms typically size, the equation can be described as follows:

$$\varepsilon_t = \sigma_t \cdot z_t \tag{3.4}$$

where the random variable z_t is a strong white noise process. And the series σ_t^2 is modelled by the following equation:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \cdot \varepsilon_{t-i}^2 \tag{3.5}$$

where $\alpha_0 > 0$ and $\alpha_i \geq 0,\ i > 0$.

An ARCH(q) model can be estimated using ordinary least squares. A method for testing whether the residuals ε_t exhibit time-varying heteroskedasticity using the Lagrange multiplier test was proposed by Engle (1982). This procedure is as follows:

1. Estimate the best fitting autoregressive model AR (q).

$$y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \cdot y_{t-i} + \varepsilon_t \tag{3.6}$$

2. Obtain the squares of the error ε_t^2 and regress them on a constant and q lagged values.

$$\varepsilon_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \cdot \varepsilon_{t-i}^2 \tag{3.7}$$

where q is the length of ARCH lags.

The null hypothesis is that, in the absence of ARCH components, we have $\alpha_i = 0$ for all $i = 1, \dots, q$. The alternative hypothesis is that, in the presence of ARCH components, at least one of the estimated α_i coefficients must be significant. In a sample of T residuals under the null hypothesis of no ARCH errors, the test statistic $T'R^2$ follows distribution with q degrees of freedom, where T' is the number of equations in the model which fits the residuals vs the lags, for example, $T' = T - q$. If $T'R^2$ is greater than the Chi-square table value, we reject the null hypothesis and conclude there is an ARCH effect in the ARMA model. If $T'R^2$ is smaller than the Chi-square table value, we do not reject the null hypothesis.

In this paper, the returns of stock prices are set as the independent variable y_t, after using unit root test and descriptive statistics, the distribution and stationary can be tested. Next the existence of autocorrelation of the series is then obtained from the correlation test of the returns, which determines the mean equation of the model. The last step is to detect whether the stock price returns have ARCH effect by testing the residual term of the model.

3.3 Generalized Autoregressive Conditional Heteroskedasticity

Since Engle (1982) proposed the ARCH model to analyse the heteroskedasticity of time series, T. Bollerslev (1986) proposed the GARCH model, which is a customized regression model for financial data, excluding the common regression model, GARCH models the variance of errors, which is particularly suitable for volatility analysis and forecasting.

A complete GARCH model contains two parts, the mean equation and the variance equation, the examples of equations are shown as follows:

$$y_t = \theta_0 + \theta_1 \cdot x_t + \varepsilon_t \tag{3.8}$$

$$\sigma_t^2 = \omega + \alpha \cdot \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 \tag{3.9}$$

where σ_t^2 is the conditional variance of error ε_t, σ_t is known as the volatility, the mean equation is generally a linear regression model or an autoregressive model. Therefore, the essence of GARCH model is mainly in the variance equation. And different variance equations will form different GARCH-like models.

And the conditional variance equation of GARCH (p, q) can be described as follows:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 \tag{3.10}$$

where ω is the constant term and $\sum_{i=1}^{q} \alpha_i + \sum_{i=1}^{p} \beta_i < 1$, while α_i , β_i is the coefficient of residuals and variance of previous day. And ε_{t-i}^2 is known as the ARCH term, while σ_{t-i}^2 is known as the GARCH term.

In this paper, the same mean equation is used as the ARCH model, and then add the GARCH term to the model, and test the reasonableness of the model with different lag orders by Akaike information criterion, Schwarz criterion, and Hannah-Quinn criterion, so as to determine the most suitable GARCH model. This is used to determine whether the return series has significant volatility clustering and whether the conditional variance has mean reversion.

3.4 GARCH-in-mean model

The GARCH-in-mean (GARCH-M) refers to add a mean term, which means a mean equation. An ARCH-M term is formed by putting σ_t^2 or some functional form thereof into the mean equation as an explanatory variable. The sample equation of GARCH-M model can be described as follows:

$$r_t = \mu + c \cdot \sigma_t + a_t \tag{3.11}$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \cdot a_{t-i}^2 + \sum_{j=1}^{q} \beta_i \cdot \sigma_{t-j}^2 \tag{3.12}$$

$$a_t = \sigma_t \cdot \varepsilon_t \tag{3.13}$$

where μ is the mean of the GARCH model, c is the volatility coefficient for the mean, a_t is the residual of the model at time t, and ε_t is the standardized residual that $[\varepsilon_t] \sim I.I.D.$ (Independent and identically distributed).

In this paper, the GARCH-M model adds variance as an explanatory variable to the GARCH model and detects the relationship between the return of the stock index and variance which as known as the risk through the same prediction steps of GARCH models.

3.5 Exponential GARCH model

The exponential general autoregressive conditional heteroskedastic (EGARCH) is another form of the GARCH model. E-GARCH model was proposed by Nelson (1991) to overcome the weakness in GARCH handling of financial time series. In particular, to allow for asymmetric effects between positive and negative asset returns. This model differs from the GARCH variance structure because of the log of the variance.

The equations of an E-GARCH(p, q, r) model can be described as follows:

$$r_t = \mu + \theta_t \cdot r_{t-i} + \varepsilon_t \tag{3.14}$$

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^{p} \alpha_i \cdot \left|\frac{\varepsilon_{t-i}}{\sigma_{t-i}}\right| + \sum_{i=1}^{q} \beta_i \cdot \log(\sigma_{t-i}^2) + \sum_{i=1}^{r} \gamma_i \cdot \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \tag{3.15}$$

If $\gamma_i < 0$, then there is a leverage effect on volatility.

By adding an asymmetric term in the model with the same steps of GARCH model. Testing whether the coefficients of different variables are significant allows testing whether the variance series are leveraged and asymmetric.

In the predictions of the EGARCH model, assuming that the coefficients of each variable are significant, the positive and negative values of the coefficients of the asymmetry terms would indicate the positive and negative leverage effects existing in the volatility series.

4 Analysis of Stock Prices and Their Volatilities at Selected Asian Markets

This section is devoted to the completion of the analysis of the stock price indices selected for this paper and the study and prediction of the volatility of these indices. There have selected different stock indices from eight Asian countries and regions by using daily closing prices as a sample during a sample period from 2010 to 2020, with 2400 data for each index. These eight stock indices are as follows:

- Shanghai Composite Index (China Shanghai Composite)
- Hang Seng Index (Hong Kong, China)
- NIKKEI 225 Index (Japan)
- KOSPI Composite Index (South Korea)
- FTSE Straits Times Index (Singapore)
- Thailand SET Index (Thailand)
- JSX Composite Index (Indonesia)
- S&P BSE Sensex Index (India)

4.1 Forecasting volatility from EWMA model

There are 2400 daily closing prices from January 14, 2010 will be chose as the sample variables. First, to calculate the periodic return, which typically is a series of daily returns where each return is expressed in continually compounded terms. Hence, it applies the log-difference method to find the rate of change of the stock price index, also called the rate of return.

$$r_t = \ln \frac{p_t}{p_{t-1}} \tag{4.1}$$

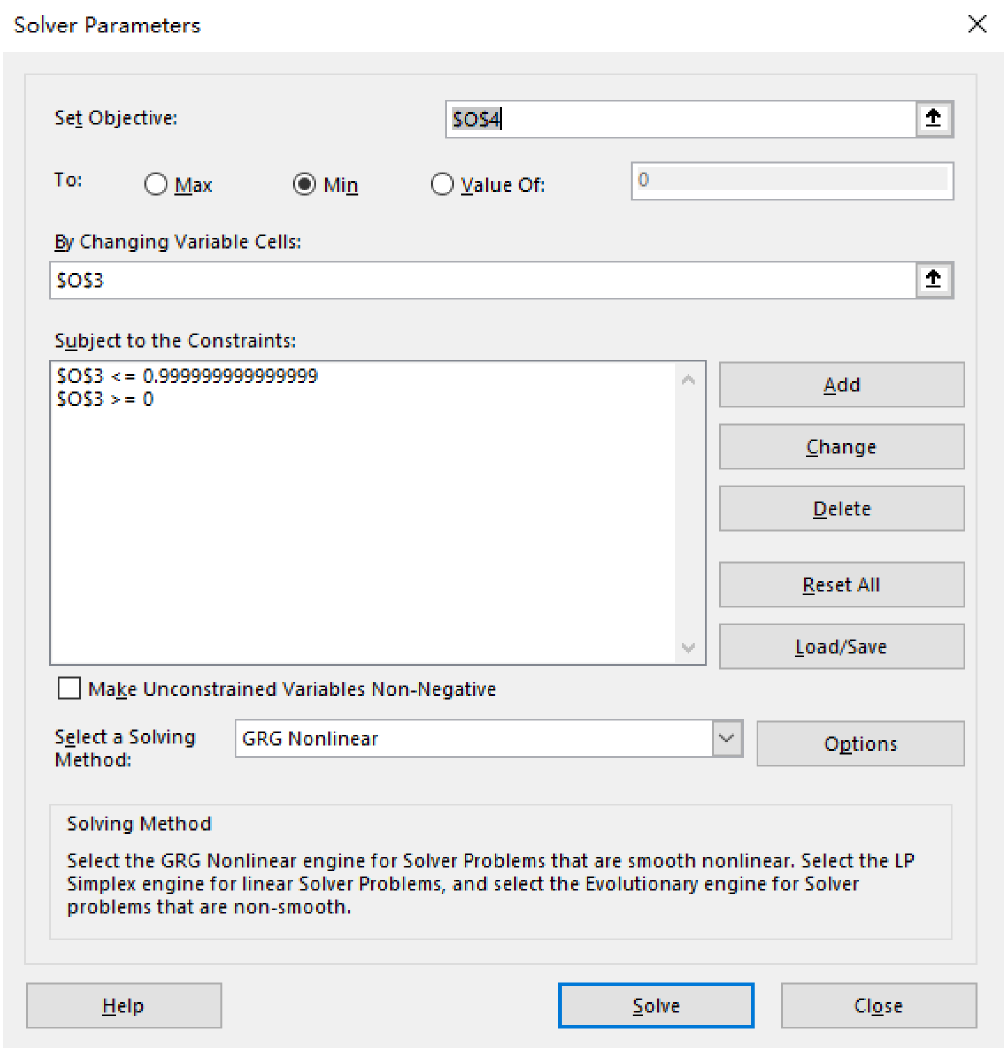
To calculated ε_t^2 as the observed variance by squaring the returns r_t, which were calculated by log-difference method.

$$\varepsilon_t^2 = r_t \cdot r_t \tag{4.2}$$

Then, to chose the ω as the weight parameter, and pre-set a basic value which is 0.5 in the model. Since it is necessary to use the previous day's data in the calculation, the average of the squared returns will be used as the forecast variance for the first day, in this case, the function (AVERAGE.) will be used in excel, and other forecasting variance was calculated by using the equation (3.1).

The following step is to calculate the forecasting error where the equation(3.3) is applied. To set up an objective function of RMSE by using the equation(3.2), which use the function (SQRT(SUMSQ(K3:K2400)/2398) in Excel. With the prerequisites obtained above to calculate the actual ω by Solver in data analysis in Excel. The Solver method can be described as the following figure 4.1, and the specific results for other parameters can be found in Annex 2.

Figure 4.1 The function of EWMA model solvency



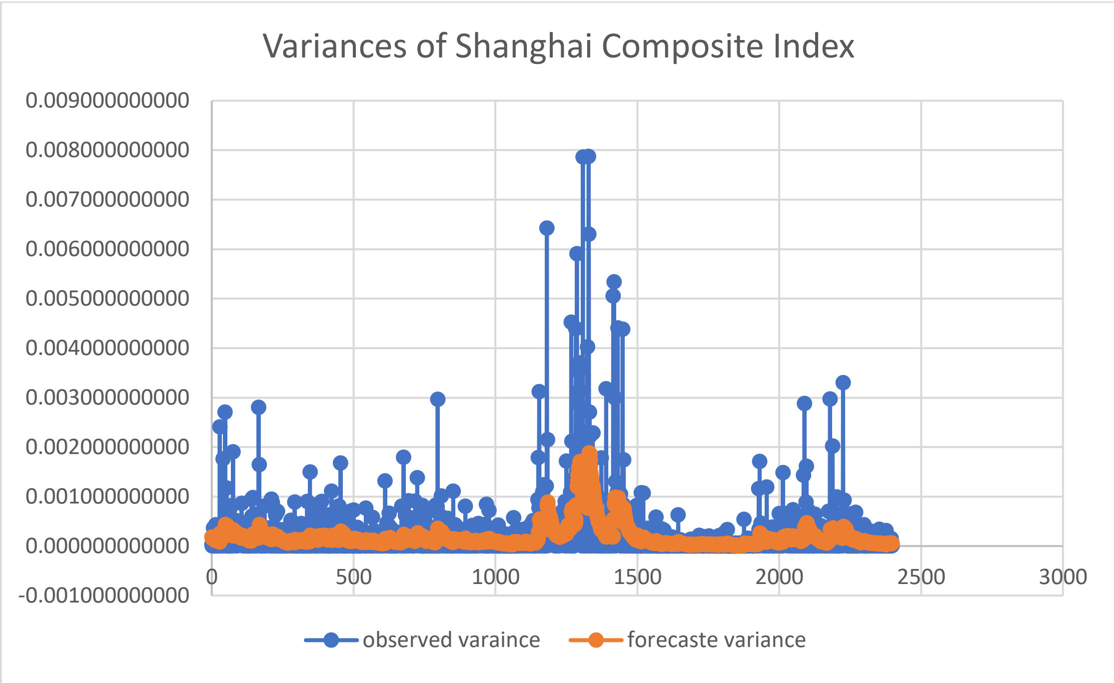
Source: Author's Analysis

4.1.1 Result of Shanghai Composite Index

After calculated the minimized RMSE, the weight ω for EWMA modelling can be calculated. The ω of Shanghai Composite Index is 0.926366088, while the RMSE is 0.000493178. Then the weight and calculated variance will be used to forecast the variance of the next day, which is 0.00005111499. According to the calculation, the model of estimation is as follow:

$$\sigma^2_{t+1,t} = 0.073633912 \cdot \varepsilon^2_t + 0.926366088 \cdot \sigma^2_{t,t-1} \quad (4.3)$$

Figure 4.2 Variance of Shanghai Composite Index from EWMA model



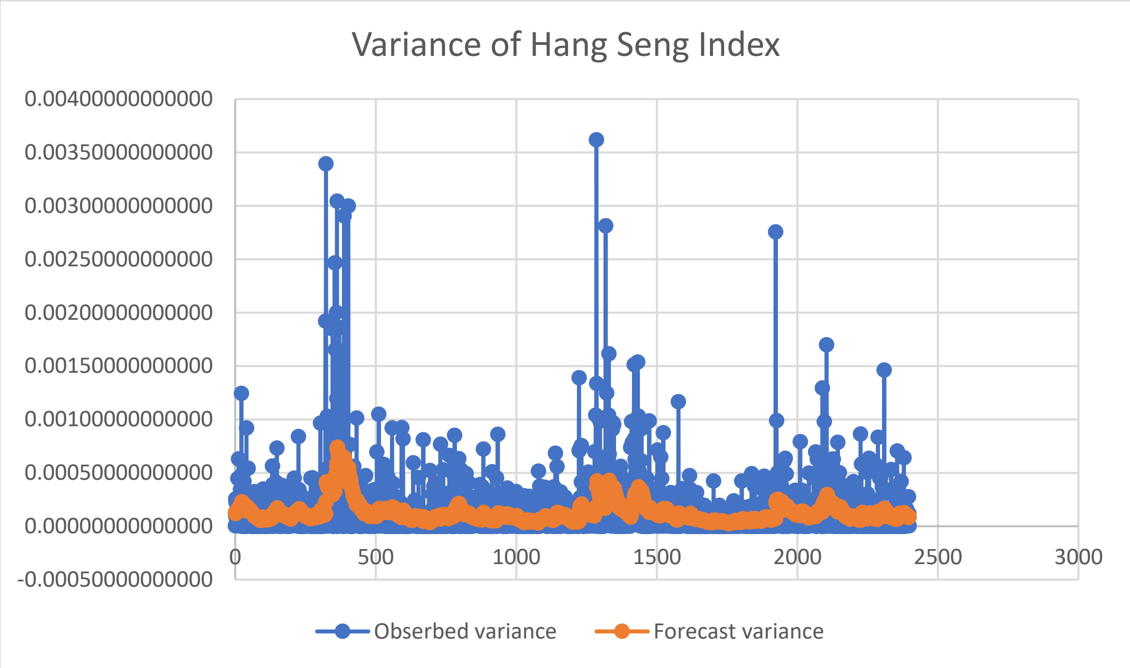
Source: Author's Analysis

4.1.2 Result of Hang Seng Index

Based on the calculation steps above, it can easily reach the results of Hang Seng Index. The value of calculated decay factor is 0.943843941, which is from the result of RMSE(0.000258757). Next, the forecasting variance of the forecasting day which is 0.0000856694 can be calculated. So the function of EWMA model for Hang Seng Index can be described as following:

$$\sigma^2_{t+1,t} = 0.056156059 \cdot \varepsilon^2_t + 0.943843941 \cdot \sigma^2_{t,t-1} \quad (4.4)$$

Figure 4.3 Variance of Hang Seng Index



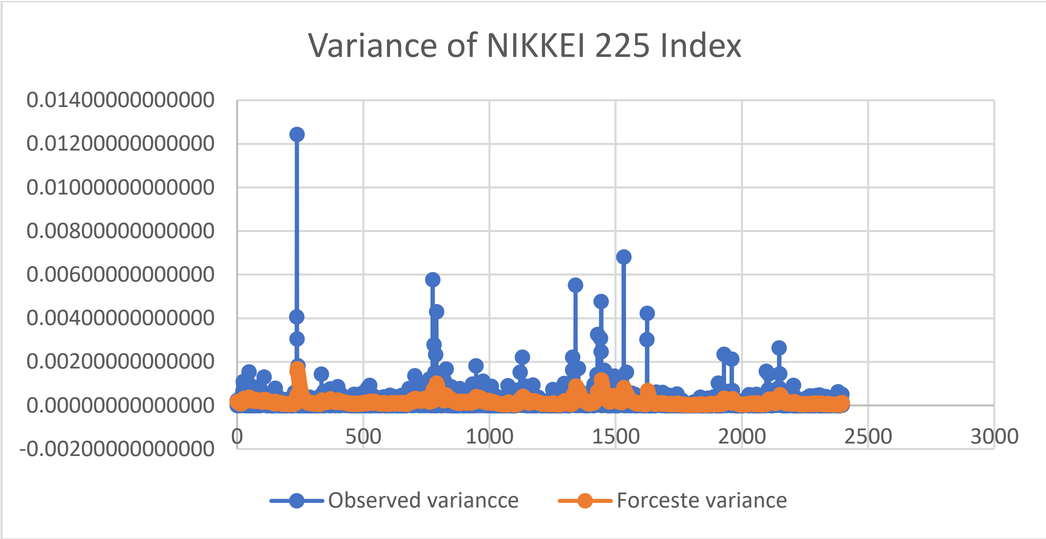
Source: Author's Analysis

4.1.3 Result of NIKKEI 225 Index

The result from the calculation shows that the weight of NIKKEI 225 Index is 0.911470701, and the RMSE is 0.000462765. After these results, it is calculated that the forecasting variance for next day which is 0.0001219525. The formula of EWMA model of NIKKEI 225 Index is:

$$\sigma_{t+1,t}^2 = 0.088529299 \cdot \varepsilon_t^2 + 0.911470701 \cdot \sigma_{t,t-1}^2 \quad (4.5)$$

Figure 4.4 Variance of NIKKEI 225 Index



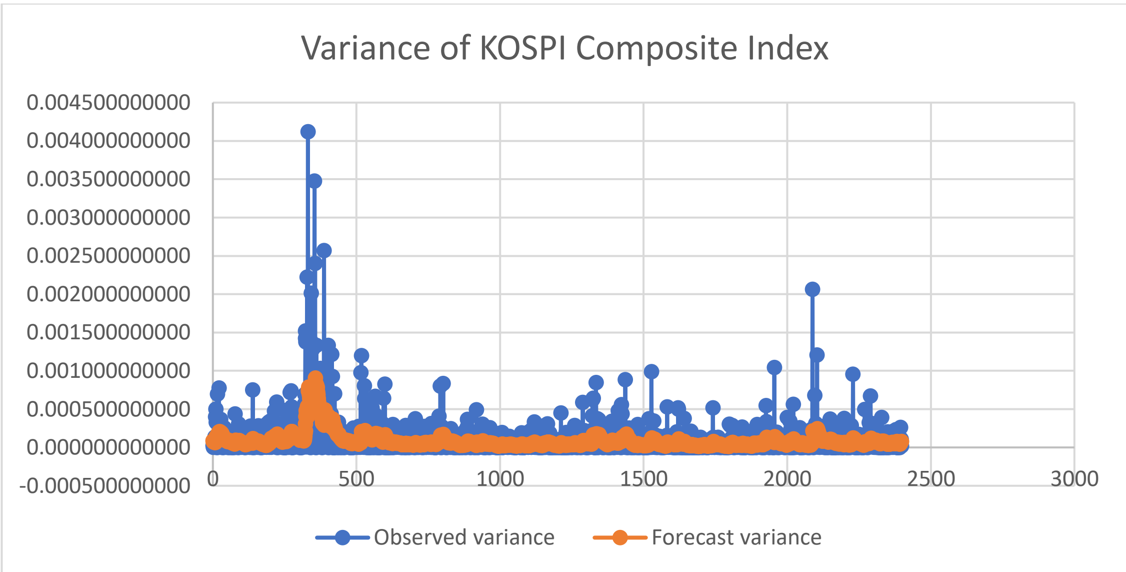
Source: Author's Analysis

4.1.4 Result of KOSPI Composite Index

The minimize Root Mean Square Error used to calculate the parameter ω of KOSPI Composite Index which is 0.000197646, and the value of ω is 0.922081898. Hence, the forecasting variance of KOSPI Composite Index for the next date is 0.0000730098, and the equation of our model is as following:

$$\sigma_{t+1,t}^2 = 0.077918102 \cdot \varepsilon_t^2 + 0.922081898 \cdot \sigma_{t,t-1}^2 \tag{4.6}$$

Figure 4.5 Variance of KOSPI Composite Index



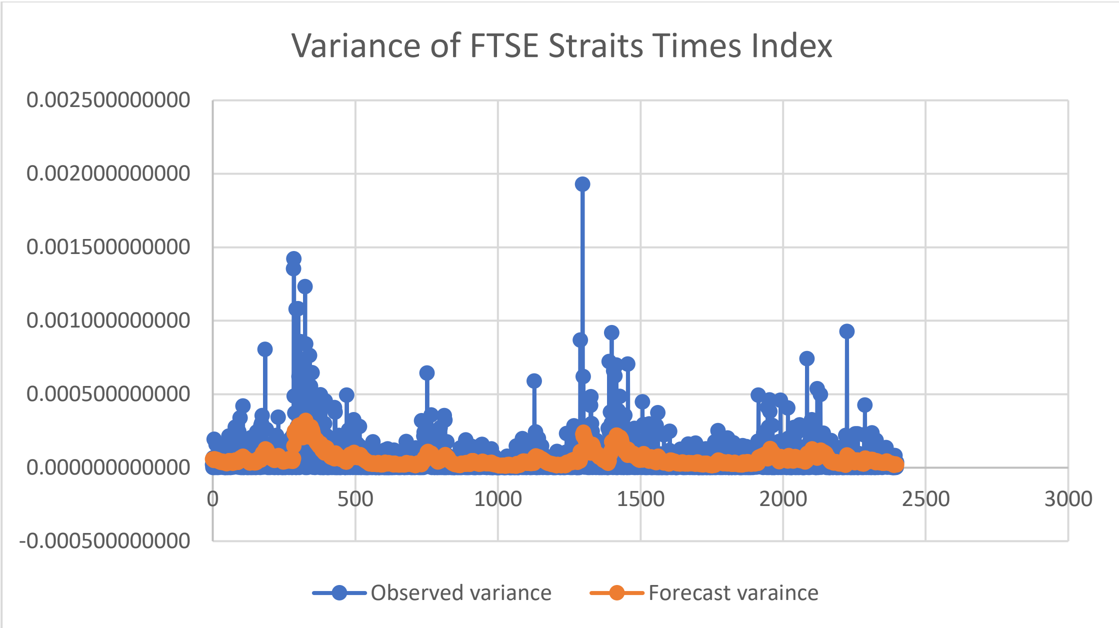
Source: Author's Analysis

4.1.5 Result of FTSE Straits Times Index

For the EWMA model in the thesis used, it is observed that the minimum Root Mean Square Error is 0.00011326, and the adjusted weight of our model is 0.933532977. As for forecasting the next value of variance, with the usage the equation(3.1), the result is 0.0000204467. finally, we can get the final equation of FTSE Straits Times Index on EWMA model which is followed:

$$\sigma_{t+1,t}^2 = 0.066467023 \cdot \varepsilon_t^2 + 0.933532977 \cdot \sigma_{t,t-1}^2 \tag{4.7}$$

Figure 4.6 Variance of FTSE Straits Times Index



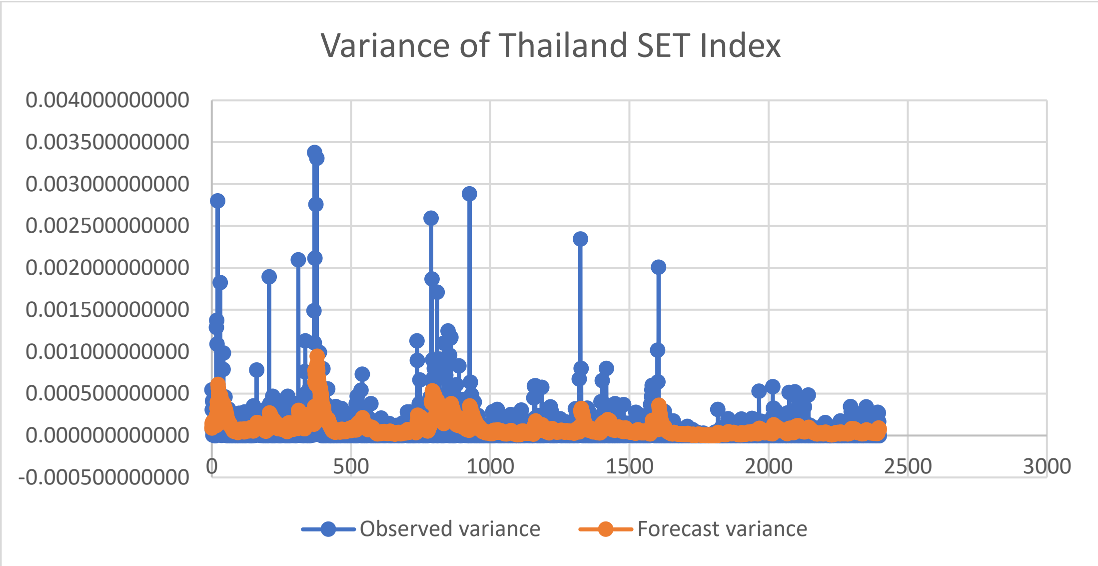
Source: Author's Analysis

4.1.6 Result of Thailand SET Index

As the same steps we calculated above, the adjusted weight of variance is 0.904181038 with the 0.000220872 as the value of RMSE of our model. Then the forecast variance for the following day of Thailand SET Index can be got, which is 0.0000674927. The final equation is :

$$\sigma_{t+1,t}^2 = 0.095818962 \cdot \varepsilon_t^2 + 0.904181038 \cdot \sigma_{t,t-1}^2 \tag{4.8}$$

Figure 4.7 Variance of Thailand SET Index



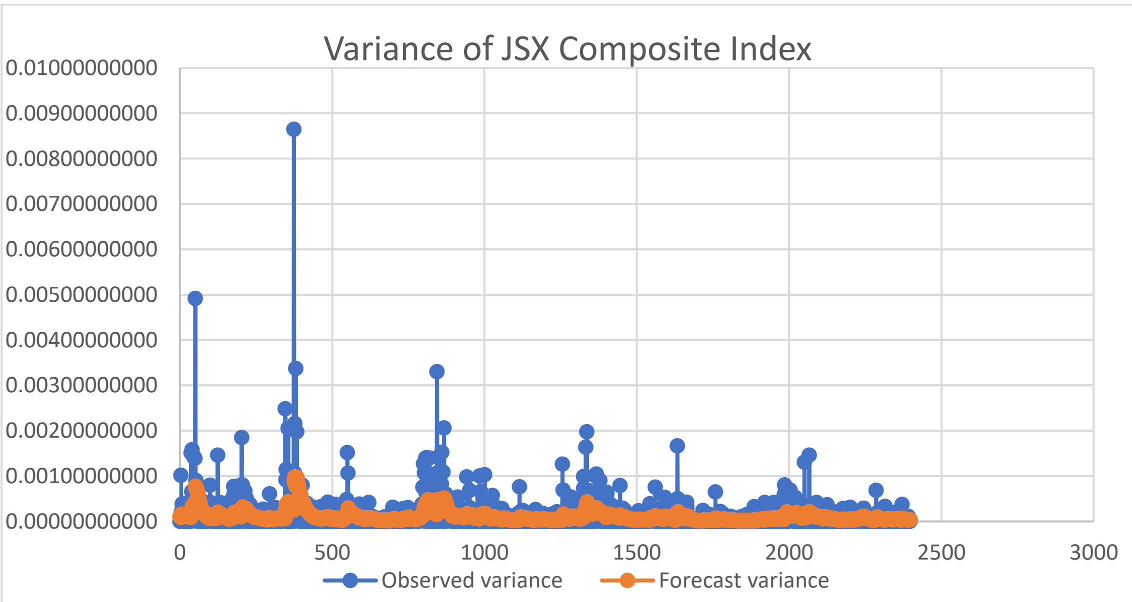
Source: Author's Analysis

4.1.7 Result of JSX Composite Index

The value of parameter ω of JSX Composite Index in the calculation is 0.920940629, and the objective function of RMSE is 0.000299838. Therefore, we can get the value of following day's variance which is 0.0000344960. Based on these results, the final equation of JSX Composite Index in EWMA model is:

$$\sigma_{t+1,t}^2 = 0.079059371 \cdot \varepsilon_t^2 + 0.920940629 \cdot \sigma_{t,t-1}^2 \tag{4.9}$$

Figure 4.8 Variance of JSX Composite Index



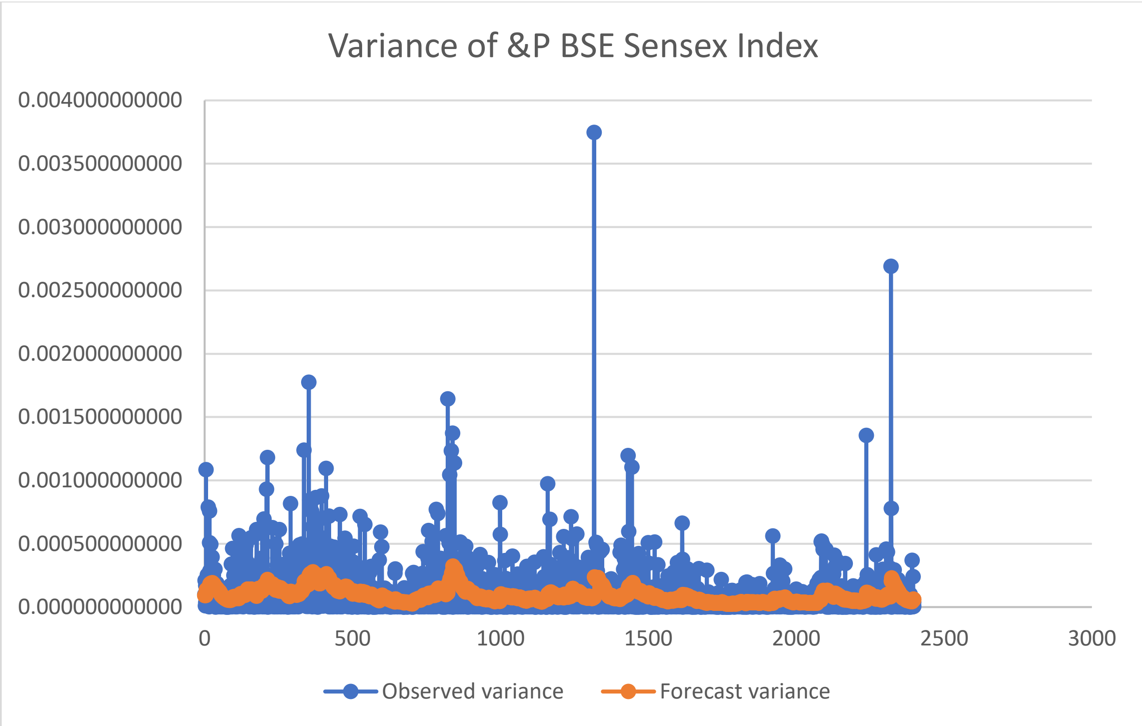
Source: Author's Analysis

4.1.8 Result of S&P BSE Sensex Index

By calculating the variance of S&P BSE Sensex Index by using EWMA model, the value of RMSE of S&P BSE Sensex Index is 0.000177676, in that case, it can be observed that the weight of past variance is 0.956320417. So, the forecasting variance for the forecasting day is 0.0000557165. Based on these calculations, we can find the modelling equation of S&P BSE Sensex Index is:

$$\sigma^2_{t+1,t} = 0.043679583 \cdot \varepsilon^2_t + 0.956320417 \cdot \sigma^2_{t,t-1} \quad (4.10)$$

Figure 4.9 Variance of S&P BSE Sensex Index



Source: Author's Analysis

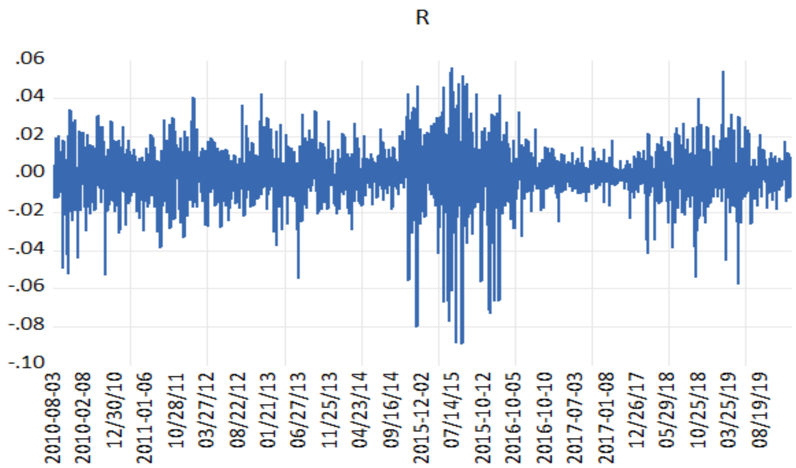
4.2 Modelling by ARCH model

In this subchapter, the Unit root test and description statistic are used for testing series of log returns, and by using the correlation test, the mean equation of ARCH model can be obtained. Then by testing the correlation of the residuals and squared residuals, the characteristic of variance volatility can be found, which is time varying and clustering.

4.2.1 Result of logarithmic rate of returns

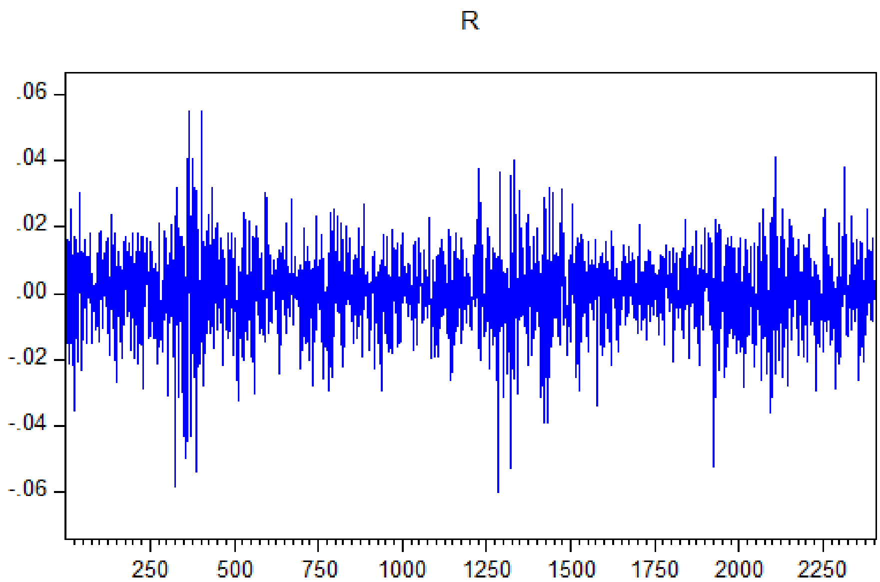
In this part, ARCH model was used to estimate the volatility of those stock Indexes. For the first step, the daily closing price of stock indexes was imported as data, then the log difference method was used to calculate the log return of indexes. The result can be described as following:

Figure 4.11 logarithmic rate of return of Shanghai Composite Index



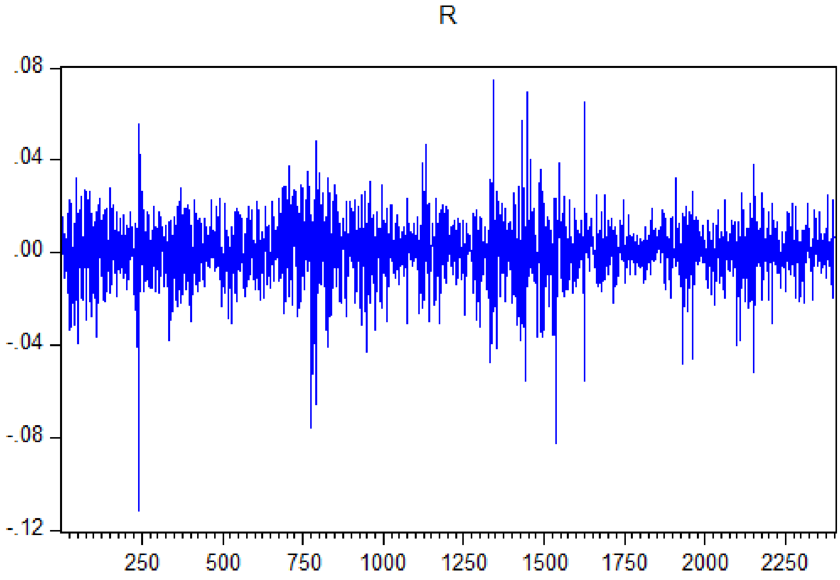
Source: Author's Analysis

Figure 4.12 logarithmic rate of return of Hang Seng Index



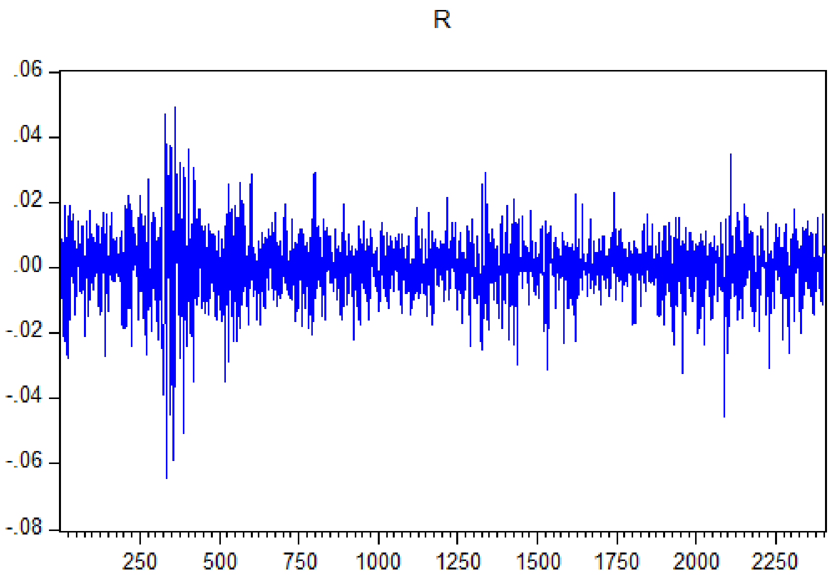
Source: Author's Analysis

Figure 4.13 Logarithmic rate of return of NIKKEI 225 Index



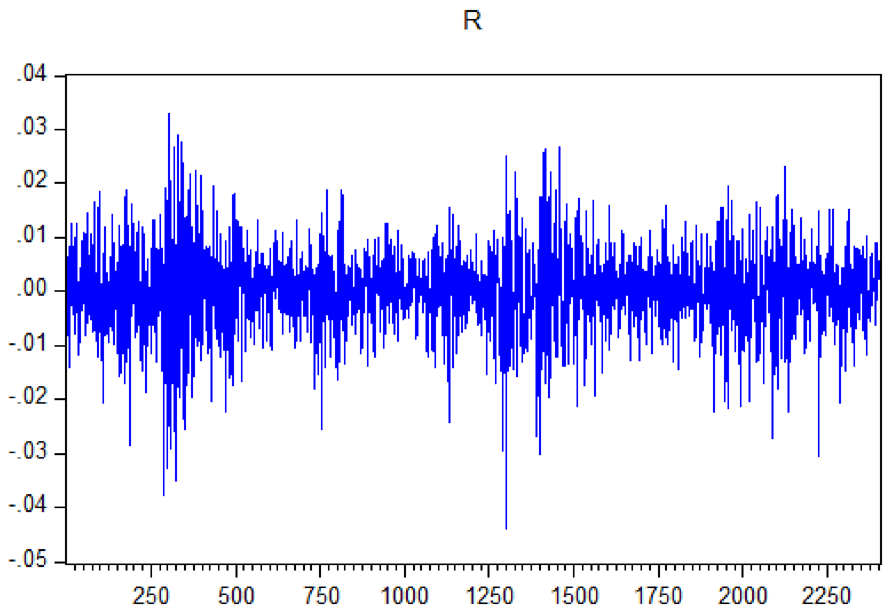
Source: Author's Analysis

Figure 4.14 Logarithmic rate of return of KOSPI Composite Index



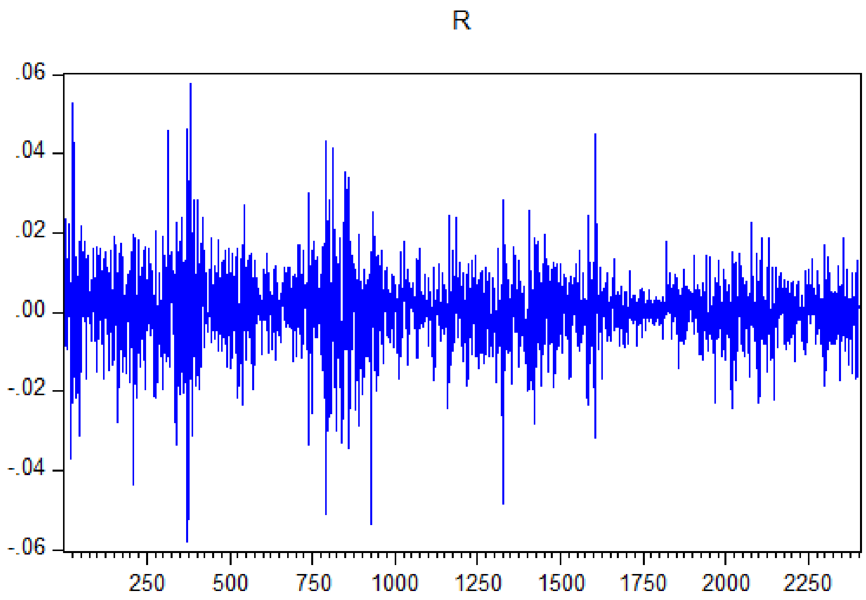
Source: Author's Analysis

Figure 4.15 Logarithmic rate of return of FTSE Straits Times Index



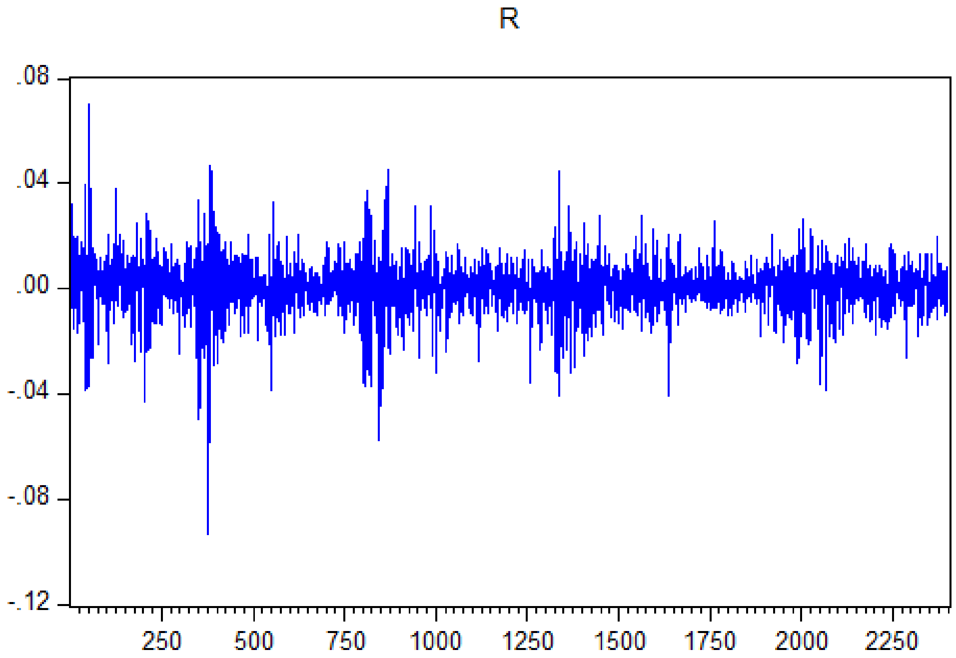
Source: Author’s Analysis

Figure 4.16 Logarithmic rate of return of Thailand SET Index



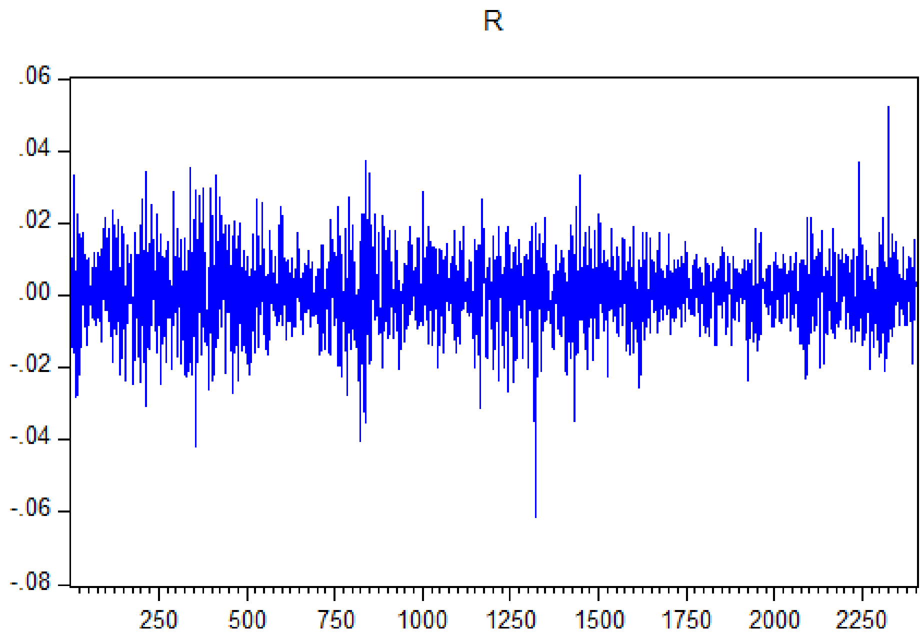
Source: Author’s Analysis

Figure 4.17 Logarithmic rate of return of JSX Composite Index



Source: Author's Analysis

Figure 4.18 Logarithmic rate return of S&P BSE Sensex Index

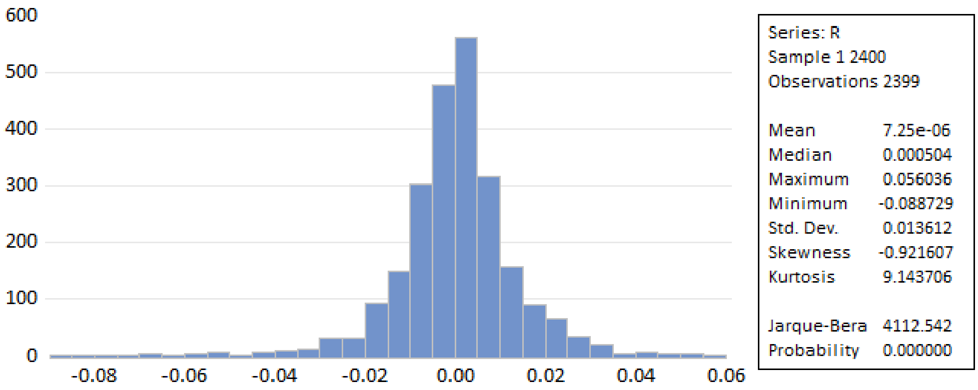


Source: Author's Analysis

From the linear plot of the log return series r of the these stock price Indexes, one can observe a "clustering" of log return fluctuations: the fluctuations are small in some time periods (e.g. Shanghai Composite Index from 27.02.12 to 22.08.12) and very large in others (e.g. Shanghai Composite Index from 12.02.2015 to 10.05.2016).

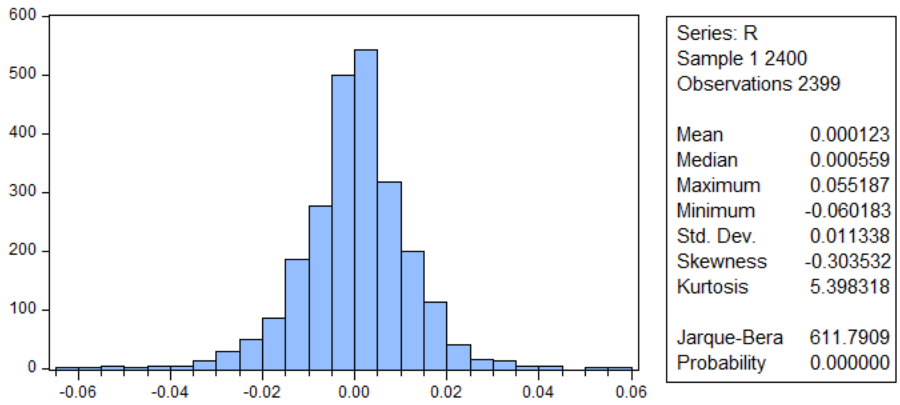
4.2.2 Descriptive statistics of log returns of stock price indexes

Figure 4.19 Bar graph of log returns of Shanghai Composite Index



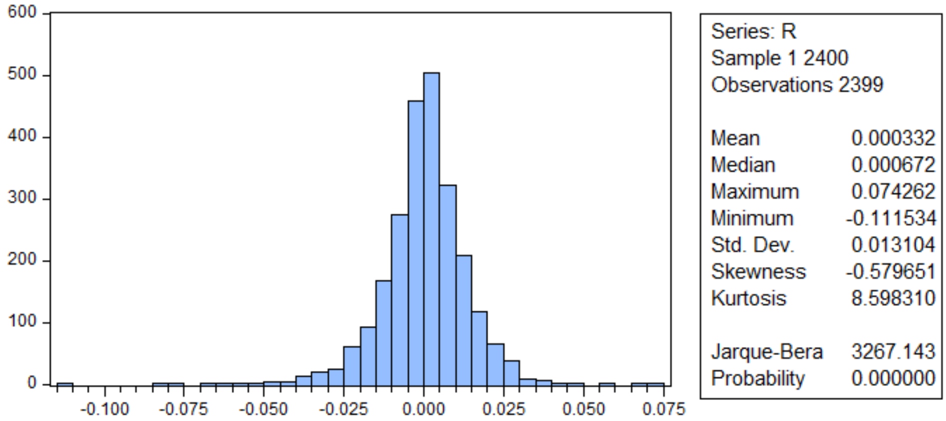
Source: Author’s Analysis

Figure 4.20 Bar graph of log returns of Hang Seng Index



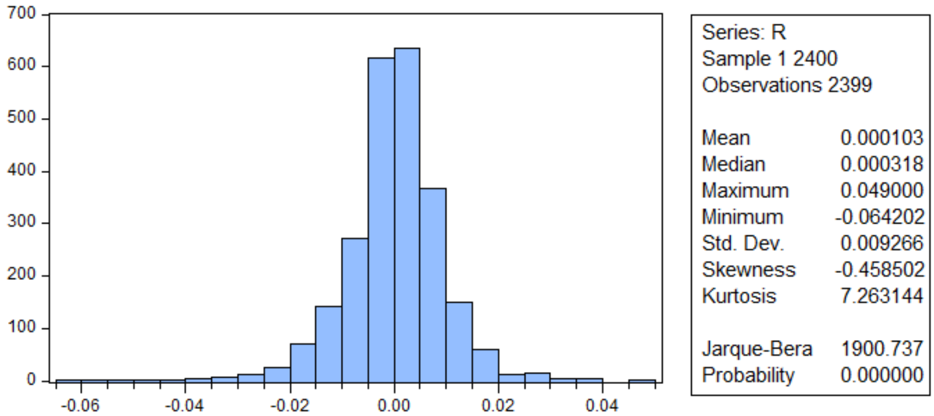
Source: Author’s Analysis

Figure 4.21 Bar graph of log returns of NIKKEI 225 INDEX



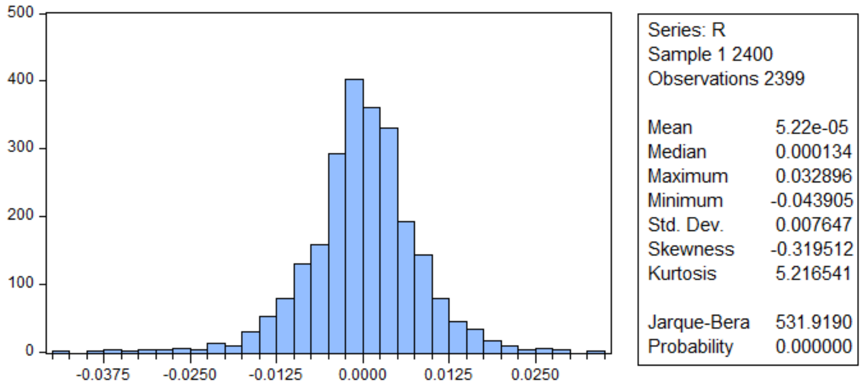
Source: Author’s Analysis

Figure 4.22 Bar graph of log returns of KOSPI Composite Index



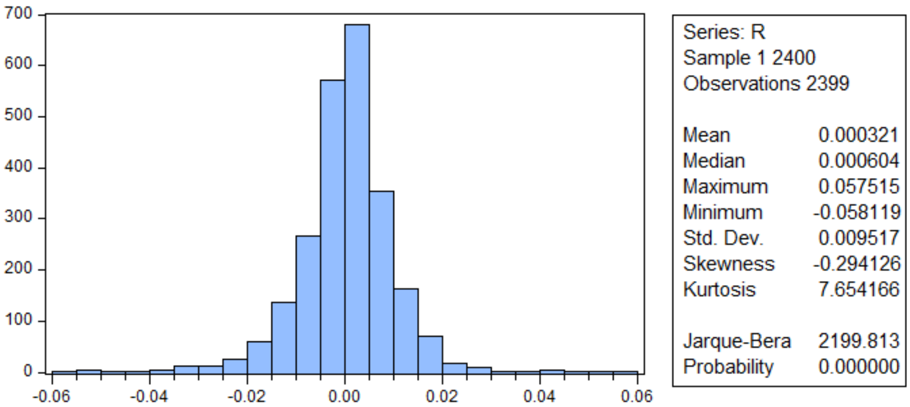
Source: Author’s Analysis

Figure 4.23 Bar graph of log returns of FTSE Straits Times Index



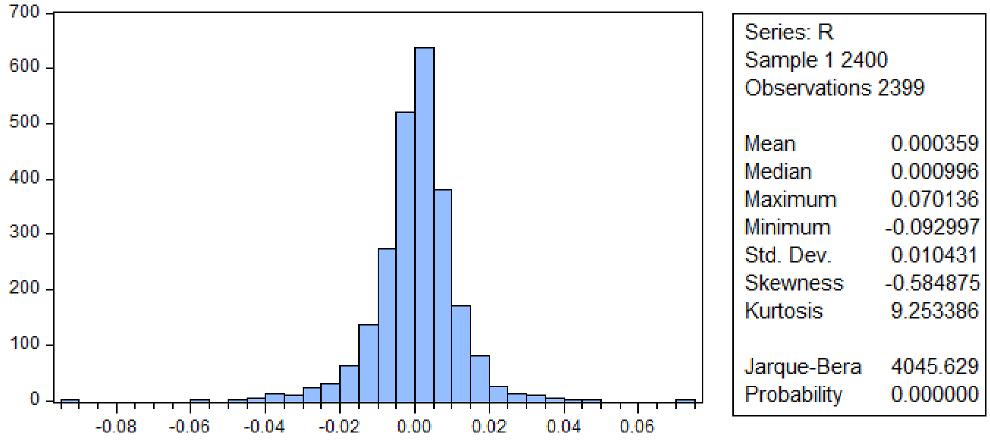
Source: Author's Analysis

Figure 4.24 Bar graph of log returns of Thailand SET Index



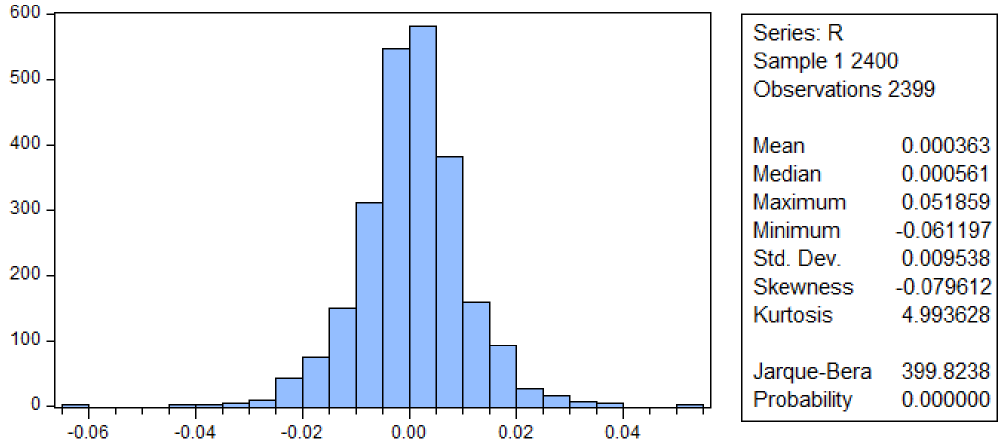
Source: Author's Analysis

Figure 4.25 Bar graph of log returns of JSX Composite Index



Source: Author's Analysis

Figure 4.26 Bar graph of log returns of S&P BSE Sensex Index



Source: Author's Analysis

Table 4.1 Descriptive statistics of log returns of all stock indexes

	SHCOMP	HSI	NIK	KOSPI	STI	SET	JAKIDX	S&P BSE
Mean	7.25E-06	0.000123	0.000332	0.000103	5.22E-05	0.000321	0.000359	0.000363
Median	0.000504	0.000559	0.000672	0.000318	0.000134	0.000604	0.000996	0.000561
Maximum	0.056036	0.055187	0.074262	0.049	0.032896	0.057515	0.070136	0.051859
Minimum	-0.08873	-0.06018	-0.11153	-0.0642	-0.04391	-0.05812	-0.093	-0.0612
Std. Dev.	0.013612	0.011338	0.013104	0.009266	0.007647	0.009517	0.010431	0.009538
Skewness	-0.92161	-0.30353	-0.57965	-0.4585	-0.31951	-0.29413	-0.58488	-0.07961
Kurtosis	9.143706	5.398318	8.59831	7.263144	5.216541	7.654166	9.253386	4.993628
Jarque-Bera	4112.542	611.7909	3267.143	1900.737	531.919	2199.813	4045.629	399.8238
Probability	0	0	0	0	0	0	0	0
Sum	0.0174	0.294766	0.796888	0.247744	0.125208	0.769899	0.862414	0.870991
Sum Sq. Dev.	0.444328	0.308251	0.411766	0.205878	0.140239	0.217209	0.260907	0.218157
Observations	2399	2399	2399	2399	2399	2399	2399	2399

Source: Author's Analysis

As can be seen from the figures and table 4.1, the mean of the log return series of the Shanghai Composite Index is 7.25e-06, with a standard deviation of 0.013612 and a skewness of -0.921607, which is less than 0, indicating that the series distribution has a long left trailing tail. The kurtosis is 9.143706, which is higher than the kurtosis value of 3 for normal distribution, indicating that the return series has the characteristics of spikes and fat tails. the Jarque-Bera statistic is 4112.542 and the p-value is 0.00000, which rejects the hypothesis that the log return series follows normal distribution. And the similar situation happened on others seven stock indexes. However, according to the standard deviation, the standard deviation of SHCOMP is the highest one which value is 0.013612, this means the volatility of log returns of SHCOMP is the highest, meanwhile, the volatility of KOSPI is lowest which value of standard deviation is 0.09226.

4.2.3 Stability test of logarithmic returns

In this subchapter, the Augmented Dickey-Fuller test was used to test for the stationarity of log-return series of the selected stock indexes. The Augmented Dickey Fuller Test (ADF) is unit root test for stationarity. Unit roots can cause unpredictable results in the time series analysis.

The hypotheses for the test is the null hypothesis for this test is that there is a unit root. And the alternate hypothesis differs slightly according to which equation we will use. The basic alternate is that the time series is stationary (or trend-stationary).

According to the analysis , the result of Shanghai Composite Index can be shown as following:

Table 4.2 ADF test of log returns of Shanghai Composite Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-47.26615	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/08/22 Time: 04:42
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-0.965009	0.020416	-47.26615	0.0000
C	4.79E-06	0.000278	0.017249	0.9862

R-squared	0.482515	Mean dependent var	-3.34E-06
Adjusted R-squared	0.482299	S.D. dependent var	0.018914
S.E. of regression	0.013609	Akaike info criterion	-5.755324
Sum squared resid	0.443757	Schwarz criterion	-5.750501
Log likelihood	6902.634	Hannan-Quinn criter.	-5.753569
F-statistic	2234.089	Durbin-Watson stat	1.997474
Prob(F-statistic)	0.000000		

Source: Author’s Analysis

According to the Table 4.2, it is observed that the value of the t-statistic is -22.88 which is lower than -3.43288 at 1% significant level, corresponding to a p-value which is 0.0001, close to 0. Therefore, the series rejects the original hypothesis at 1% level of significance, there is no unit root and it is a smooth series, so the test indicated that the series of log returns is flat. This result is consistent with several scholarly studies on volatility in developed and mature markets: Pagan (1996) and Bollerslev (1994) pointed out that the prices of financial assets are generally non-stationary, often with a unit root (random wandering), while the return series is usually stationary. The similar results of other 7 stock indexes can be found in Annex 2.

4.2.4 Determination of the mean equation and autocorrelation test of the residual series

For deciding the mean equation, it is necessary to analysis the autocorrelation and partial autocorrelation tests for selected sequences, with 36 as lag length.

Table 4.3 Correlation test of log returns of Shanghai Composite Index

Date: 04/08/22 Time: 05:29
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.035	0.035	2.9408	0.086
		2	-0.031	-0.032	5.2149	0.074
		3	0.026	0.029	6.8745	0.076
		4	0.047	0.044	12.244	0.016
		5	0.002	0.001	12.256	0.031
		6	-0.062	-0.060	21.574	0.001
		7	0.047	0.050	26.904	0.000
		8	0.038	0.029	30.398	0.000
		9	0.032	0.036	32.932	0.000
		10	-0.028	-0.026	34.806	0.000
		11	-0.020	-0.022	35.803	0.000
		12	0.011	0.002	36.097	0.000
		13	0.056	0.060	43.718	0.000
		14	-0.068	-0.068	54.979	0.000
		15	0.019	0.030	55.842	0.000
		16	0.035	0.018	58.808	0.000
		17	0.017	0.014	59.540	0.000
		18	0.006	0.014	59.641	0.000
		19	-0.013	-0.006	60.020	0.000
		20	0.067	0.052	70.890	0.000
		21	0.030	0.029	73.073	0.000
		22	-0.021	-0.020	74.127	0.000
		23	-0.077	-0.073	88.468	0.000
		24	-0.026	-0.033	90.139	0.000
		25	0.037	0.028	93.454	0.000
		26	-0.035	-0.028	96.467	0.000
		27	-0.036	-0.019	99.590	0.000
		28	0.059	0.047	107.95	0.000
		29	0.002	-0.016	107.95	0.000
		30	-0.032	-0.019	110.48	0.000
		31	-0.061	-0.047	119.49	0.000
		32	-0.032	-0.033	121.98	0.000
		33	0.038	0.029	125.52	0.000
		34	0.020	0.032	126.52	0.000
		35	0.011	0.017	126.84	0.000
		36	-0.004	-0.006	126.88	0.000

Source: Author's Analysis

As the autocorrelation test, it is observed that the log return is significantly autocorrelated after its lags of order 6(like 14, 20, 23,28). Therefore, the mean equation for Shanghai Composite Index's log returns r_t takes the following form:

$$r_t = c + ar_{t-6} + \varepsilon_t \tag{4.10}$$

The similar situation also included KOSIP Composite Index, FTSE Straits Times Index, JSX Composite Index. The mean equation of these three Indexes can be described as following:

KOSIP Composite Index $\quad r_t = c + ar_{t-7} + \varepsilon_t \quad$ (4.11)

FTSE Straits Times Index $\quad r_t = c + ar_{t-5} + \varepsilon_t \quad$ (4.12)

JSX Composite Index $\quad r_t = c + ar_{t-3} + \varepsilon_t \quad$ (4.13)

Then for the first step, we did an autoregression on the log returns, the Shanghai Composite Index as an example, the result is as follows:

Table 4.4 Autoregression of log returns of Shanghai Composite Index

Dependent Variable: R
Method: Least Squares
Date: 04/08/22 Time: 09:40
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.59E-05	0.000278	0.057105	0.9545
R(-6)	-0.062268	0.020410	-3.050891	0.0023

R-squared	0.003878	Mean dependent var	1.56E-05
Adjusted R-squared	0.003461	S.D. dependent var	0.013623
S.E. of regression	0.013599	Akaike info criterion	-5.756743
Sum squared resid	0.442202	Schwarz criterion	-5.751912
Log likelihood	6889.943	Hannan-Quinn criter.	-5.754985
F-statistic	9.307935	Durbin-Watson stat	1.923006
Prob(F-statistic)	0.002307		

Source: Author's Analysis

The results of other indexes can be found in Annex 3.

Then, autocorrelation tests were done on the residuals ε_t and the squared residuals ε_t^2 after fitting the mean equation using the Ljung-Box Q statistic. In that case, the ACF value and PACF value of autocorrelation coefficient of the residual term of the Shanghai Composite Index's log return can be obtained.

Table 4.5 Correlogram of Residuals of Shanghai Composite Index

Date: 04/08/22 Time: 09:43
Sample (adjusted): 8 2400
Q-statistic probabilities adjusted for 1 dynamic regressor

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.038	0.038	3.4713	0.062
		2	-0.025	-0.027	4.9903	0.082
		3	0.031	0.033	7.2297	0.065
		4	0.044	0.041	11.935	0.018
		5	0.004	0.002	11.969	0.035
		6	-0.000	0.001	11.969	0.063
		7	0.053	0.051	18.786	0.009
		8	0.032	0.026	21.205	0.007
		9	0.035	0.036	24.183	0.004
		10	-0.022	-0.026	25.337	0.005
		11	-0.019	-0.021	26.185	0.006
		12	0.008	0.003	26.327	0.010
		13	0.059	0.057	34.732	0.001
		14	-0.062	-0.067	44.020	0.000
		15	0.023	0.030	45.286	0.000
		16	0.033	0.019	47.859	0.000
		17	0.011	0.010	48.146	0.000
		18	0.006	0.012	48.221	0.000
		19	-0.007	-0.008	48.334	0.000
		20	0.061	0.055	57.358	0.000
		21	0.030	0.027	59.506	0.000
		22	-0.015	-0.019	60.065	0.000
		23	-0.076	-0.075	73.998	0.000
		24	-0.030	-0.037	76.160	0.000
		25	0.031	0.024	78.498	0.000
		26	-0.033	-0.033	81.106	0.000
		27	-0.032	-0.019	83.620	0.000
		28	0.059	0.050	92.130	0.000
		29	-0.002	-0.010	92.140	0.000
		30	-0.036	-0.018	95.213	0.000
		31	-0.058	-0.049	103.46	0.000
		32	-0.033	-0.030	106.06	0.000
		33	0.035	0.030	108.96	0.000
		34	0.024	0.029	110.34	0.000
		35	0.014	0.019	110.79	0.000
		36	-0.003	-0.001	110.81	0.000

Source: Author’s Analysis

Further, the autocorrelation coefficient of the squared residuals of the log returns of Shanghai Composite Index was tested.

Table 4.6 Correlogram of Residuals squared of Shanghai Composite Index

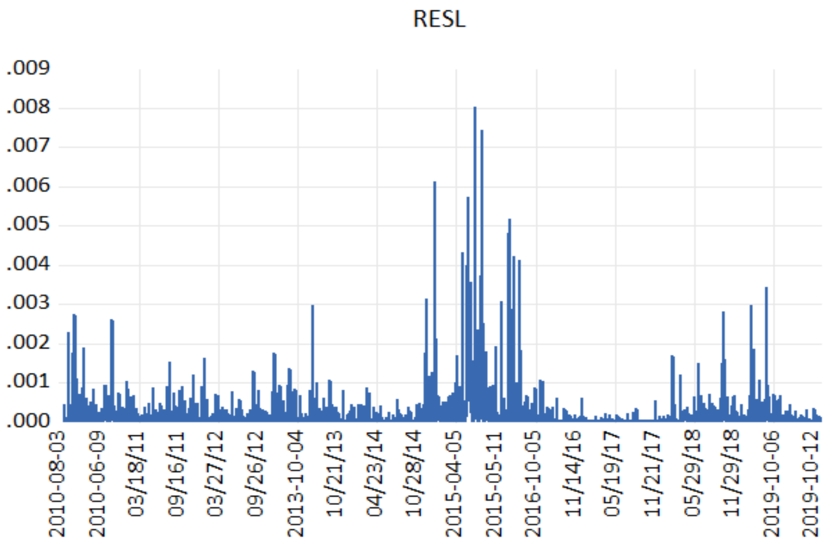
Date: 04/08/22 Time: 09:46
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.202	0.202	97.809	0.000
		2	0.246	0.214	243.03	0.000
		3	0.231	0.163	371.36	0.000
		4	0.209	0.113	475.68	0.000
		5	0.198	0.088	569.37	0.000
		6	0.127	0.002	607.94	0.000
		7	0.153	0.042	663.94	0.000
		8	0.119	0.014	697.78	0.000
		9	0.131	0.038	738.95	0.000
		10	0.163	0.080	802.63	0.000
		11	0.122	0.029	838.70	0.000
		12	0.114	0.010	869.91	0.000
		13	0.188	0.102	954.84	0.000
		14	0.137	0.031	1000.3	0.000
		15	0.113	-0.006	1030.8	0.000
		16	0.190	0.095	1117.9	0.000
		17	0.129	0.013	1157.9	0.000
		18	0.116	-0.009	1190.4	0.000
		19	0.139	0.037	1236.8	0.000
		20	0.192	0.094	1326.0	0.000
		21	0.199	0.093	1421.5	0.000
		22	0.095	-0.038	1443.5	0.000
		23	0.114	-0.033	1475.1	0.000
		24	0.087	-0.038	1493.3	0.000
		25	0.151	0.061	1548.7	0.000
		26	0.099	-0.008	1572.3	0.000
		27	0.113	0.025	1603.3	0.000
		28	0.174	0.102	1676.5	0.000
		29	0.097	-0.024	1699.4	0.000
		30	0.141	0.013	1747.6	0.000
		31	0.093	-0.018	1768.6	0.000
		32	0.141	0.035	1816.6	0.000
		33	0.139	0.032	1863.2	0.000
		34	0.128	0.019	1902.8	0.000
		35	0.133	0.022	1945.6	0.000
		36	0.116	0.008	1978.4	0.000

Source: Author's Analysis

With the comparison of residuals and squared residuals, it is observed that the results show that there is no significant autocorrelation between the residuals of Shanghai Composite Index, while there is a significant autocorrelation between the squared residuals. So there is a new parameter which is the squared residuals to analysis. Hence, the line graph of the squared residuals is shown as following:

Figure 4.27 Line graph of squared residuals of Shanghai Composite Index



Source: Author's Analysis

It can be seen that the fluctuations of ε_t^2 are characterized by time varying and clustering, so it is suitable for modelling with GARCH-type models.

Next step is to do the same autocorrelation of log returns with lags of 6 orders as equation(4.10), and ARCH-LM test is used on the residual term after regression of r_t equation.

Table 4.7 ARCH-LM Test of log returns of Shanghai Composite Index

Heteroskedasticity Test: ARCH

F-statistic	101.7272	Prob. F(1,2390)	0.0000
Obs*R-squared	97.65576	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/08/22 Time: 09:50
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000147	1.11E-05	13.27124	0.0000
RESID^2(-1)	0.202054	0.020033	10.08599	0.0000

R-squared	0.040826	Mean dependent var	0.000185
Adjusted R-squared	0.040425	S.D. dependent var	0.000523
S.E. of regression	0.000512	Akaike info criterion	-12.31583
Sum squared resid	0.000626	Schwarz criterion	-12.31100
Log likelihood	14731.73	Hannan-Quinn criter.	-12.31407
F-statistic	101.7272	Durbin-Watson stat	2.086260
Prob(F-statistic)	0.000000		

Source: Author's Analysis

It is observed that f-test of squared residuals is 101.7272, and the p-value is 0. The results above show that the ARCH effect in the residuals is significant. The same steps have done to the other three stock index: KOSIP Composite Index, FTSE Straits Times Index, JSX Composite Index. And the tables of results can be found in Annex 3.

However, there are some differences between some selected indexes.

Table 4.8 Correlation test of log returns of Hang Seng Index

Date: 04/17/22 Time: 05:59
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.018	0.018	0.7878	0.375
		2	0.008	0.008	0.9592	0.619
		3	0.010	0.010	1.2193	0.748
		4	-0.031	-0.032	3.5957	0.463
		5	-0.004	-0.003	3.6276	0.604
		6	-0.016	-0.016	4.2665	0.641
		7	0.021	0.022	5.2893	0.625
		8	-0.016	-0.018	5.9238	0.656
		9	0.034	0.035	8.7758	0.458
		10	-0.025	-0.028	10.280	0.416
		11	-0.039	-0.037	13.900	0.239
		12	0.014	0.013	14.340	0.280
		13	0.023	0.027	15.667	0.268
		14	-0.005	-0.008	15.720	0.331
		15	-0.034	-0.036	18.588	0.233
		16	0.017	0.016	19.268	0.255
		17	-0.005	-0.002	19.325	0.310
		18	-0.015	-0.015	19.868	0.340
		19	0.001	-0.000	19.869	0.402
		20	0.012	0.014	20.203	0.445
		21	0.003	-0.001	20.222	0.507
		22	-0.042	-0.045	24.515	0.321
		23	-0.034	-0.032	27.297	0.244
		24	-0.027	-0.020	29.064	0.218
		25	0.016	0.015	29.659	0.237
		26	0.026	0.022	31.283	0.218
		27	-0.028	-0.028	33.187	0.191
		28	0.011	0.009	33.502	0.218
		29	-0.012	-0.015	33.875	0.244
		30	-0.006	-0.004	33.960	0.282
		31	-0.005	-0.001	34.032	0.324
		32	0.024	0.024	35.466	0.308
		33	0.022	0.015	36.664	0.303
		34	-0.006	-0.009	36.763	0.342
		35	0.016	0.014	37.374	0.361
		36	-0.028	-0.021	39.312	0.324

Source: Author's Analysis

From Table 4.8, it is observed that the autocorrelation and partial autocorrelation coefficients of the series fall within twice the estimated standard deviation, and the corresponding p-values of the Q-statistics are all greater than the confidence level of 0.05, so the series are not significantly correlated at the 5% significance level. Therefore the mean equation of Hang Seng Index was set to be white noise which can be described as following:

$$r_t = c + \varepsilon_t \tag{4.14}$$

In this case, the de-meaning equation of log returns of Hang Seng Index is got as follows:

$$w = r_t - 0.000123 \tag{4.15}$$

And the similar situation included NIKKEI 225 Index, Thailand Set Index, S&P BSE Sensex Index, the de-meaning equation of log returns of these indexes is shown as following:

NIKKEI 225 Index $$w = r_t - 0.000332 \tag{4.16}$$

Thailand Set Index $$w = r_t - 0.000321 \tag{4.17}$$

S&P BSE Sensex Index $$w = r_t - 0.000363 \tag{4.18}$$

Then the ARCH effect of log returns of Hang Seng Index was detected by testing the squared correlation plot of the residuals. the equation is set as following:

$$z = w^2 \tag{4.19}$$

Table 4.9 Correlation test of squared residuals of Hang Seng Index

Date: 04/18/22 Time: 07:10
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.112	0.112	29.906	0.000
		2	0.144	0.133	79.432	0.000
		3	0.173	0.148	151.04	0.000
		4	0.102	0.058	175.92	0.000
		5	0.107	0.056	203.27	0.000
		6	0.134	0.083	246.23	0.000
		7	0.119	0.067	280.17	0.000
		8	0.129	0.071	320.19	0.000
		9	0.104	0.036	346.04	0.000
		10	0.123	0.058	382.78	0.000
		11	0.090	0.020	402.21	0.000
		12	0.106	0.039	429.30	0.000
		13	0.143	0.078	478.84	0.000
		14	0.068	-0.005	490.12	0.000
		15	0.138	0.067	536.04	0.000
		16	0.086	0.006	553.82	0.000
		17	0.059	-0.013	562.19	0.000
		18	0.071	-0.006	574.25	0.000
		19	0.072	0.007	586.94	0.000
		20	0.145	0.092	637.90	0.000
		21	0.069	-0.003	649.57	0.000
		22	0.038	-0.038	653.03	0.000
		23	0.082	0.007	669.21	0.000
		24	0.115	0.069	701.37	0.000
		25	0.107	0.053	729.27	0.000
		26	0.079	0.003	744.43	0.000
		27	0.085	0.012	762.03	0.000
		28	0.068	-0.010	773.17	0.000
		29	0.056	-0.002	780.69	0.000
		30	0.093	0.032	801.72	0.000
		31	0.114	0.059	833.26	0.000
		32	0.084	0.021	850.61	0.000
		33	0.136	0.059	895.47	0.000
		34	0.070	-0.004	907.50	0.000
		35	0.052	-0.029	914.20	0.000
		36	0.110	0.041	943.75	0.000

Source: Author's Analysis

According to Table 4.9, it is observed that the series of squared residuals of Hang Seng Index has a significant autocorrelation which means there is ARCH effects. And the same results can be tested by ARCH-LM test which is shown below.

Table 4.10 ARCH-LM Test of log returns of Hang Seng Index

Heteroskedasticity Test: ARCH

F-statistic	30.21236	Prob. F(1,2396)	0.0000
Obs*R-squared	29.86105	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 05:42
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000114	6.06E-06	18.83770	0.0000
RESID^2(-1)	0.111591	0.020302	5.496577	0.0000

R-squared	0.012452	Mean dependent var	0.000129
Adjusted R-squared	0.012040	S.D. dependent var	0.000270
S.E. of regression	0.000268	Akaike info criterion	-13.61073
Sum squared resid	0.000172	Schwarz criterion	-13.60590
Log likelihood	16321.26	Hannan-Quinn criter.	-13.60897
F-statistic	30.21236	Durbin-Watson stat	2.029568
Prob(F-statistic)	0.000000		

Source: Author's Analysis

The results of other three indexes can be found in Annex3.

4.3 Modelling by GARCH-like models

By analyzing the log-return data, there is significant heteroskedasticity in the return series, it should be considered for the ARCH/GARCH model. Since the GARCH model has superior properties to ARCH model, for example, it requires smaller lag orders than the ARCH model and has a similar ARMA model, the GARCH model is directly built in our cases.

Building a GARCH model usually involves three steps, the first is to estimate a best-fitting autoregressive model. The second is to compute autocorrelations of the error term. The third step is to test for significance.

The mean equation of selected indexes can be used as equation (4.10), (4.11), (4.12), (4.13). and the de-meaning equation can be used as equation (4.15), (4.16), (4.17), (4.18).

And the conditional variance equation can be described as following:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 \quad (4.20)$$

where ω is the constant term and $\sum_{i=1}^{q} \alpha_i + \sum_{i=1}^{p} \beta_i < 1$, while α_i, β_i is the coefficient of residuals and variance of previous day.

4.3.1 GARCH (p, q) model estimation

In this subchapter, the statistic software Eviews (Econometrics Views) was used to build the GARCH model of returns of Shanghai Composite Index, firstly by using GARCH (1,1), GARCH (1,2), GARCH (2,1) to model. there added the mean equation of log returns(equation 4.10) into the model.

Table 4.11 Results of GARCH(1:1) model on Shanghai Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/08/22 Time: 11:19
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments
Convergence achieved after 37 iterations
Coefficient covariance computed using outer product of gradients
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.
C	9.54E-05	0.000199	0.479160	0.6318
R(-6)	-0.036011	0.021182	-1.700065	0.0891
Variance Equation				
C	6.35E-07	1.44E-07	4.418419	0.0000
RESID(-1)^2	0.049769	0.003972	12.53028	0.0000
GARCH(-1)	0.947831	0.003648	259.8347	0.0000

R-squared	0.003154	Mean dependent var	1.56E-05
Adjusted R-squared	0.002737	S.D. dependent var	0.013623
S.E. of regression	0.013604	Akaike info criterion	-6.066014
Sum squared resid	0.442523	Schwarz criterion	-6.053937
Log likelihood	7262.986	Hannan-Quinn criter.	-6.061620
Durbin-Watson stat	1.925788		

Source: Author’s Analysis

Table 4.12 Results of GARCH(1:2) model on Shanghai Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/18/22 Time: 23:23
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments
Convergence achieved after 48 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1) + C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000112	0.000199	0.563820	0.5729
R(-6)	-0.035628	0.021341	-1.669447	0.0950
Variance Equation				
C	4.28E-07	1.66E-07	2.573151	0.0101
RESID(-1)^2	0.032674	0.010769	3.033948	0.0024
GARCH(-1)	1.343180	0.230229	5.834105	0.0000
GARCH(-2)	-0.377409	0.219083	-1.722677	0.0849

R-squared	0.003118	Mean dependent var	1.56E-05
Adjusted R-squared	0.002701	S.D. dependent var	0.013623
S.E. of regression	0.013605	Akaike info criterion	-6.065941
Sum squared resid	0.442539	Schwarz criterion	-6.051448
Log likelihood	7263.898	Hannan-Quinn criter.	-6.060667
Durbin-Watson stat	1.925799		

Source: Author’s Analysis

Table 4.13 Results of GARCH(2:1) model on Shanghai Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/18/22 Time: 23:25
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments
Convergence achieved after 41 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-2)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000144	0.000197	0.729162	0.4659
R(-6)	-0.036724	0.021393	-1.716654	0.0860
Variance Equation				
C	7.47E-07	1.61E-07	4.635393	0.0000
RESID(-1)^2	0.006953	0.012045	0.577211	0.5638
RESID(-2)^2	0.047905	0.012979	3.690921	0.0002
GARCH(-1)	0.942320	0.004019	234.4536	0.0000

R-squared	0.003137	Mean dependent var	1.56E-05
Adjusted R-squared	0.002720	S.D. dependent var	0.013623
S.E. of regression	0.013604	Akaike info criterion	-6.066957
Sum squared resid	0.442531	Schwarz criterion	-6.052464
Log likelihood	7265.114	Hannan-Quinn criter.	-6.061684
Durbin-Watson stat	1.925605		

Source: Author’s Analysis

Based on the comparison of the above three models, all coefficients of GARCH (1,1) passed the t-test with the best results. According to GARCH(1:1), the ARCH term and GARCH term in the conditional variance equation of return of Shanghai Composite Index are both highly significant, which indicates that the return series has significant volatility clustering. The sum of the coefficients of the ARCH and GARCH terms is 0.99 which is less than 1. Therefore, the GARCH(1,1) process is smooth and its conditional variance exhibits mean-reversion, which means the effect of past fluctuations on the future is gradually decaying.

Table 4.14 results of selecting GARCH model for other indexes

		SHCI	HIS	NIKKEI 225	KOSPI
	AIC	-6.066014	-6.231635	-6.013201	-6.728002
	SC	-6.053937	-6.224404	-6.005970	-6.715940
GARCH (1,1)	HQC	-6.061620	-6.229004	-6.010571	-6.723626
	Significance of coefficients	√	√	√	√
	AIC	-6.065941	-6.232518	-6.012372	-6.728137
	SC	-6.051448	-6.222876	-6.002730	-6.713639
GARCH (1,2)	HQC	-6.060667	-6.229010	-6.008864	-6.722862
	Significance of coefficients	*	√	*	√
	AIC	-6.066957	-6.234898	-6.012378	-6.728301
	SC	-6.052464	-6.225256	-6.002736	-6.713803
GARCH (2,1)	HQC	-6.061684	-6.23139	-6.008870	-6.723026
	Significance of coefficients	*	*	*	*
		FTSE	THA	JSX	S&P
	AIC	-7.071119	-6.751341	-6.524593	-6.567194
	SC	-7.059046	-6.744109	-6.512528	-6.559963
GARCH (1,1)	HQC	-7.066727	-6.74871	-6.520204	-6.564564
	Significance of coefficients	√	√	√	√
	AIC	-7.071890	-6.750536	-6.524389	-6.568163
	SC	-7.057402	-6.740894	-6.509911	-6.558521
GARCH (1,2)	HQC	-7.066619	-6.747028	-6.519121	-6.564655
	Significance of coefficients	√	*	*	√
	AIC	-7.071761	-6.750608	-6.524398	-6.568048
	SC	-7.057273	-6.740966	-6.509920	-6.558406
GARCH (2,1)	HQC	-7.066489	-6.747100	-6.519130	-6.56454
	Significance of coefficients	√	*	*	*

Source: Author's Analysis

Notes: "√" means all the coefficients are acceptable at 5% significant level. "" means there is one coefficient which is not significant at 5% % significant level.*

To choose a specification that indicates the best statistical properties, AIC (Akaike information criterion), SC (Schwarz criterion) and HQC (Hannah-Quinn criterion) information criteria were calculated for all models that were estimated. And in this thesis, which should be chose is the lowest value of information criteria for the best model. The significance of each coefficient are also considered about. The specific calculation procedure of other indexes can be found in Annex 4.

In this way, using Shanghai Composite Index as an example, the results of our models can be shown as following:

Shanghai Composite Index :

$$r_t = 9.536436\text{e} - 05 \ - 0.0360108124611 \cdot r_{t-6} + \varepsilon_t \quad (4.21)$$

$$\sigma_t^2 = 6.346184\text{e} - 07 + 0.04976945 \cdot \varepsilon_{t-i}^2 + 0.9478306 \cdot \sigma_{t-i}^2 \quad (4.22)$$

4.3.2 GARCH-M model estimation

Then we used GARCH-M model to analysis. The GARCH-in-mean (GARCH-M) model adds a heteroskedasticity term into the mean equation.

And the variance were added in the ARCH-M term in Eviews to get the results of GARCH-M model. The results is shown following.

Table 4.15 Results of GARCH-M model of Shanghai Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/08/22 Time: 12:09
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments
Convergence achieved after 56 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	-1.442815	2.294248	-0.628884	0.5294
C	0.000246	0.000316	0.777946	0.4366
R(-6)	-0.036634	0.021164	-1.730943	0.0835
Variance Equation				
C	6.36E-07	1.51E-07	4.214101	0.0000
RESID(-1)^2	0.049622	0.003982	12.46210	0.0000
GARCH(-1)	0.947923	0.003645	260.0852	0.0000

R-squared	0.003892	Mean dependent var	1.56E-05
Adjusted R-squared	0.003058	S.D. dependent var	0.013623
S.E. of regression	0.013602	Akaike info criterion	-6.065379
Sum squared resid	0.442196	Schwarz criterion	-6.050886
Log likelihood	7263.226	Hannan-Quinn criter.	-6.060106
Durbin-Watson stat	1.928760		

Source: Author’s Analysis

The results shows that the coefficient estimates of the conditional variance term GARCH in the mean equation is -1.4428, and the p-value is 0.5294 which means the Shanghai Composite Index doesn't have significant GARCH-M effect.

Table 4.16 Results of GARCH-M model of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 09:47
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 25 iterations
Coefficient covariance computed using outer product of gradients
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.
GARCH	3.405773	1.422308	2.394539	0.0166
Variance Equation				
C	7.05E-06	1.04E-06	6.775797	0.0000
RESID(-1)^2	0.133492	0.010472	12.74801	0.0000
GARCH(-1)	0.830473	0.013223	62.80283	0.0000

R-squared	0.000506	Mean dependent var	1.75E-07
Adjusted R-squared	0.000506	S.D. dependent var	0.013104
S.E. of regression	0.013101	Akaike info criterion	-6.014666
Sum squared resid	0.411558	Schwarz criterion	-6.005024
Log likelihood	7218.592	Hannan-Quinn criter.	-6.011158
Durbin-Watson stat	2.072194		

Source: Author's Analysis

From table 4.16, it is observed that the coefficient of conditional variance (GARCH) is 3.405773 and it is significant at 5% significant level, which reflects a positive correlation between returns and risk, indicating that returns have a positive risk premium on NIKKEI 225 Index. And the error of this GARCH-M model is normally distributed, then we test for the Student's t distribution and Generalized error distribution (GED).

Table 4.17 GARCH-M model of Student's t distribution of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Student's t distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 17:06
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 34 iterations
Coefficient covariance computed using outer product of gradients
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.
GARCH	4.652328	1.404140	3.313294	0.0009
		Variance Equation		
C	6.10E-06	1.54E-06	3.961475	0.0001
RESID(-1)^2	0.124279	0.017791	6.985442	0.0000
GARCH(-1)	0.846327	0.020703	40.87953	0.0000
T-DIST. DOF	5.814244	0.706607	8.228394	0.0000

R-squared	-0.001390	Mean dependent var	1.75E-07
Adjusted R-squared	-0.001390	S.D. dependent var	0.013104
S.E. of regression	0.013113	Akaike info criterion	-6.067787
Sum squared resid	0.412338	Schwarz criterion	-6.055735
Log likelihood	7283.311	Hannan-Quinn criter.	-6.063402
Durbin-Watson stat	2.064449		

Source: Author's Analysis

Table 4.18 GARCH-M model of GED of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Generalized error distribution (GED) (BFGS / Marquardt steps)
Date: 04/19/22 Time: 17:07
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
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.
GARCH	4.027142	1.354444	2.973280	0.0029
		Variance Equation		
C	6.28E-06	1.58E-06	3.971836	0.0001
RESID(-1)^2	0.126893	0.017217	7.370136	0.0000
GARCH(-1)	0.840638	0.021053	39.92908	0.0000
GED PARAMETER	1.294194	0.045497	28.44577	0.0000

R-squared	-0.000260	Mean dependent var	1.75E-07
Adjusted R-squared	-0.000260	S.D. dependent var	0.013104
S.E. of regression	0.013106	Akaike info criterion	-6.068363
Sum squared resid	0.411873	Schwarz criterion	-6.056311
Log likelihood	7284.002	Hannan-Quinn criter.	-6.063979
Durbin-Watson stat	2.068899		

Source: Author's Analysis

Under all three distributional assumptions, the GARCH term in the mean equation is significant, indicating that the expected return in the securities market is proportional to the risk, which means the greater the risk, the greater the expected return.

The results of other indexes can be found in Annex 5.

4.3.3 E-GARCH model estimation

In this subchapter, we used E-GARCH (Exponential General Autoregressive Conditional Heteroskedastic) to portraying the leverage effect of volatility. Because EGARCH model relaxes the non-negative restrictions on parameters in the traditional GARCH model. According to estimation of different lags, we found that the results of E-GARCH (2,2) model for Shanghai Composite Index was the best. And for other indexes, E-GARCH (1,1) model were generally good.

Table 4.19 Results of E-GARCH (2,2) model of Shanghai Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 04:41
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments
Convergence achieved after 54 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1)) + C(8)*LOG(GARCH(-2))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000110	0.000192	0.572760	0.5668
R(-6)	-0.035109	0.020376	-1.723073	0.0849
Variance Equation				
C(3)	-0.265275	0.027972	-9.483670	0.0000
C(4)	0.135271	0.011655	11.60673	0.0000
C(5)	0.102315	0.015798	6.476547	0.0000
C(6)	-0.014283	0.007003	-2.039521	0.0414
C(7)	0.044571	0.041649	1.070158	0.2845
C(8)	0.945219	0.041037	23.03321	0.0000

R-squared	0.003092	Mean dependent var	1.56E-05
Adjusted R-squared	0.002675	S.D. dependent var	0.013623
S.E. of regression	0.013605	Akaike info criterion	-6.068113
Sum squared resid	0.442551	Schwarz criterion	-6.048789
Log likelihood	7268.497	Hannan-Quinn criter.	-6.061082
Durbin-Watson stat	1.925859		

Source: Author's Analysis

According to the results above, the coefficient C(6) is -0.014283, and the p-value is 0.0414 which means the leverage effect of Shanghai Composite Index is significant. And it shown large unanticipated downward shocks increase the variance which means the volatility caused by bad news in the stock market is greater than that caused by good news on Shanghai Composite Index.

Table 4.20 Results of E-GARCH (1,1) model of Hang Seng Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 04:38
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 48 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)
*RESID(-1)/@SQRT(GARCH(-1)) + C(4)*LOG(GARCH(-1))

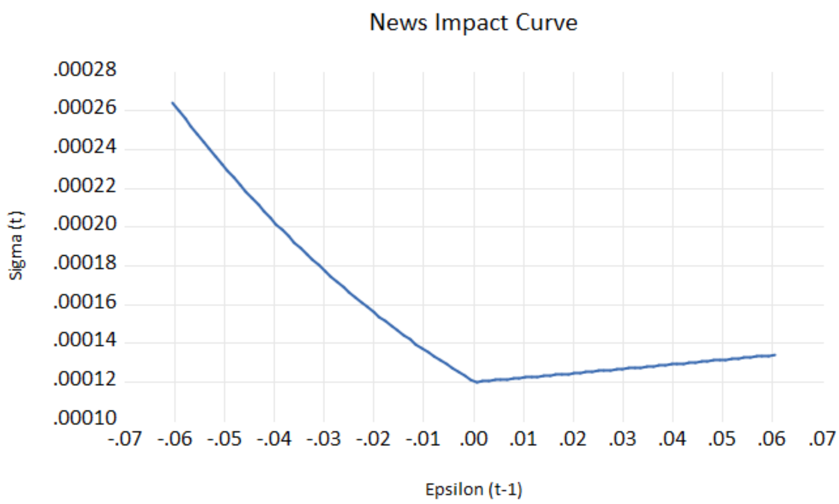
Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	-0.310033	0.040370	-7.679760	0.0000
C(2)	0.084465	0.010424	8.102805	0.0000
C(3)	-0.063938	0.007167	-8.920891	0.0000
C(4)	0.972951	0.004063	239.4461	0.0000

R-squared	-0.000000	Mean dependent var	-1.30E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.011338
S.E. of regression	0.011335	Akaike info criterion	-6.248325
Sum squared resid	0.308251	Schwarz criterion	-6.238683
Log likelihood	7498.866	Hannan-Quinn criter.	-6.244817
Durbin-Watson stat	1.963734		

Source: Author's Analysis

Based on the results of table 4.18, the value of coefficient C (3) is -0.063938 and it is highly significant at 5% significant level, which describes that the logarithmic returns of Hang Seng Index has effect of leverage and asymmetry. It means the decreasing of stock returns has higher impact to the volatility than the increasing of stock returns. The results can also be explained by the news impact curve.

Graph 4.1 News Impact Curve of Hang Seng Index



Source: Author's Analysis

This curve is steeper when the information shock is less than 0, which represents a negative shock, and more flatter, which indicates that negative shocks make the change in volatility greater.

The similar results can be found in Annex 6.

4.4 Empirical Results

According to the estimation model we used above, we can get the parameters of each model, so we can get the mean equation and variance equation of each model. In the prediction of GARCH models, for all selected stock price indexes, it is observed that the significant coefficients in the conditional variance equation indicate that the return series has significant volatility clustering and the sum of the ARCH and GARCH terms coefficients are less than 1. Therefore the GARCH(1,1) process is stationary.

As for GARCH-m models, the process are also stationary for all the selected stock price indexes except Shanghai Composite Index, since the value of coefficient term of conditional variance is -1.442815, which is negative and the p-value shows it is not significant at 5% significant level. On the other hand, the positive value of coefficients and significant at 5% significant level are considered as good GARCH-M effect, which means that there are positive risk premium in the stock price indexes.

All the negative value of coefficients of asymmetry term shows that the variance series of all the stock price indexes have the negative asymmetry and leverage effect on the prices of indexes. In other words, the volatilities of the indexes will be higher when the prices of indexes is falling down than when the index price is rising at the same level.

The results are shown as following Table 4.21 and Table 4.22.

Table 4.21 Parameter estimates for selected models

		SHCI	HIS	NIKKEI 225	KOSPI
GARCH	Mean Equation				
	θ_0	9.54E-05	White Noise	White Noise	0.000273
	θ_1	-0.036011			0.015533
	Variance Equation				
	ω	6.35E-07	2.09E-06	6.92E-06	2.14E-06
	α	0.049769	0.045525	0.130433	0.069442
	β	0.947831	0.937395	0.833850	0.902035
	α+β	0.997600	0.982920	0.964283	0.971477
GARCH-M	Mean Equation				
	c	0.000246			-0.000220
	a	-1.442815	2.422366	3.405773	7.823791
	Variance Equation				
	α_0	6.36E-07	2.14E-06	7.05E-06	2.18E-06
	α	0.049622	0.046203	0.133492	0.070362
	β	0.947923	0.936381	0.830473	0.900708
	α+β	0.997545	0.982584	0.963965	0.97107
E-GARCH	Mean Equation				
	c	0.000110	White Noise	White Noise	4.94E-05
	a	-0.035109			0.019116
	Variance Equation				
	ω	-0.265275	-0.310033	-0.686522	-0.333785
	α_1	0.135271	0.084465	0.220496	0.097319
	α_2	0.102315			
	β_1	0.044571	0.972951	0.941448	0.972942
	β_2	0.945219			
	γ	-0.014283	-0.063938	-0.118588	-0.093475

Source: Author’s Analysis

Table 4.22 Parameter estimates for selected models

		FTSE	THA	JSX	S&P
GARCH	Mean Equation				
	θ_0	0.000199	White Noise	0.00055	White Noise
	θ_1	0.040575		-0.089708	
	Variance Equation				
	ω	8.88E-07	9.05E-07	2.63E-06	1.37E-06
	α	0.064683	0.105771	0.100928	0.057702
	β	0.919727	0.889269	0.875872	0.927675
	$\alpha+\beta$	0.984410	0.995040	0.976800	0.985377
GARCH-M	Mean Equation				
	c	6.88E-06		0.000172	
	a	4.361353	4.284031	5.206469	3.727635
	Variance Equation				
	α_0	8.92E-07	9.34E-07	2.76E-06	1.42E-06
	α	0.064901	0.107431	0.103968	0.059726
	β	0.919435	0.887432	0.871707	0.925203
	$\alpha+\beta$	0.984336	0.994863	0.975675	0.984929
E-GARCH	Mean Equation				
	c	1.64E-05	White Noise	0.000372	White Noise
	a	0.037674		-0.078305	
	Variance Equation				
	ω	-0.223777	-0.373823	-0.391328	-0.344223
	α_1	0.079741	0.172764	0.164205	0.103427
	α_2				
	β_1	0.983677	0.974882	0.971556	0.972071
	β_2				
	γ	-0.069885	-0.084685	-0.074479	-0.095288

Source: Author’s Analysis

5 Conclusion

The prediction of volatility can be applied to portfolio selection, option pricing, risk management and volatility-based trading strategies. Nowadays, the GARCH model family is widely used to simulate and predict the volatility of financial assets. Another commonly used model is the simple time series models, such as Exponentially Weighted Moving Average (EWMA) models

In Chapter 2, the basic principles of financial markets are divided into two parts: the first part is the classification of financial markets which consist of stock markets, bond markets, money markets, derivatives markets and commodity markets. In addition, the introduction of 8 selected stock price indexes are presented in the second part.

In Chapter 3, several models are defined detailly. It is concerns that EWMA model is a simple extension to the standard weighting scheme which assigns equal weight to every point in time for the calculation of the volatility, by assigning more weight to the most recent observations using an exponential scheme. The ARCH model is the model appropriated when the error variance in a time series follows an autoregressive (AR) mode. Then the GARCH-like models are a series of models including GARCH (p,q) model, GARCH-M model, and E-GARCH model.

In Chapter 4 which is the most important part of the thesis, presenting the steps and final results of selected models. From the analysis of EWMA model, the volatility of 8 stock indexes can be calculated by using the constant coefficient of historical volatility which from the daily stock prices. Then the daily returns of each stock index are then calculated by the log-difference method, followed by descriptive statistics and unit root tests to derive the distribution of the log-return series of stock indices as spike-fat-tailed while the series are stationary.

The mean equation of the model is then obtained by an autocorrelation test on the log returns of each index. However, there are four stock indexes However, four stock indices are correlated at a particular lag order and the other four are not significantly correlated, hence the mean equation is also divided into a lag order equation and a white noise equation.

By using GARCH-like models, a comprehensive analysis of the volatility of Shanghai and Shenzhen stock market returns, the asymmetry of volatility, and the leverage effect of volatility is done. Through the analysis, the following conclusions can be basically drawn.

First, there is a significant GARCH effect for each stock market return.

Second, there is a significant GARCH-M effect for all stock price indices except the Shanghai Composite Index, and the KOSPI Composite Index has the highest positive risk premium, reflecting that investors in the KOSPI Composite Index are more averse to the risk of falling stock prices than investors in other regions .

Third, there is a significant leverage effect for all stock price indices, reflecting the fact that volatility caused by bad news is greater than volatility caused by good news in the stock market, which means that volatility is higher when stock prices are falling than when stock prices are rising.

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List of Abbreviations

SHCI	Shanghai Composite Index
HSI	Hang Seng Index
NIKKEI 225	NIKKEI 225 Index
KOSPI	KOSPI Composite index
FTSE	FTSE Straits Times Index
THA	Thailand SET Index
JSX	JSX Composite Index
S&P	BSE Sensex Index
ADF	Augmented Dickey Fuller Test
EWMA	Exponentially Weighted Moving Average
ARCH	Autoregressive conditional heteroskedasticity
GARCH	Generalized autoregressive conditional heteroskedasticity
GARCH-M	Generalized autoregressive conditional heteroskedasticity in mean
E-GARCH	Exponential general autoregressive conditional heteroskedasticity
AIC	Akaike information criterion
SC	Schwarz criterion
HQC	Hannah-Quinn criterion

List of Annexes

Annex 1

Logarithmic returns of 8 stock price indexes

Time Series	SHCI	HSI	NIKKEI 225	KOSPI	FTSE	THA	JSX	S&P
1	0.520%	-0.261%	1.535%	-0.462%	-0.463%	2.336%	0.236%	-0.988%
2	-0.661%	-0.986%	-0.090%	-0.143%	-0.044%	1.758%	-0.375%	-1.442%
3	0.077%	1.600%	1.002%	0.870%	-0.820%	-0.855%	0.116%	-0.287%
4	-1.249%	-1.518%	-0.065%	-0.151%	0.141%	2.031%	3.194%	-0.589%
5	-1.218%	-1.480%	1.383%	-0.898%	0.641%	-0.303%	-0.692%	-1.294%
6	0.533%	-0.817%	0.370%	-0.317%	-1.391%	1.316%	0.209%	3.293%
7	1.908%	1.574%	0.470%	0.757%	0.182%	0.518%	-1.490%	-1.097%
8	-0.144%	-1.418%	-0.504%	-1.175%	-0.536%	-0.275%	0.681%	0.316%
9	0.709%	-0.232%	0.093%	-0.143%	0.842%	-0.706%	1.965%	0.407%
10	0.222%	-2.120%	-1.110%	-2.000%	-0.006%	-0.962%	0.872%	-1.584%
11	-0.700%	-0.960%	0.323%	-2.233%	0.840%	2.231%	0.496%	-0.940%
12	0.120%	-1.064%	0.424%	1.812%	-0.244%	-0.104%	-0.653%	0.238%
13	-1.239%	2.510%	-0.809%	-0.441%	1.255%	1.679%	0.125%	-2.808%
14	1.334%	-1.381%	0.391%	-0.433%	0.689%	-0.021%	-0.752%	0.675%
15	2.073%	0.327%	0.613%	1.879%	0.279%	0.870%	1.880%	-0.449%
16	0.149%	1.033%	-1.534%	0.062%	0.115%	0.553%	2.003%	0.145%
17	-0.621%	-1.366%	-1.757%	-2.636%	0.820%	-3.596%	-0.218%	-2.752%
…	…	…	…	…	…	…	…	…
2390	0.332%	-0.459%	-0.200%	-0.297%	0.012%	0.103%	-0.471%	0.127%
2391	1.144%	1.247%	0.596%	-1.029%	0.901%	1.006%	-0.254%	0.773%
2392	-0.046%	-0.323%	-0.365%	0.059%	-0.406%	-0.053%	0.633%	-0.390%
2393	-0.012%	-0.795%	-0.763%	-0.988%	-0.618%	-1.674%	-1.050%	-1.919%
2394	0.691%	0.339%	-1.928%	0.945%	0.897%	1.061%	0.350%	0.473%
2395	-1.229%	-0.830%	1.586%	-1.120%	-0.061%	-1.651%	-0.858%	-0.127%
2396	0.909%	1.670%	-1.586%	1.620%	0.049%	1.298%	0.781%	1.543%
2397	-0.084%	0.270%	2.280%	0.908%	0.260%	0.063%	0.007%	0.355%
2398	0.750%	1.100%	0.465%	1.031%	-0.150%	0.349%	0.344%	0.623%
2399	-0.281%	-0.241%	0.729%	0.431%	0.597%	0.047%	0.457%	0.222%

Annex 2 ADF test of indexes

ADF test of log returns of Hang Seng Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-48.07042	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 05:58
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-0.981889	0.020426	-48.07042	0.0000
C	0.000122	0.000232	0.525757	0.5991

R-squared	0.490945	Mean dependent var	8.04E-08
Adjusted R-squared	0.490733	S.D. dependent var	0.015891
S.E. of regression	0.011341	Akaike info criterion	-6.120038
Sum squared resid	0.308143	Schwarz criterion	-6.115215
Log likelihood	7339.925	Hannan-Quinn criter.	-6.118283
F-statistic	2310.765	Durbin-Watson stat	2.000126
Prob(F-statistic)	0.000000		

ADF test of log returns of NIKKEI 225 Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-51.03167	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 06:20
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-1.041429	0.020408	-51.03167	0.0000
C	0.000340	0.000267	1.269422	0.2044

R-squared	0.520822	Mean dependent var	-3.36E-06
Adjusted R-squared	0.520622	S.D. dependent var	0.018913
S.E. of regression	0.013095	Akaike info criterion	-5.832413
Sum squared resid	0.410833	Schwarz criterion	-5.827590
Log likelihood	6995.063	Hannan-Quinn criter.	-5.830658
F-statistic	2604.231	Durbin-Watson stat	1.998302
Prob(F-statistic)	0.000000		

ADF test of log returns of KOSPI Composite Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-47.67423	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 06:23
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-0.973608	0.020422	-47.67423	0.0000
C	0.000103	0.000189	0.541994	0.5879

R-squared	0.486810	Mean dependent var	3.72E-06
Adjusted R-squared	0.486595	S.D. dependent var	0.012932
S.E. of regression	0.009266	Akaike info criterion	-6.524122
Sum squared resid	0.205712	Schwarz criterion	-6.519300
Log likelihood	7824.423	Hannan-Quinn criter.	-6.522368
F-statistic	2272.833	Durbin-Watson stat	1.999773
Prob(F-statistic)	0.000000		

ADF test of log returns of FTSE Straits Times Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-46.46171	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 06:24
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-0.947945	0.020403	-46.46171	0.0000
C	5.16E-05	0.000156	0.330476	0.7411

R-squared	0.473949	Mean dependent var	4.42E-06
Adjusted R-squared	0.473729	S.D. dependent var	0.010531
S.E. of regression	0.007640	Akaike info criterion	-6.910121
Sum squared resid	0.139837	Schwarz criterion	-6.905299
Log likelihood	8287.235	Hannan-Quinn criter.	-6.908367
F-statistic	2158.691	Durbin-Watson stat	1.999898
Prob(F-statistic)	0.000000		

ADF test of log returns of Thailand SET Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-47.12996	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 06:25
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-0.960925	0.020389	-47.12996	0.0000
C	0.000299	0.000194	1.538848	0.1240

R-squared	0.481074	Mean dependent var	-9.55E-06
Adjusted R-squared	0.480858	S.D. dependent var	0.013188
S.E. of regression	0.009502	Akaike info criterion	-6.473723
Sum squared resid	0.216346	Schwarz criterion	-6.468900
Log likelihood	7763.994	Hannan-Quinn criter.	-6.471968
F-statistic	2221.233	Durbin-Watson stat	2.002615
Prob(F-statistic)	0.000000		

ADF test of log returns of JSX Composite Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-31.67864	0.0000
Test critical values:	1% level	-3.432884	
	5% level	-2.862546	
	10% level	-2.567351	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 06:28
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-1.087186	0.034319	-31.67864	0.0000
D(R(-1))	0.124820	0.028151	4.433958	0.0000
D(R(-2))	0.123248	0.020291	6.074071	0.0000
C	0.000391	0.000212	1.845213	0.0651

R-squared	0.488805	Mean dependent var	1.42E-06
Adjusted R-squared	0.488164	S.D. dependent var	0.014475
S.E. of regression	0.010356	Akaike info criterion	-6.300819
Sum squared resid	0.256538	Schwarz criterion	-6.291167
Log likelihood	7552.381	Hannan-Quinn criter.	-6.297307
F-statistic	762.4099	Durbin-Watson stat	2.009147
Prob(F-statistic)	0.000000		

ADF test of log returns of S&P BSE Sensex Index

Null Hypothesis: R has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-45.96806	0.0001
Test critical values:	1% level	-3.432882	
	5% level	-2.862545	
	10% level	-2.567350	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(R)
Method: Least Squares
Date: 04/17/22 Time: 06:29
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R(-1)	-0.937019	0.020384	-45.96806	0.0000
C	0.000345	0.000195	1.770722	0.0767

R-squared	0.468626	Mean dependent var	5.05E-06
Adjusted R-squared	0.468404	S.D. dependent var	0.013058
S.E. of regression	0.009521	Akaike info criterion	-6.469843
Sum squared resid	0.217187	Schwarz criterion	-6.465020
Log likelihood	7759.341	Hannan-Quinn criter.	-6.468088
F-statistic	2113.062	Durbin-Watson stat	2.000046
Prob(F-statistic)	0.000000		

Annex 3 Autocorrelation and ARCH model of indexes

Autoregression of log returns of KOSPI Composite Index

Dependent Variable: R
Method: Least Squares
Date: 04/19/22 Time: 05:23
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000101	0.000189	0.530805	0.5956
R(-7)	0.048598	0.020457	2.375620	0.0176

R-squared	0.002356	Mean dependent var	0.000105
Adjusted R-squared	0.001938	S.D. dependent var	0.009274
S.E. of regression	0.009265	Akaike info criterion	-6.524382
Sum squared resid	0.205143	Schwarz criterion	-6.519549
Log likelihood	7805.161	Hannan-Quinn criter.	-6.522623
F-statistic	5.643571	Durbin-Watson stat	1.940542
Prob(F-statistic)	0.017598		

Autoregression of log returns of FTSE Straits Times Index

Dependent Variable: R
Method: Least Squares
Date: 04/19/22 Time: 05:28
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.24E-05	0.000156	0.335110	0.7376
R(-5)	0.044674	0.020420	2.187782	0.0288

R-squared	0.001997	Mean dependent var	5.46E-05
Adjusted R-squared	0.001580	S.D. dependent var	0.007652
S.E. of regression	0.007646	Akaike info criterion	-6.908524
Sum squared resid	0.139827	Schwarz criterion	-6.903695
Log likelihood	8271.504	Hannan-Quinn criter.	-6.906767
F-statistic	4.786392	Durbin-Watson stat	1.890004
Prob(F-statistic)	0.028782		

Autoregression of log returns of JSX Composite Index

Dependent Variable: R
Method: Least Squares
Date: 04/19/22 Time: 05:29
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000404	0.000212	1.908169	0.0565
R(-3)	-0.123489	0.020282	-6.088669	0.0000

R-squared	0.015249	Mean dependent var	0.000360
Adjusted R-squared	0.014838	S.D. dependent var	0.010437
S.E. of regression	0.010359	Akaike info criterion	-6.301051
Sum squared resid	0.256907	Schwarz criterion	-6.296225
Log likelihood	7550.659	Hannan-Quinn criter.	-6.299295
F-statistic	37.07189	Durbin-Watson stat	1.933965
Prob(F-statistic)	0.000000		

Correlogram of residuals of KOSPI Composite Index

Date: 04/19/22 Time: 06:11
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.029	0.029	2.0640	0.151
		2	-0.001	-0.002	2.0686	0.355
		3	-0.003	-0.003	2.0861	0.555
		4	-0.050	-0.050	8.1866	0.085
		5	-0.028	-0.025	10.111	0.072
		6	-0.046	-0.045	15.183	0.019
		7	0.003	0.005	15.198	0.034
		8	-0.004	-0.007	15.239	0.055
		9	0.001	-0.001	15.242	0.084
		10	0.005	0.000	15.310	0.121
		11	0.029	0.027	17.323	0.099
		12	0.042	0.038	21.557	0.043
		13	-0.046	-0.048	26.636	0.014
		14	-0.023	-0.021	27.914	0.015
		15	-0.002	0.002	27.927	0.022
		16	-0.019	-0.014	28.791	0.025
		17	-0.011	-0.011	29.101	0.034
		18	0.003	0.003	29.129	0.047
		19	0.019	0.013	29.964	0.052
		20	-0.014	-0.018	30.439	0.063
		21	-0.028	-0.030	32.376	0.054
		22	-0.033	-0.035	35.053	0.038
		23	0.024	0.025	36.430	0.037
		24	-0.031	-0.032	38.689	0.029
		25	-0.027	-0.023	40.477	0.026
		26	-0.038	-0.044	44.008	0.015
		27	0.013	0.013	44.447	0.019
		28	0.012	0.008	44.789	0.023
		29	-0.008	-0.012	44.957	0.030
		30	0.057	0.047	52.803	0.006
		31	-0.010	-0.017	53.067	0.008
		32	-0.039	-0.037	56.792	0.004
		33	0.019	0.025	57.712	0.005
		34	0.007	0.008	57.818	0.007
		35	-0.016	-0.021	58.440	0.008
		36	-0.035	-0.030	61.367	0.005

Correlogram of residuals of FTSE Straits Times Index

Date: 04/19/22 Time: 06:18
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.054	0.054	7.0447	0.008
		2	0.002	-0.001	7.0510	0.029
		3	0.026	0.026	8.7146	0.033
		4	-0.011	-0.013	8.9835	0.062
		5	-0.001	0.000	8.9877	0.110
		6	-0.023	-0.024	10.272	0.114
		7	0.032	0.036	12.797	0.077
		8	-0.002	-0.006	12.809	0.119
		9	0.034	0.036	15.559	0.077
		10	0.013	0.007	15.971	0.100
		11	-0.038	-0.038	19.448	0.054
		12	-0.029	-0.028	21.523	0.043
		13	-0.000	0.005	21.523	0.063
		14	0.004	0.004	21.553	0.088
		15	-0.023	-0.021	22.874	0.087
		16	-0.071	-0.072	35.165	0.004
		17	0.012	0.017	35.500	0.005
		18	0.019	0.019	36.388	0.006
		19	-0.036	-0.034	39.578	0.004
		20	-0.012	-0.009	39.916	0.005
		21	0.014	0.016	40.407	0.007
		22	0.011	0.009	40.702	0.009
		23	-0.045	-0.045	45.660	0.003
		24	-0.015	-0.012	46.208	0.004
		25	-0.031	-0.027	48.495	0.003
		26	-0.010	-0.003	48.731	0.004
		27	0.007	-0.000	48.851	0.006
		28	-0.014	-0.015	49.335	0.008
		29	-0.034	-0.032	52.092	0.005
		30	-0.010	-0.007	52.340	0.007
		31	0.037	0.031	55.642	0.004
		32	-0.029	-0.031	57.640	0.004
		33	-0.003	0.006	57.664	0.005
		34	0.005	0.003	57.734	0.007
		35	-0.003	-0.010	57.754	0.009
		36	-0.006	-0.008	57.833	0.012

Correlogram of residuals of JSX Composite Index

Date: 04/19/22 Time: 06:21
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.031	0.031	2.3047	0.129
		2	-0.001	-0.002	2.3090	0.315
		3	-0.009	-0.009	2.4909	0.477
		4	-0.049	-0.048	8.1928	0.085
		5	-0.014	-0.011	8.6673	0.123
		6	-0.066	-0.065	19.027	0.004
		7	0.069	0.073	30.567	0.000
		8	0.002	-0.005	30.580	0.000
		9	0.018	0.017	31.382	0.000
		10	0.011	0.004	31.683	0.000
		11	-0.003	0.002	31.700	0.001
		12	0.035	0.032	34.582	0.001
		13	-0.022	-0.013	35.731	0.001
		14	-0.022	-0.024	36.847	0.001
		15	-0.031	-0.027	39.147	0.001
		16	0.000	0.004	39.147	0.001
		17	-0.047	-0.051	44.524	0.000
		18	0.001	0.005	44.525	0.000
		19	-0.002	-0.013	44.533	0.001
		20	0.008	0.008	44.690	0.001
		21	0.019	0.012	45.553	0.001
		22	-0.043	-0.041	50.003	0.001
		23	0.007	0.004	50.109	0.001
		24	-0.006	0.001	50.200	0.001
		25	0.019	0.021	51.100	0.002
		26	0.059	0.060	59.612	0.000
		27	0.010	0.009	59.853	0.000
		28	0.061	0.053	68.948	0.000
		29	-0.024	-0.018	70.404	0.000
		30	0.033	0.038	73.106	0.000
		31	-0.029	-0.028	75.212	0.000
		32	-0.063	-0.055	84.806	0.000
		33	-0.034	-0.041	87.689	0.000
		34	-0.021	-0.012	88.763	0.000
		35	0.062	0.048	98.106	0.000
		36	0.013	0.007	98.505	0.000

Correlogram of squared residuals of KOSPI Composite Index

Date: 04/19/22 Time: 06:12
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.174	0.174	72.270	0.000
		2	0.296	0.274	282.75	0.000
		3	0.182	0.108	362.30	0.000
		4	0.178	0.072	437.94	0.000
		5	0.241	0.158	577.61	0.000
		6	0.185	0.082	660.14	0.000
		7	0.210	0.079	765.72	0.000
		8	0.177	0.054	841.04	0.000
		9	0.239	0.121	978.30	0.000
		10	0.170	0.032	1047.8	0.000
		11	0.224	0.079	1168.4	0.000
		12	0.202	0.070	1266.7	0.000
		13	0.178	0.025	1342.7	0.000
		14	0.215	0.061	1453.6	0.000
		15	0.122	-0.030	1489.7	0.000
		16	0.194	0.036	1580.0	0.000
		17	0.082	-0.067	1596.4	0.000
		18	0.185	0.041	1678.6	0.000
		19	0.132	0.007	1720.6	0.000
		20	0.124	-0.024	1757.6	0.000
		21	0.157	0.023	1817.2	0.000
		22	0.086	-0.033	1835.2	0.000
		23	0.237	0.121	1971.3	0.000
		24	0.104	-0.009	1997.3	0.000
		25	0.224	0.087	2118.9	0.000
		26	0.139	0.031	2165.7	0.000
		27	0.200	0.072	2262.1	0.000
		28	0.128	-0.015	2301.5	0.000
		29	0.151	0.026	2356.7	0.000
		30	0.136	-0.006	2401.8	0.000
		31	0.152	0.043	2458.0	0.000
		32	0.180	0.028	2537.1	0.000
		33	0.180	0.072	2615.8	0.000
		34	0.146	-0.026	2667.8	0.000
		35	0.088	-0.075	2686.6	0.000
		36	0.093	-0.060	2707.4	0.000

Correlogram of squared residuals of JSX Composite Index

Date: 04/19/22 Time: 06:22
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.130	0.130	40.794	0.000
		2	0.123	0.108	77.138	0.000
		3	0.186	0.162	160.20	0.000
		4	0.089	0.041	179.28	0.000
		5	0.095	0.049	200.95	0.000
		6	0.106	0.054	227.93	0.000
		7	0.237	0.202	363.41	0.000
		8	0.119	0.049	397.36	0.000
		9	0.064	-0.014	407.34	0.000
		10	0.125	0.037	445.18	0.000
		11	0.130	0.075	485.92	0.000
		12	0.054	-0.010	492.89	0.000
		13	0.074	-0.000	506.15	0.000
		14	0.084	-0.010	523.09	0.000
		15	0.059	0.002	531.53	0.000
		16	0.050	0.003	537.45	0.000
		17	0.058	-0.003	545.46	0.000
		18	0.059	-0.009	553.80	0.000
		19	0.108	0.078	582.11	0.000
		20	0.050	0.004	588.22	0.000
		21	0.032	-0.025	590.71	0.000
		22	0.080	0.030	606.09	0.000
		23	0.056	0.027	613.68	0.000
		24	0.033	-0.005	616.37	0.000
		25	0.094	0.053	637.79	0.000
		26	0.085	0.024	655.19	0.000
		27	0.030	-0.017	657.43	0.000
		28	0.160	0.136	719.25	0.000
		29	0.050	-0.022	725.42	0.000
		30	0.052	-0.013	732.03	0.000
		31	0.046	-0.012	737.25	0.000
		32	0.034	-0.016	740.03	0.000
		33	0.037	-0.025	743.34	0.000
		34	0.037	0.007	746.59	0.000
		35	0.078	0.007	761.41	0.000
		36	0.042	-0.009	765.80	0.000

Correlogram of squared residuals of FTSE Straits Times Index

Date: 04/19/22 Time: 06:19
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.177	0.177	75.298	0.000
		2	0.161	0.134	137.76	0.000
		3	0.200	0.160	233.98	0.000
		4	0.144	0.077	283.91	0.000
		5	0.133	0.062	326.09	0.000
		6	0.115	0.038	357.69	0.000
		7	0.132	0.063	399.47	0.000
		8	0.221	0.158	516.91	0.000
		9	0.166	0.078	583.19	0.000
		10	0.128	0.027	622.32	0.000
		11	0.129	0.020	662.65	0.000
		12	0.123	0.023	699.10	0.000
		13	0.094	0.001	720.41	0.000
		14	0.125	0.046	758.29	0.000
		15	0.159	0.078	819.10	0.000
		16	0.205	0.111	920.15	0.000
		17	0.126	0.006	958.39	0.000
		18	0.118	0.003	992.28	0.000
		19	0.148	0.038	1045.3	0.000
		20	0.114	0.012	1076.5	0.000
		21	0.132	0.047	1118.7	0.000
		22	0.075	-0.030	1132.4	0.000
		23	0.163	0.066	1196.6	0.000
		24	0.109	-0.021	1225.6	0.000
		25	0.105	0.004	1252.0	0.000
		26	0.112	0.011	1282.2	0.000
		27	0.087	-0.012	1300.6	0.000
		28	0.087	-0.003	1319.1	0.000
		29	0.092	0.004	1339.5	0.000
		30	0.121	0.043	1374.9	0.000
		31	0.125	0.022	1412.7	0.000
		32	0.088	-0.016	1431.4	0.000
		33	0.095	0.002	1453.3	0.000
		34	0.115	0.027	1485.6	0.000
		35	0.093	0.001	1506.8	0.000
		36	0.076	-0.004	1520.7	0.000

Correlogram of squared residuals of NIKKEI 225 Index

Date: 04/19/22 Time: 07:16
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.253	0.253	153.50	0.000
		2	0.119	0.059	187.71	0.000
		3	0.118	0.080	221.06	0.000
		4	0.078	0.027	235.61	0.000
		5	0.066	0.030	246.24	0.000
		6	0.069	0.035	257.71	0.000
		7	0.061	0.026	266.73	0.000
		8	0.055	0.022	274.00	0.000
		9	0.073	0.043	287.00	0.000
		10	0.079	0.040	301.87	0.000
		11	0.065	0.022	311.93	0.000
		12	0.112	0.078	342.40	0.000
		13	0.044	-0.020	347.15	0.000
		14	0.033	0.000	349.72	0.000
		15	0.088	0.060	368.27	0.000
		16	0.008	-0.046	368.43	0.000
		17	0.021	0.007	369.52	0.000
		18	0.010	-0.019	369.75	0.000
		19	0.022	0.010	370.91	0.000
		20	0.020	0.001	371.91	0.000
		21	0.027	0.008	373.74	0.000
		22	0.005	-0.019	373.81	0.000
		23	0.005	-0.003	373.88	0.000
		24	0.003	-0.014	373.90	0.000
		25	0.013	0.010	374.33	0.000
		26	0.002	-0.006	374.34	0.000
		27	0.023	0.012	375.59	0.000
		28	0.011	0.006	375.91	0.000
		29	-0.002	-0.011	375.91	0.000
		30	0.010	0.005	376.17	0.000
		31	0.019	0.017	377.08	0.000
		32	0.008	-0.004	377.21	0.000
		33	0.040	0.040	381.20	0.000
		34	0.002	-0.021	381.21	0.000
		35	0.025	0.026	382.79	0.000
		36	0.019	0.002	383.71	0.000

Correlogram of squared residuals of Thailand SET Index

Date: 04/19/22 Time: 07:18
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments

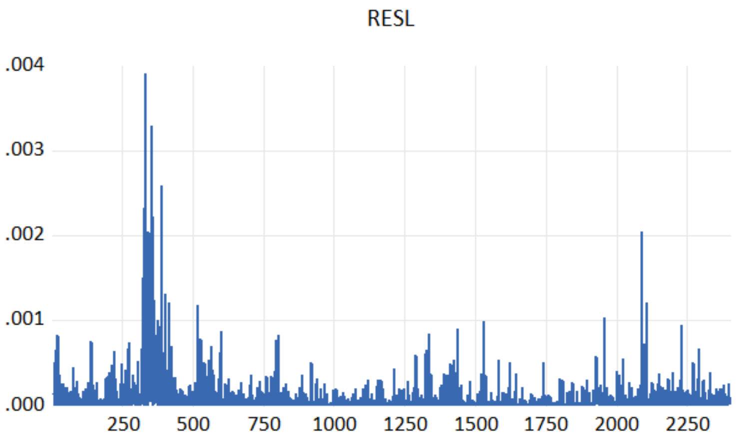
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.159	0.159	61.022	0.000
		2	0.220	0.199	176.90	0.000
		3	0.272	0.227	354.63	0.000
		4	0.127	0.035	393.23	0.000
		5	0.195	0.097	484.59	0.000
		6	0.107	-0.004	512.06	0.000
		7	0.163	0.083	575.85	0.000
		8	0.161	0.067	637.97	0.000
		9	0.151	0.073	693.26	0.000
		10	0.156	0.046	752.22	0.000
		11	0.110	0.003	781.53	0.000
		12	0.112	-0.001	811.59	0.000
		13	0.088	-0.010	830.32	0.000
		14	0.069	-0.016	841.67	0.000
		15	0.118	0.048	875.15	0.000
		16	0.060	-0.010	883.95	0.000
		17	0.080	0.006	899.37	0.000
		18	0.129	0.059	939.65	0.000
		19	0.069	0.005	951.09	0.000
		20	0.109	0.034	979.95	0.000
		21	0.100	0.030	1004.4	0.000
		22	0.085	0.017	1021.8	0.000
		23	0.098	0.018	1045.0	0.000
		24	0.054	-0.019	1052.0	0.000
		25	0.115	0.045	1083.9	0.000
		26	0.071	0.000	1096.1	0.000
		27	0.049	-0.025	1101.9	0.000
		28	0.045	-0.042	1106.7	0.000
		29	0.064	0.015	1116.6	0.000
		30	0.100	0.050	1141.1	0.000
		31	0.080	0.039	1156.6	0.000
		32	0.041	-0.031	1160.6	0.000
		33	0.059	-0.017	1169.0	0.000
		34	0.065	0.014	1179.3	0.000
		35	0.065	0.025	1189.6	0.000
		36	0.056	0.011	1197.3	0.000

Correlogram of squared residuals of S&P BSE Sensex Index

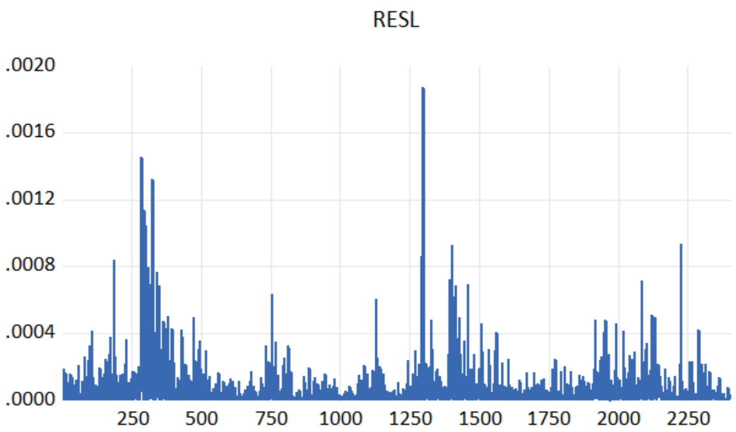
Date: 04/19/22   Time: 07:19
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.069	0.069	11.550	0.001
		2	0.082	0.078	27.720	0.000
		3	0.117	0.107	60.353	0.000
		4	0.081	0.063	76.079	0.000
		5	0.058	0.035	84.241	0.000
		6	0.103	0.078	109.65	0.000
		7	0.115	0.088	141.44	0.000
		8	0.073	0.040	154.19	0.000
		9	0.129	0.093	194.32	0.000
		10	0.056	0.010	201.80	0.000
		11	0.085	0.045	219.36	0.000
		12	0.106	0.062	246.48	0.000
		13	0.073	0.027	259.41	0.000
		14	0.084	0.038	276.53	0.000
		15	0.048	-0.007	282.16	0.000
		16	0.117	0.069	315.03	0.000
		17	0.050	0.002	321.05	0.000
		18	0.080	0.028	336.63	0.000
		19	0.057	0.005	344.63	0.000
		20	0.080	0.030	360.20	0.000
		21	0.034	-0.018	363.04	0.000
		22	0.036	-0.012	366.18	0.000
		23	0.051	-0.001	372.46	0.000
		24	0.064	0.026	382.42	0.000
		25	0.031	-0.019	384.80	0.000
		26	0.061	0.023	393.91	0.000
		27	0.043	-0.003	398.45	0.000
		28	0.037	-0.001	401.79	0.000
		29	0.023	-0.017	403.04	0.000
		30	0.051	0.015	409.29	0.000
		31	0.022	-0.010	410.46	0.000
		32	0.042	0.006	414.84	0.000
		33	0.060	0.030	423.70	0.000
		34	0.031	0.001	425.98	0.000
		35	0.027	-0.004	427.72	0.000
		36	0.024	-0.012	429.09	0.000

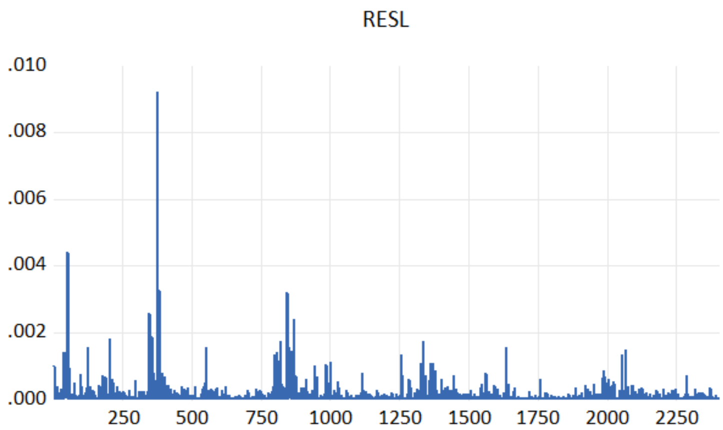
Line graph of squared residuals of KOSPI Composite Index



Line graph of squared residuals of FTSE Straits Times Index



Line graph of squared residuals of JSX Composite Index



ARCH-LM Test of log returns of KOSPI Composite Index

Heteroskedasticity Test: ARCH

F-statistic	74.33738	Prob. F(1,2389)	0.0000
Obs*R-squared	72.15442	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 06:16
Sample (adjusted): 10 2400
Included observations: 2391 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.08E-05	4.59E-06	15.41862	0.0000
RESID^2(-1)	0.173719	0.020148	8.621913	0.0000

R-squared	0.030178	Mean dependent var	8.57E-05
Adjusted R-squared	0.029772	S.D. dependent var	0.000211
S.E. of regression	0.000208	Akaike info criterion	-14.11583
Sum squared resid	0.000104	Schwarz criterion	-14.11100
Log likelihood	16877.47	Hannan-Quinn criter.	-14.11407
F-statistic	74.33738	Durbin-Watson stat	2.095149
Prob(F-statistic)	0.000000		

ARCH-LM Test of log returns of FTSE Straits Times Index

Heteroskedasticity Test: ARCH

F-statistic	77.58691	Prob. F(1,2391)	0.0000
Obs*R-squared	75.21124	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 06:20
Sample (adjusted): 8 2400
Included observations: 2393 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.80E-05	2.69E-06	17.85077	0.0000
RESID^2(-1)	0.177242	0.020122	8.808343	0.0000

R-squared	0.031430	Mean dependent var	5.84E-05
Adjusted R-squared	0.031025	S.D. dependent var	0.000120
S.E. of regression	0.000118	Akaike info criterion	-15.24588
Sum squared resid	3.35E-05	Schwarz criterion	-15.24105
Log likelihood	18243.70	Hannan-Quinn criter.	-15.24412
F-statistic	77.58691	Durbin-Watson stat	2.046792
Prob(F-statistic)	0.000000		

ARCH-LM Test of log returns of JSX Composite Index

Heteroskedasticity Test: ARCH

F-statistic	41.54872	Prob. F(1,2393)	0.0000
Obs*R-squared	40.87377	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 06:23
Sample (adjusted): 6 2400
Included observations: 2395 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.29E-05	6.63E-06	14.01459	0.0000
RESID^2(-1)	0.130406	0.020231	6.445830	0.0000

R-squared	0.017066	Mean dependent var	0.000107
Adjusted R-squared	0.016656	S.D. dependent var	0.000309
S.E. of regression	0.000306	Akaike info criterion	-13.34268
Sum squared resid	0.000225	Schwarz criterion	-13.33785
Log likelihood	15979.85	Hannan-Quinn criter.	-13.34092
F-statistic	41.54872	Durbin-Watson stat	2.026777
Prob(F-statistic)	0.000000		

ARCH-LM Test of log returns of NIKKEI 225 Index

Heteroskedasticity Test: ARCH

F-statistic	163.5749	Prob. F(1,2396)	0.0000
Obs*R-squared	153.2491	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 07:18
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000128	9.95E-06	12.88542	0.0000
RESID^2(-1)	0.252801	0.019766	12.78964	0.0000

R-squared	0.063907	Mean dependent var	0.000172
Adjusted R-squared	0.063516	S.D. dependent var	0.000473
S.E. of regression	0.000458	Akaike info criterion	-12.53837
Sum squared resid	0.000503	Schwarz criterion	-12.53355
Log likelihood	15035.51	Hannan-Quinn criter.	-12.53662
F-statistic	163.5749	Durbin-Watson stat	2.029810
Prob(F-statistic)	0.000000		

ARCH-LM Test of log returns of Thailand SET Index

Heteroskedasticity Test: ARCH

F-statistic	62.55480	Prob. F(1,2396)	0.0000
Obs*R-squared	61.01406	Prob. Chi-Square(1)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 07:19
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.59E-05	5.05E-06	15.03544	0.0000
RESID^2(-1)	0.159398	0.020154	7.909159	0.0000

R-squared	0.025444	Mean dependent var	9.04E-05
Adjusted R-squared	0.025037	S.D. dependent var	0.000233
S.E. of regression	0.000231	Akaike info criterion	-13.91146
Sum squared resid	0.000127	Schwarz criterion	-13.90664
Log likelihood	16681.84	Hannan-Quinn criter.	-13.90971
F-statistic	62.55480	Durbin-Watson stat	2.064374
Prob(F-statistic)	0.000000		

ARCH-LM Test of log returns of S&P BSE Sensex Index

Heteroskedasticity Test: ARCH

F-statistic	11.57824	Prob. F(1,2396)	0.0007
Obs*R-squared	11.53217	Prob. Chi-Square(1)	0.0007

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/19/22 Time: 07:20
Sample (adjusted): 3 2400
Included observations: 2398 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.46E-05	4.14E-06	20.42745	0.0000
RESID^2(-1)	0.069351	0.020381	3.402681	0.0007

R-squared	0.004809	Mean dependent var	9.09E-05
Adjusted R-squared	0.004394	S.D. dependent var	0.000182
S.E. of regression	0.000181	Akaike info criterion	-14.39085
Sum squared resid	7.88E-05	Schwarz criterion	-14.38603
Log likelihood	17256.64	Hannan-Quinn criter.	-14.38910
F-statistic	11.57824	Durbin-Watson stat	2.010516
Prob(F-statistic)	0.000678		

Annex 4 GARCH model of indexes

GARCH (1,1) model of Hang Seng Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 01:00
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 25 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Variance Equation			
C	2.09E-06	4.97E-07	4.216181	0.0000
RESID(-1)^2	0.045525	0.005688	8.003832	0.0000
GARCH(-1)	0.937395	0.008389	111.7450	0.0000

R-squared	-0.000000	Mean dependent var	-1.30E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.011338
S.E. of regression	0.011335	Akaike info criterion	-6.231635
Sum squared resid	0.308251	Schwarz criterion	-6.224404
Log likelihood	7477.847	Hannan-Quinn criter.	-6.229004
Durbin-Watson stat	1.963734		

GARCH (1,2) model of Hang Seng Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 01:01
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 38 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1) + C(4)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Variance Equation			
C	1.41E-06	5.04E-07	2.808079	0.0050
RESID(-1)^2	0.029788	0.008745	3.406351	0.0007
GARCH(-1)	1.389716	0.205267	6.770289	0.0000
GARCH(-2)	-0.430944	0.193688	-2.224935	0.0261

R-squared	-0.000000	Mean dependent var	-1.30E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.011338
S.E. of regression	0.011335	Akaike info criterion	-6.232518
Sum squared resid	0.308251	Schwarz criterion	-6.222876
Log likelihood	7479.905	Hannan-Quinn criter.	-6.229010
Durbin-Watson stat	1.963734		

GARCH (2,1) model of Hang Seng Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 01:02
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Variance Equation		
C	3.06E-06	6.49E-07	4.710691	0.0000
RESID(-1)^2	0.002106	0.009130	0.230695	0.8176
RESID(-2)^2	0.059884	0.012424	4.820084	0.0000
GARCH(-1)	0.913445	0.010910	83.72753	0.0000

R-squared	-0.000000	Mean dependent var	-1.30E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.011338
S.E. of regression	0.011335	Akaike info criterion	-6.234898
Sum squared resid	0.308251	Schwarz criterion	-6.225256
Log likelihood	7482.760	Hannan-Quinn criter.	-6.231390
Durbin-Watson stat	1.963734		

GARCH (1,1) model of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:35
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 24 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Variance Equation		
C	6.92E-06	1.03E-06	6.701307	0.0000
RESID(-1)^2	0.130433	0.010153	12.84663	0.0000
GARCH(-1)	0.833850	0.013008	64.10302	0.0000

R-squared	-0.000000	Mean dependent var	1.75E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.013104
S.E. of regression	0.013101	Akaike info criterion	-6.013201
Sum squared resid	0.411766	Schwarz criterion	-6.005970
Log likelihood	7215.835	Hannan-Quinn criter.	-6.010571
Durbin-Watson stat	2.082183		

GARCH (1,2) model of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:37
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 26 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1) + C(4)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	6.97E-06	1.23E-06	5.679818	0.0000
RESID(-1)^2	0.131549	0.014479	9.085380	0.0000
GARCH(-1)	0.820237	0.133862	6.127480	0.0000
GARCH(-2)	0.012201	0.118887	0.102625	0.9183

R-squared	-0.000000	Mean dependent var	1.75E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.013104
S.E. of regression	0.013101	Akaike info criterion	-6.012372
Sum squared resid	0.411766	Schwarz criterion	-6.002730
Log likelihood	7215.840	Hannan-Quinn criter.	-6.008864
Durbin-Watson stat	2.082183		

GARCH (2,1) model of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:39
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 26 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	6.80E-06	1.08E-06	6.320966	0.0000
RESID(-1)^2	0.133028	0.014663	9.072526	0.0000
RESID(-2)^2	-0.004424	0.018582	-0.238055	0.8118
GARCH(-1)	0.836206	0.015890	52.62492	0.0000

R-squared	-0.000000	Mean dependent var	1.75E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.013104
S.E. of regression	0.013101	Akaike info criterion	-6.012378
Sum squared resid	0.411766	Schwarz criterion	-6.002736
Log likelihood	7215.847	Hannan-Quinn criter.	-6.008870
Durbin-Watson stat	2.082183		

GARCH (1,1) model of KOSPI Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:41
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments
Convergence achieved after 24 iterations
Coefficient covariance computed using outer product of gradients
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.
C	0.000273	0.000166	1.646898	0.0996
R(-7)	0.015533	0.021724	0.714992	0.4746
		Variance Equation		
C	2.14E-06	3.90E-07	5.503851	0.0000
RESID(-1)^2	0.069442	0.008003	8.676492	0.0000
GARCH(-1)	0.902035	0.010774	83.72626	0.0000

R-squared	0.000932	Mean dependent var	0.000105
Adjusted R-squared	0.000514	S.D. dependent var	0.009274
S.E. of regression	0.009271	Akaike info criterion	-6.728022
Sum squared resid	0.205436	Schwarz criterion	-6.715940
Log likelihood	8051.714	Hannan-Quinn criter.	-6.723626
Durbin-Watson stat	1.943287		

GARCH (1,2) model of KOSPI Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:43
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments
Convergence achieved after 36 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1) + C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000266	0.000165	1.614385	0.1064
R(-7)	0.016392	0.021977	0.745887	0.4557
		Variance Equation		
C	1.54E-06	4.35E-07	3.542790	0.0004
RESID(-1)^2	0.047657	0.012971	3.674176	0.0002
GARCH(-1)	1.319504	0.187038	7.054742	0.0000
GARCH(-2)	-0.387498	0.170403	-2.274003	0.0230

R-squared	0.001013	Mean dependent var	0.000105
Adjusted R-squared	0.000595	S.D. dependent var	0.009274
S.E. of regression	0.009271	Akaike info criterion	-6.728137
Sum squared resid	0.205419	Schwarz criterion	-6.713639
Log likelihood	8052.852	Hannan-Quinn criter.	-6.722862
Durbin-Watson stat	1.943247		

GARCH (2,1) model of KOSPI Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:45
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments
Convergence achieved after 24 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-2)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000259	0.000165	1.566020	0.1173
R(-7)	0.016122	0.021856	0.737650	0.4607
Variance Equation				
C	2.56E-06	4.82E-07	5.325205	0.0000
RESID(-1)^2	0.039145	0.016764	2.335109	0.0195
RESID(-2)^2	0.039829	0.019450	2.047754	0.0406
GARCH(-1)	0.887012	0.013429	66.05098	0.0000

R-squared	0.001023	Mean dependent var	0.000105
Adjusted R-squared	0.000605	S.D. dependent var	0.009274
S.E. of regression	0.009271	Akaike info criterion	-6.728301
Sum squared resid	0.205417	Schwarz criterion	-6.713803
Log likelihood	8053.048	Hannan-Quinn criter.	-6.723026
Durbin-Watson stat	1.943328		

GARCH (1,1) model of FTSE Straits Times Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:47
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
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.
C	0.000199	0.000137	1.450331	0.1470
R(-5)	0.040575	0.021560	1.881972	0.0598
Variance Equation				
C	8.88E-07	2.25E-07	3.944468	0.0001
RESID(-1)^2	0.064683	0.007328	8.826432	0.0000
GARCH(-1)	0.919727	0.009536	96.44781	0.0000

R-squared	0.001615	Mean dependent var	5.46E-05
Adjusted R-squared	0.001197	S.D. dependent var	0.007652
S.E. of regression	0.007647	Akaike info criterion	-7.071119
Sum squared resid	0.139880	Schwarz criterion	-7.059046
Log likelihood	8469.130	Hannan-Quinn criter.	-7.066727
Durbin-Watson stat	1.889583		

GARCH (1,2) model of FTSE Straits Times Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:48
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments
Convergence achieved after 41 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1) + C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000202	0.000137	1.472512	0.1409
R(-5)	0.040228	0.021420	1.878049	0.0604
Variance Equation				
C	1.18E-06	3.37E-07	3.505347	0.0005
RESID(-1)^2	0.091839	0.012684	7.240396	0.0000
GARCH(-1)	0.443507	0.159769	2.775931	0.0055
GARCH(-2)	0.444059	0.149814	2.964067	0.0030

R-squared	0.001597	Mean dependent var	5.46E-05
Adjusted R-squared	0.001180	S.D. dependent var	0.007652
S.E. of regression	0.007647	Akaike info criterion	-7.071890
Sum squared resid	0.139883	Schwarz criterion	-7.057402
Log likelihood	8471.053	Hannan-Quinn criter.	-7.066619
Durbin-Watson stat	1.889578		

GARCH (2,1) model of FTSE Straits Times Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:50
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments
Convergence achieved after 27 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-2)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000210	0.000137	1.535784	0.1246
R(-5)	0.041399	0.021111	1.961025	0.0499
Variance Equation				
C	7.05E-07	1.98E-07	3.556664	0.0004
RESID(-1)^2	0.106796	0.020573	5.191078	0.0000
RESID(-2)^2	-0.049663	0.022312	-2.225850	0.0260
GARCH(-1)	0.930646	0.009748	95.47084	0.0000

R-squared	0.001562	Mean dependent var	5.46E-05
Adjusted R-squared	0.001144	S.D. dependent var	0.007652
S.E. of regression	0.007647	Akaike info criterion	-7.071761
Sum squared resid	0.139888	Schwarz criterion	-7.057273
Log likelihood	8470.897	Hannan-Quinn criter.	-7.066489
Durbin-Watson stat	1.889416		

GARCH (1,1) model of Thailand SET Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:52
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 23 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Variance Equation		
C	9.05E-07	1.85E-07	4.898314	0.0000
RESID(-1)^2	0.105771	0.008900	11.88450	0.0000
GARCH(-1)	0.889269	0.008850	100.4769	0.0000

R-squared	-0.000000	Mean dependent var	-7.52E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009517
S.E. of regression	0.009515	Akaike info criterion	-6.751341
Sum squared resid	0.217209	Schwarz criterion	-6.744109
Log likelihood	8101.233	Hannan-Quinn criter.	-6.748710
Durbin-Watson stat	1.919405		

GARCH (1,2) model of Thailand SET Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:53
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 32 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1) + C(4)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Variance Equation		
C	8.90E-07	2.07E-07	4.307529	0.0000
RESID(-1)^2	0.102627	0.020572	4.988756	0.0000
GARCH(-1)	0.928586	0.201001	4.619805	0.0000
GARCH(-2)	-0.036185	0.182131	-0.198678	0.8425

R-squared	-0.000000	Mean dependent var	-7.52E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009517
S.E. of regression	0.009515	Akaike info criterion	-6.750536
Sum squared resid	0.217209	Schwarz criterion	-6.740894
Log likelihood	8101.268	Hannan-Quinn criter.	-6.747028
Durbin-Watson stat	1.919405		

GARCH (2,1) model of Thailand SET Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:54
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	9.85E-07	2.15E-07	4.578540	0.0000
RESID(-1)^2	0.094896	0.020127	4.714821	0.0000
RESID(-2)^2	0.014863	0.021209	0.700789	0.4834
GARCH(-1)	0.884497	0.009978	88.64685	0.0000

R-squared	-0.000000	Mean dependent var	-7.52E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009517
S.E. of regression	0.009515	Akaike info criterion	-6.750608
Sum squared resid	0.217209	Schwarz criterion	-6.740966
Log likelihood	8101.354	Hannan-Quinn criter.	-6.747100
Durbin-Watson stat	1.919405		

GARCH (1,1) model of JSX Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:56
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments
Convergence achieved after 24 iterations
Coefficient covariance computed using outer product of gradients
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.
C	0.000550	0.000179	3.079507	0.0021
R(-3)	-0.089708	0.021417	-4.188666	0.0000
Variance Equation				
C	2.63E-06	4.01E-07	6.558259	0.0000
RESID(-1)^2	0.100928	0.010523	9.591467	0.0000
GARCH(-1)	0.875872	0.011910	73.54142	0.0000

R-squared	0.013879	Mean dependent var	0.000360
Adjusted R-squared	0.013467	S.D. dependent var	0.010437
S.E. of regression	0.010366	Akaike info criterion	-6.524593
Sum squared resid	0.257264	Schwarz criterion	-6.512528
Log likelihood	7821.463	Hannan-Quinn criter.	-6.520204
Durbin-Watson stat	1.929666		

GARCH (1,2) model of JSX Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:57
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments
Convergence achieved after 33 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1) + C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000547	0.000180	3.034785	0.0024
R(-3)	-0.089002	0.021296	-4.179299	0.0000
Variance Equation				
C	3.23E-06	6.70E-07	4.822725	0.0000
RESID(-1)^2	0.123891	0.018268	6.781975	0.0000
GARCH(-1)	0.591311	0.153699	3.847198	0.0001
GARCH(-2)	0.255996	0.136010	1.882193	0.0598

R-squared	0.013839	Mean dependent var	0.000360
Adjusted R-squared	0.013427	S.D. dependent var	0.010437
S.E. of regression	0.010367	Akaike info criterion	-6.524389
Sum squared resid	0.257275	Schwarz criterion	-6.509911
Log likelihood	7822.218	Hannan-Quinn criter.	-6.519121
Durbin-Watson stat	1.929600		

GARCH (2,1) model of JSX Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:57
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*RESID(-2)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000552	0.000180	3.064503	0.0022
R(-3)	-0.088886	0.021068	-4.219092	0.0000
Variance Equation				
C	2.32E-06	3.63E-07	6.403816	0.0000
RESID(-1)^2	0.124374	0.019860	6.262442	0.0000
RESID(-2)^2	-0.033719	0.019505	-1.728737	0.0839
GARCH(-1)	0.888477	0.011520	77.12189	0.0000

R-squared	0.013816	Mean dependent var	0.000360
Adjusted R-squared	0.013404	S.D. dependent var	0.010437
S.E. of regression	0.010367	Akaike info criterion	-6.524398
Sum squared resid	0.257281	Schwarz criterion	-6.509920
Log likelihood	7822.228	Hannan-Quinn criter.	-6.519130
Durbin-Watson stat	1.929558		

GARCH (1,1) model of S&P BSE Sensex Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:58
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 26 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	1.37E-06	3.90E-07	3.507114	0.0005
RESID(-1)^2	0.057702	0.008287	6.962911	0.0000
GARCH(-1)	0.927675	0.010754	86.26311	0.0000

R-squared	-0.000000	Mean dependent var	6.42E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009538
S.E. of regression	0.009536	Akaike info criterion	-6.567194
Sum squared resid	0.218157	Schwarz criterion	-6.559963
Log likelihood	7880.350	Hannan-Quinn criter.	-6.564564
Durbin-Watson stat	1.873542		

GARCH (1,2) model of S&P BSE Sensex Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:59
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 48 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1) + C(4)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	6.85E-07	2.50E-07	2.736206	0.0062
RESID(-1)^2	0.026564	0.008384	3.168414	0.0015
GARCH(-1)	1.576903	0.133959	11.77154	0.0000
GARCH(-2)	-0.610668	0.124312	-4.912368	0.0000

R-squared	-0.000000	Mean dependent var	6.42E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009538
S.E. of regression	0.009536	Akaike info criterion	-6.568163
Sum squared resid	0.218157	Schwarz criterion	-6.558521
Log likelihood	7882.512	Hannan-Quinn criter.	-6.564655
Durbin-Watson stat	1.873542		

GARCH (2,1) model of S&P BSE Sensex Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 07:59
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 32 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Variance Equation		
C	1.66E-06	4.64E-07	3.564938	0.0004
RESID(-1)^2	0.025225	0.013777	1.831002	0.0671
RESID(-2)^2	0.042369	0.017035	2.487237	0.0129
GARCH(-1)	0.914957	0.013147	69.59422	0.0000

R-squared	-0.000000	Mean dependent var	6.42E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009538
S.E. of regression	0.009536	Akaike info criterion	-6.568048
Sum squared resid	0.218157	Schwarz criterion	-6.558406
Log likelihood	7882.374	Hannan-Quinn criter.	-6.564540
Durbin-Watson stat	1.873542		

Annex 5 GARCH-M model of indexes

GARCH-M model of Hang Seng Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 09:57
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 27 iterations
Coefficient covariance computed using outer product of gradients
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.
GARCH	2.422366	1.792977	1.351030	0.1767
Variance Equation				
C	2.14E-06	5.02E-07	4.251809	0.0000
RESID(-1)^2	0.046203	0.005740	8.049325	0.0000
GARCH(-1)	0.936381	0.008481	110.4141	0.0000

R-squared	-0.000316	Mean dependent var	-1.30E-07
Adjusted R-squared	-0.000316	S.D. dependent var	0.011338
S.E. of regression	0.011340	Akaike info criterion	-6.231565
Sum squared resid	0.308349	Schwarz criterion	-6.221923
Log likelihood	7478.762	Hannan-Quinn criter.	-6.228057
Durbin-Watson stat	1.961958		

GARCH-M model of KOSPI Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:01
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments
Convergence achieved after 27 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	7.823791	4.197893	1.863742	0.0624
C	-0.000220	0.000312	-0.705226	0.4807
R(-7)	0.017986	0.021899	0.821328	0.4115
Variance Equation				
C	2.18E-06	3.99E-07	5.463296	0.0000
RESID(-1)^2	0.070362	0.008123	8.662544	0.0000
GARCH(-1)	0.900708	0.010924	82.45263	0.0000

R-squared	-0.000584	Mean dependent var	0.000105
Adjusted R-squared	-0.001421	S.D. dependent var	0.009274
S.E. of regression	0.009280	Akaike info criterion	-6.728378
Sum squared resid	0.205748	Schwarz criterion	-6.713880
Log likelihood	8053.141	Hannan-Quinn criter.	-6.723103
Durbin-Watson stat	1.934330		

GARCH-M model of FTSE Straits Times Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:04
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments
Convergence achieved after 29 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	4.361353	5.278701	0.826217	0.4087
C	6.88E-06	0.000265	0.025948	0.9793
R(-5)	0.041214	0.021562	1.911390	0.0560
Variance Equation				
C	8.92E-07	2.27E-07	3.920403	0.0001
RESID(-1)^2	0.064901	0.007383	8.790356	0.0000
GARCH(-1)	0.919435	0.009614	95.63378	0.0000

R-squared	0.001417	Mean dependent var	5.46E-05
Adjusted R-squared	0.000582	S.D. dependent var	0.007652
S.E. of regression	0.007649	Akaike info criterion	-7.070569
Sum squared resid	0.139908	Schwarz criterion	-7.056081
Log likelihood	8469.472	Hannan-Quinn criter.	-7.065298
Durbin-Watson stat	1.887633		

GARCH-M model of Thailand SET Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:05
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 25 iterations
Coefficient covariance computed using outer product of gradients
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.
GARCH	4.284031	2.123705	2.017244	0.0437
Variance Equation				
C	9.34E-07	1.89E-07	4.936980	0.0000
RESID(-1)^2	0.107431	0.009111	11.79098	0.0000
GARCH(-1)	0.887432	0.009055	98.00645	0.0000

R-squared	-0.001525	Mean dependent var	-7.52E-08
Adjusted R-squared	-0.001525	S.D. dependent var	0.009517
S.E. of regression	0.009525	Akaike info criterion	-6.752513
Sum squared resid	0.217540	Schwarz criterion	-6.742871
Log likelihood	8103.639	Hannan-Quinn criter.	-6.749005
Durbin-Watson stat	1.912923		

GARCH-M model of JSX Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:06
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments
Convergence achieved after 27 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	5.206469	3.241815	1.606035	0.1083
C	0.000172	0.000299	0.576946	0.5640
R(-3)	-0.087595	0.021562	-4.062539	0.0000
		Variance Equation		
C	2.76E-06	4.26E-07	6.482217	0.0000
RESID(-1)^2	0.103968	0.010888	9.549181	0.0000
GARCH(-1)	0.871707	0.012504	69.71202	0.0000

R-squared	0.013784	Mean dependent var	0.000360
Adjusted R-squared	0.012960	S.D. dependent var	0.010437
S.E. of regression	0.010369	Akaike info criterion	-6.524862
Sum squared resid	0.257289	Schwarz criterion	-6.510384
Log likelihood	7822.784	Hannan-Quinn criter.	-6.519594
Durbin-Watson stat	1.920119		

GARCH-M model of S&P BSE Sensex Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:08
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 26 iterations
Coefficient covariance computed using outer product of gradients
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.
GARCH	3.727635	2.076705	1.794975	0.0727
		Variance Equation		
C	1.42E-06	3.97E-07	3.565090	0.0004
RESID(-1)^2	0.059726	0.008518	7.011929	0.0000
GARCH(-1)	0.925203	0.011009	84.03868	0.0000

R-squared	-0.000526	Mean dependent var	6.42E-08
Adjusted R-squared	-0.000526	S.D. dependent var	0.009538
S.E. of regression	0.009541	Akaike info criterion	-6.567693
Sum squared resid	0.218272	Schwarz criterion	-6.558051
Log likelihood	7881.948	Hannan-Quinn criter.	-6.564185
Durbin-Watson stat	1.871512		

Annex 6 E-GARCH model of indexes

E-GARCH model of NIKKEI 225 Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 12:16
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 40 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)
*RESID(-1)/@SQRT(GARCH(-1)) + C(4)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	-0.686522	0.062701	-10.94911	0.0000
C(2)	0.220496	0.015092	14.60982	0.0000
C(3)	-0.118588	0.007141	-16.60573	0.0000
C(4)	0.941448	0.006392	147.2774	0.0000

R-squared	-0.000000	Mean dependent var	1.75E-07
Adjusted R-squared	0.000417	S.D. dependent var	0.013104
S.E. of regression	0.013101	Akaike info criterion	-6.047370
Sum squared resid	0.411766	Schwarz criterion	-6.037728
Log likelihood	7257.821	Hannan-Quinn criter.	-6.043862
Durbin-Watson stat	2.082183		

E-GARCH model of KOSPI Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:02
Sample (adjusted): 9 2400
Included observations: 2392 after adjustments
Convergence achieved after 49 iterations
Coefficient covariance computed using outer product of gradients
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.
C	4.94E-05	0.000159	0.310152	0.7564
R(-7)	0.019116	0.020832	0.917613	0.3588
Variance Equation				
C(3)	-0.333785	0.039315	-8.490122	0.0000
C(4)	0.097319	0.013744	7.080833	0.0000
C(5)	-0.093475	0.008482	-11.02076	0.0000
C(6)	0.972942	0.003521	276.3189	0.0000

R-squared	0.001455	Mean dependent var	0.000105
Adjusted R-squared	0.001037	S.D. dependent var	0.009274
S.E. of regression	0.009269	Akaike info criterion	-6.754787
Sum squared resid	0.205329	Schwarz criterion	-6.740289
Log likelihood	8084.726	Hannan-Quinn criter.	-6.749512
Durbin-Watson stat	1.943502		

E-GARCH model of FTSE Straits Times Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:04
Sample (adjusted): 7 2400
Included observations: 2394 after adjustments
Convergence achieved after 56 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)
*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	4.786932	5.241435	0.913287	0.3611
C	-0.000197	0.000265	-0.744823	0.4564
R(-5)	0.041191	0.021459	1.919491	0.0549
		Variance Equation		
C(4)	-0.244987	0.044452	-5.511280	0.0000
C(5)	0.079225	0.012013	6.594766	0.0000
C(6)	-0.069885	0.007772	-8.991480	0.0000
C(7)	0.981525	0.004135	237.3547	0.0000

R-squared	0.002421	Mean dependent var	5.46E-05
Adjusted R-squared	0.001587	S.D. dependent var	0.007652
S.E. of regression	0.007646	Akaike info criterion	-7.083220
Sum squared resid	0.139767	Schwarz criterion	-7.066317
Log likelihood	8485.614	Hannan-Quinn criter.	-7.077070
Durbin-Watson stat	1.884733		

E-GARCH model of Thailand SET Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:06
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 42 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)
*RESID(-1)/@SQRT(GARCH(-1)) + C(4)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Variance Equation		
C(1)	-0.373823	0.037696	-9.916730	0.0000
C(2)	0.172764	0.016672	10.36236	0.0000
C(3)	-0.084685	0.008068	-10.49687	0.0000
C(4)	0.974882	0.003139	310.6061	0.0000

R-squared	-0.000000	Mean dependent var	-7.52E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009517
S.E. of regression	0.009515	Akaike info criterion	-6.778386
Sum squared resid	0.217209	Schwarz criterion	-6.768744
Log likelihood	8134.674	Hannan-Quinn criter.	-6.774878
Durbin-Watson stat	1.919405		

E-GARCH model of JSX Composite Index

Dependent Variable: R
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:07
Sample (adjusted): 5 2400
Included observations: 2396 after adjustments
Convergence achieved after 54 iterations
Coefficient covariance computed using outer product of gradients
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.
C	0.000372	0.000179	2.079167	0.0376
R(-3)	-0.078305	0.020948	-3.738113	0.0002
Variance Equation				
C(3)	-0.391328	0.046373	-8.438748	0.0000
C(4)	0.164205	0.015103	10.87229	0.0000
C(5)	-0.074479	0.008790	-8.472872	0.0000
C(6)	0.971556	0.004202	231.2228	0.0000

R-squared	0.013205	Mean dependent var	0.000360
Adjusted R-squared	0.012793	S.D. dependent var	0.010437
S.E. of regression	0.010370	Akaike info criterion	-6.538790
Sum squared resid	0.257440	Schwarz criterion	-6.524312
Log likelihood	7839.471	Hannan-Quinn criter.	-6.533523
Durbin-Watson stat	1.928808		

E-GARCH model of S&P BSE Sensex Index

Dependent Variable: W
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 04/19/22 Time: 10:09
Sample (adjusted): 2 2400
Included observations: 2399 after adjustments
Convergence achieved after 74 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)
*RESID(-1)/@SQRT(GARCH(-1)) + C(4)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	-0.344223	0.047981	-7.174109	0.0000
C(2)	0.103427	0.016406	6.304082	0.0000
C(3)	-0.095288	0.009353	-10.18752	0.0000
C(4)	0.972071	0.004407	220.5499	0.0000

R-squared	-0.000000	Mean dependent var	6.42E-08
Adjusted R-squared	0.000417	S.D. dependent var	0.009538
S.E. of regression	0.009536	Akaike info criterion	-6.603564
Sum squared resid	0.218157	Schwarz criterion	-6.593922
Log likelihood	7924.975	Hannan-Quinn criter.	-6.600056
Durbin-Watson stat	1.873542		