MAXIMUM OVERLAPPING DISCRETE WAVELET METHODS FOR MODELLING THE SAUDI STOCK EXCHANGE

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by

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LIST OF SYMBOLS AND ABBREVIATION

ABC	Artificial Bee Colony
ACD	Autoregressive conditional duration
ADCC-EGARCH	Asymmetric Dynamic Conditional Correlation EGARCH
AFE	Arab Federation of Exchanges
ANFIS	Adaptive Neural Fuzzy Inference System
ANNs	Artificial Neural Networks
APT	Arbitrage Pricing Model
ARCH	Autoregressive Conditional Heteroskedasticity
ARCH-LM	ARCH Lagrange Multiplier
AR-GARCH	Autoregressive GARCH
ARIMA	Autoregressive integrated moving average
BP	Back Propagation
BPNN	Backpropagation Neural Networks
BPTT	Backpropagation Through Time
CAPM	Capital Asset Pricing Model
CCF	Cross-Correlation Function
CHT	Chunghwa Telecom
CWT	Continuous Wavelet Transforms
DWT	Discrete Wavelet Transforms
EGARCH	Exponential GARCH
FIGARCH	Fractionally Integrated GARCH
GARCH	Generalized Autoregressive conditional heteroskedasticity
GARCH-M	GARCH in Mean
GCC	Gulf Cooperation Council
GED	Generalized Error Distribution
RNHD	Risk Neutral Historic Distribution
GJR-GARCH	Glosten-Jagannathan-Runkle GARCH
HV	Historical Volatility
IGARCH	Integrated GARCH
IOSCO	International Organization of Securities Commissions
KSA	Kingdom of Saudi Arabia

LA8	Wavelet Filter
LSTM	Long Short-Term Memory
MAE	Mean Absolute Error
MAPD	Mean Absolute Percentage Deviation
MAPE	Mean Absolute Percentage Error
MARS	Mean Autoregression Scale
MASE	Mean Absolute Scaled Error
MODWT	Maximum Overlap Discrete Wavelet Transform
MRA	Multi-Resolution Analysis
MSE	Mean Square Error
OPEC	Organization of the Petroleum Exporting Countries
RMSD	Root-Mean-Square Deviation
RMSE	Root Mean Squared Standard Error
RNN	Recurrent Neural Network
SRCS	Stepwise Regression-Correlation Selection
TASI	Tadawul All Share Index
TSEM	Tadawul Stock Exchange Market
UK	United Kingdom
US	United States
WFE	World Federation of Exchanges

KAEDAH WAVELET DISKRIT BERTINDIH MAKSIMUM UNTUK PEMODELAN PERTUKARAN SAHAM SAUDI

ABSTRAK

Kajian ini meramalkan kemeruapan saham berdasarkan kaedah heteroskedastisiti bersyarat autoregresif teritlak (GARCH) berdasarkan wavelet. Ia membina model ramalan berdasarkan kaedah GARCH, kaedah autoregresif purata bergerak bersepadu (ARIMA) dan transformasi wavelet diskret bertindih maksimum (MODWT) berdasarkan model terbaik fungsi setempat (Bl14). Matlamatnya ialah untuk mengukur kemeruapan ramalan pasaran saham melalui model spektrum tak linear, model GARCH, yang merupakan GARCH am (gGARCH), heteroskedastisiti bersyarat autoregresif teritlak eksponen (EGARCH) dan fungsi Glosten-Jagannathan-Runkle-GARCH (GJR-GARCH), MODWT berdasarkan fungsi setempat terbaik (Bl14) dan model ARIMA. Juga, kajian ini akan membina model ramalan berdasarkan kaedah GARCH, ARIMA dan MODWT berdasarkan model fungsi setempat terbaik (Bl14). Model yang dibina digunakan di pasaran saham Saudi dari Ogos 2011 hingga 31 Disember 2019. Hasil kajian menunjukkan bahawa pasaran saham Saudi menyaksikan kemeruapan yang tinggi dalam beberapa tempoh. Pulangan pasaran menunjukkan taburan yang tidak normal yang menunjukkan kemeruapan yang tinggi di antara pulangan. Kemeruapan harga penutupan dan pulangan tertinggi direkodkan pada 2015 dan 2016. Model GARCH (1,1) adalah model terbaik yang digunakan untuk mengukur kemeruapan. Ketidakstabilan disemak dan dipaparkan menggunakan MODWT berdasarkan keupayaan B114. Kaedah hibrid ialah kaedah terbaik untuk mencapai ramalan harga penutupan dan pulangan dalam Pasaran Tukaran Saham Tadawul (TSEM). Kaedah hibrid ialah kaedah terbaik untuk mencapai ramalan harga penutupan dan pulangan dalam TSEM. Kajian mengesyorkan model GARCH berdasarkan taburan normal adalah yang terbaik untuk mengukur kemeruapan, dan kaedah hibrid adalah kaedah terbaik yang boleh digunakan untuk peramalan.

MAXIMUM OVERLAPPING DISCRETE WAVELET METHODS FOR MODELLING THE SAUDI STOCK EXCHANGE

ABSTRACT

This study forecasts the stock volatility based on wavelet-based generalized autoregressive conditional heteroscedasticity (GARCH) methods. It builds a forecast model based on GARCH methods, autoregressive integrated moving average (ARIMA) method, and maximum overlap discrete wavelet transform (MODWT) based on the best-localized function (Bl14) models. The aim is to measure the volatility of stock market forecasting through the non-linear spectral model, GARCH models, which are general GARCH (gGARCH), exponential generalized autoregressive conditional heteroscedasticity (EGARCH) and Glostsen-Jagannathan-Runkle-GARCH (GJR-GARCH) functions, MODWT based on best-localized function (Bl14), and ARIMA model. Also, the study will build a prediction model based on GARCH, ARIMA and MODWT methods based on best-localized function models (Bl14). The developed model was used in the Saudi stock market from August 2011 to December 31, 2019. The study results show that the Saudi Stock Exchange Market witnessed high volatility in several periods. Market returns show a non-normal distribution indicating high volatility among returns. The highest closing price and return volatility was recorded in 2015 and 2016. The GARCH (1,1) model is the best model used to measure volatility. Instabilities are checked and displayed using MODWT based on B114 capabilities. The hybrid method is best for forecasting closing prices and returns in Tadawul Stock Exchange Market (TSEM). The study recommends that the GARCH model based on the normal distribution is the best for measuring volatility, and the hybrid method is the best method that can be used for forecasting.

CHAPTER 1

INTRODUCTION

1.1 Study Background

The country's economic situation can be reflected through the index of the financial market that works as a mirror of the economy. It helps to predict its future economic situation within restrictions related to the degree of market efficiency and its breadth, such as tracking the movement. Thus, it reflects the general direction of the movement of stock prices and is a comprehensive measure of the direction of the market movement. Stock prices reflect the expectations of economic events that prevail in the future. So, the trend in the index level will reflect the current economic situation, which helps the economic decision-makers to choose the right actions. In addition, the prediction of the financial market index is considered a subject to the field of continuous studies by investors. They make their investment decisions based on the forecast of future events. Volatility in the stock market is a measure of the degree of variation of a stock's price over time. Various factors, including changes in market sentiment, economic conditions, company-specific news or events, and global events such as political instability or pandemics can cause it. High volatility is associated with increased risk because it indicates that the price of a stock is fluctuating rapidly and unpredictably, making it difficult to predict future returns.

Effective risk management in the stock market requires accurate modelling and forecasting of volatility. Understanding the sources of volatility and the factors that drive it can help investors and market analysts develop effective risk mitigation strategies and make informed investment decisions. Therefore, volatility is an important aspect of the stock market that market participants closely monitor and analyze. Moreover, the financial markets witness an excellent interest for the researchers and analysts who are trying to predict the trends of the index market and the securities prices traded in it. The measure of volatility relies on many traditional and modern forecasting methods to make rational investment decisions at the right time.

The study of financial time series witnessed great importance at the end of the twentieth century because of its characteristics that make the process of analyzing and studying them complicated because of their random movement. The difficulty of analyzing and modelling a series of financial indicators increases with the increasing level of market efficiency. Of course, these fluctuations are not preferred by investors or decision-makers because it increases the degree of risk and the possibility of achieving unexpected losses. The autoregressive conditional heteroskedasticity (ARCH) model was used to implement price-return volatility modelling in the UK for the first time (Engle, 1982). The use of the model has shown the changes in stock markets and vice versa. This phenomenon was dubbed cluster volatility. Based on the assumption of a constant conditional average return value, Engle has measured pooling effects, but the ARCH model cannot capture the other typical volatility features (Gencay et al., 2001). MODWT filters enable the emergence of properties approximation, instability, and multiple resolutions. Besides, MODWT is considered a direct tool for studying various properties of numerous solutions. Different time scales can analyze different time series due to their ability to specify the process's local and global dynamic characteristics. They show the combinations of volatility and structural discontinuities. Their ability is also used to find the correlation structure across time scales.

1.2 Problem Statement

Predicting the direction of stock prices and their fluctuations has become a major requirement, especially after the financial markets have become one of the most important ways to invest in many countries. Investors have generally tended to invest in the financial markets in recent years, particularly in the Kingdom of Saudi Arabia. They used two common analytical approaches to analyze the stock market. The two approaches are regarded as fundamental and technical analyses. Fundamental analysis relies on macroeconomic data statistics such as interest rates, money supply, inflation rates, and foreign exchange rates, as well as a company's underlying financial position. After all these factors are considered, a decision can be taken by the analyst to sell or buy a stock. In contrast, technical analysis is based on historical financial time series data. Financial time series show complex patterns such as high volatility and un-normal distribution returns. The Saudi Stock Exchange is a crucial component of the country's economy, and accurate modelling and forecasting of its behaviour are essential for investors and market analysts. However, the precise modelling and forecasting of the stock market, particularly with regard to volatility, remains a challenging task. Traditional time series analysis techniques may not be sufficient to capture the complex and dynamic nature of the stock market. Therefore, there is a need to explore and develop alternative modelling and forecasting techniques that can provide improved accuracy and reliability in predicting the behaviour of the Saudi Stock Exchange.

The main problem addressed in this study is the need for accurate modelling and forecasting of the Saudi Stock Exchange, particularly with regard to volatility. The existing literature has explored various modelling and forecasting techniques, including Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models, Autoregressive Integrated Moving Average (ARIMA) models, and wavelet-based methods. However, there is still a need to investigate the potential of the Maximum Overlapping Discrete Wavelet method (MODWT) for modelling and forecasting the Saudi Stock Exchange, particularly with regard to volatility.

The specific problem addressed in this study is the lack of comprehensive research on the application of the MODWT method in modelling and forecasting the Saudi Stock Exchange, particularly with regard to volatility. The use of the MODWT method can potentially provide more accurate and reliable predictions of stock market behaviour, thereby improving investment decision-making and risk management strategies. Therefore, this study aims to contribute to the existing literature on financial modelling and provide valuable insights for investors and market analysts in the Saudi Stock Exchange.

1.3 Research question

Thus, regarding the question of how to model the Saudi Stock Exchange using the maximum overlapping discrete wavelet methods (MODWT), this research works to answer these questions:

a) How can we forecast the stock volatility based on wavelet-based generalized autoregressive conditional heteroscedasticity methods?

b) Can the study build a forecast model based on generalized autoregressive conditional heteroskedasticity (GARCH) methods, (ARIMA) method, and (MODWT) based on the best-localized function (Bl14) models?

c) How can measure the volatility of stock market forecasting through the non-linear spectral model, generalized autoregressive conditional heteroscedasticity (GARCH) models, which are general GARCH (gGARCH), exponential generalized autoregressive conditional heteroscedasticity (EGARCH) and Glosten-Jagannathan-Runkle-GARCH (GJR-GARCH) functions, maximum overlapping discrete wavelet transforms (MODWT) based on best-localized function (Bl14), and autoregressive integrated moving average (ARIMA) model?

1.4 Research Objectives

The main objective of this study is to model the Saudi Stock Exchange using the maximum overlapping discrete wavelet methods (MODWT), through the accomplish the following objectives:

a) To forecast the stock volatility based on wavelet-based generalized autoregressive conditional heteroscedasticity methods.
b) To build a forecast model based on generalized autoregressive conditional heteroskedasticity (GARCH) methods, (ARIMA) method, and (MODWT) based on the best-localized function (Bl14) models.
c) To measure the volatility of stock market forecasting through the non-linear spectral model, (GARCH) models which are general GARCH (gGARCH), exponential generalized autoregressive conditional heteroscedasticity (EGARCH) and Glosten-Jagannathan-Runkle-GARCH (GJR-GARCH) functions, maximum overlapping discrete wavelet transforms (MODWT) based on best-localized function (Bl14), and (ARIMA) model.

1.5 Research Significance

Stock market studies have chiefly focused on developed economies utilizing various models to investigate their effects empirically. Consequently, due to the disparities inherent in a different context, applying a single-most model for unravelling the impact of stock market volatility may need to be more consistent and accurate. This is because developing economies may display market indices not explicitly possessed by their superior developed counterparts. The difficulty continues in adopting an efficient quantitative tool with a suitable measurement tendency. It conscripts all the antecedents that are based on a volatility model and volatility of stock markets in the field of developing economies. This is important because developing economies offer a more comprehensive range of possibilities for foreign investors to make a profit.

1.6 Limitations of the Study

This study needs to consider several limitations regarding the application of Maximum Overlapping Discrete Wavelet methods (MODWT) for modelling the Saudi Stock Exchange. These include limitations related to data availability, model assumptions and specifications, types of data and volatility, and the choice of wavelet functions.

One of the primary limitations of this study is the availability of data. The accuracy and reliability of the modelling and forecasting results will depend on the quality and quantity of data available for analysis. Moreover, the quality of the data can be affected by factors such as missing data, data errors, and data outliers, which can affect the overall accuracy of the results.

Another area for improvement concerns the assumptions and specifications of the models used in this study. The accuracy of the forecasting results will depend on the validity of the assumptions made by the models, such as the assumption of normality in the distribution of the residuals. Violation of these assumptions can lead to biased and inconsistent results.

1.7 Organization of the Thesis

The objective of the thesis is to provide a comprehensive analysis of the Saudi financial market and its behaviour, especially with regard to fluctuations. To achieve this goal, the researcher divided the study into six chapters, as follows: The second chapter presents a large number of related literature related to this topic. It clarifies some controversial issues in the literature about the fluctuations of stocks and the expected returns in the financial markets. The chapter also explains the fluctuations in the financial markets and their impact on investors’ decisions. In addition, it clarifies the extent of its impact on the investors' portfolios and the liquidity of their investment portfolios. The third chapter dealt with the approach followed in the thesis, discussing volatility models, examining the characteristics of each model, and what are the methods used to estimate the parameters of the model, which were carefully discussed. It also described the design of the model and discussed the statistical tests used in the thesis. The fourth chapter dealt with the results and discussion through the use of the closing price of the Saudi stock market for the period between (2011-2019). In this chapter, the models are described to be used in measuring price fluctuations and comparing them to find out which modern models are more accurate in predicting prices. Chapter five discusses the results that introduce the history of the Tadawul Stock Exchange Market (TSEM) in Saudi Arabia. It also discusses the results of the models used to forecast the volatility in the TSEM market. Finally, chapter six states the conclusion based on the results. It clarifies the recommendations for the use of the suggested models.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many investors in the financial market prefer to accept relatively low returns and avoid investments with high risks. It is impossible to imagine an investment that protects its owner from risks, invests in stocks, and exposes investors to multiple risks, including what may result from a decrease in the value of the stock. When investors decide to invest in the stock market, it is necessary to find scientific methods that study fluctuations in stock prices and model economic phenomena to help the investor predict future values, which are still considered a thorny and complicated issue nowadays.

2.2 Volatility Models

Volatility models are statistical models that capture the dynamics of volatility, or the degree of variation in the price of a financial instrument over time. There are many different types of volatility models, each with its own strengths and weaknesses. Some popular examples of volatility models include the GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model, which is widely used in financial time series data and models the conditional variance of a time series as a function of its past values and past variances. Another popular model is the SV (Stochastic Volatility) model, which is more flexible and allows for the volatility to evolve dynamically over time (Dritsaki, 2017).

The EGARCH (Exponential GARCH) model is a variation of the GARCH model that allows for asymmetric effects of positive and negative shocks on volatility. The ARCH (Autoregressive Conditional Heteroskedasticity) model is an earlier version of the

GARCH model that models the conditional variance of a time series as a function of its past values only, without considering past variances. Finally, the HAR (Heterogeneous Autoregressive) model captures the persistence of volatility and models the conditional variance of a time series as a function of its past values, past variances, and past realized volatility over different time horizons (Natsir, 2018).

Every economic relationship in any trading environment is based on the principle of risk and returns, where investors and traders review their investment decisions based on risk and return estimates. Moreover, in the money market, these estimates are calculated based on the concept of volatility. Volatility describes the variation of the potential results of the investment. Since the emergence of financial markets, the authors explained the interrelationship between volatility and return and its development passing time. This is the reason for the emergence of many theories and literature about financial time series. The statistical returning variables reflect the mechanisms that drive the generation of the return.

Mutasem and Naomie (2019) believe that the relationship between risk and return is the mechanism underlying each economic transaction that occurs in any trading environment. In the financial market, there is no exception, as investors and traders constantly review their decisions and strategies based on varying estimates of risk and return. The broad concept is also clarified relative to risk through the concept of 'volatility', describing the variability of potential investment outcomes. Several authors have attempted to explain the complex interrelationship between return and volatility and its evolution over time, particularly in the field of resulting in an impressive body of literature on financial time series.

Nikolić (2019) explained that the financial time series of stock prices that often exhibit cluster volatility phenomena due to the arrival of diverse information from different sources, external economic events, and other undesirable events like wars have a huge impact on the stock price time series pattern. In most cases, financial time series behave in a way that is inconsistent with a normal distribution. There are several inflated facts based on individual ones that support the claims. There is a natural level of volatility to which volatility will eventually return. Gourieronx and Jasiak (2007) also claimed that the long expectations of volatility are related to the natural level of volatility, and these facts change with discoveries. There is a variation in those facts from one market to another.

It is observed that the volatility behaviour causes invariance in the dependence structure of the absolute changes, and the squared returns “long memory”. According to the traditional approach and defining the volatility of returns, it constantly changes. Among the most prominent facts that are achieved by the authors and researchers, the abnormal heavy-tailed distribution of returns is used. The negligible correlation between individual returns is separated from the short-range correlation due to the microstructural effects. With a large autocorrelation of their absolute values that remains very constant in the long run, many econometrics have achieved a satisfactory fit with the empirical data.

In connection with the above discussions, the comprehensive modelling of volatility requires an approach that can include information on the behavior of volatility in both frequency and time models. As a result, examining daily financial prices at various metrics will provide important insights regarding essential components of volatility dynamics.

2.3 Wavelets History

The origin of wavelets is traced back to Joseph Fourier in 1807 when he proposed a new way to look at time series, which he called the Fourier Series. Generally, there are two ways that time series can be considered: The first is called "the frequency model", which is often represented by the Fourier Transform (FT). The second way is the time model. However, there are drawbacks to these two methods. When a method is used, the other one is excluded. It means there is no method that both methods can use the frequency model and time model at the same time. This changed with the advent of waves. The first step forward was taken by Alfred Haar (1910), who proposed an orthogonal system of functions defined in [0,1]. He found the simplest possible wavelet, which is now called a Haar Wavelet (Haar).

However, it is not constantly distinguishable, so its application is limited. Littlewood and Paley (1931) also investigated the localization of energy in the Fourier Transform (FT), in which he used pairwise blocks to analyze time series and then applied the Fourier Transform to it. The results of the method showed that it is impossible to save energy. The results also differ when it is focused on some points or distributed over a larger period. Coifman and Weiss (1977) later interpreted Hardy spaces regarding atoms and their decay. They became one of the mainstays of wavelet theory. Goupillaud et al. (1984) formulated the continuous wavelet transformation. Mallat (1989) standardized the wavelet theory and introduced the analysis of multiple resolutions. Later, Daubechies (1992) built on Malat's discoveries (1989) and also built a family of perpendicular waves with compressed supports. Nowadays, a wavelet is a tool used in many fields of science, and finance is one of them.

The application of wavelet in financial analysis is based on its ability to provide feedback using time and frequency changes. This is crucial in financial analysis as most variables behave differently over time. This gives the wavelet the advantage of decomposing data over a wide range of time to predict the volatility over time. The wavelet decomposition of the financial data will facilitate the second stage concentration on applying econometrics to analyze the data (Nguyen and He, 2015). Moreover, the wavelet only requires a few assumptions to start the analysis. This will improve the financial analysis since the structure of the financial analysis is complicated. The third benefit of wavelet is related to the ability of wavelet to find discontinuities in data which will facilitate the researchers to determine the times of shifts in data.

2.4 History of Volatility Models

Time series analysis in the financial markets is one of the most widely used methods for predicting future values. Forecasting is a necessary process that has a role in decision-making, formulating economic decisions, future planning, and forecasting financial market indicators. Forecasting attracted the interest of investors to invest in this market, as forecasting helps to know the degree of risk. It helps to achieve the largest possible amount of profits and avoids potential losses. The current study uses the volatility models to predict the share's future values, and the following explains the models used in the study.

Volatility modelling methods, one of the most important components of value at risk estimation, is the use of the *autoregressive conditional heteroskedasticity* (ARCH) model Taylor (1986) and (Engle, 1982), Bollerslev (1986) have independently generalized the ARCH model. ARCH has volatile aggregation and is considered the most common method (Teräsvirta, 2006). According to Andersen et al. (2007), univariate models can be used to measure the risk side by side with the use of multivariate GARCH to manage portfolio risk. The univariate models can improve volatility prediction (Andersen & Bollerslev, 1998). The developments of the GARCH model are very widespread nowadays. Poon and Granger (2003) reported that ARCH is more dominant than GARCH. On the other hand, exponential GARCH (Nelson, 1991) and GIR-GARCH (Glosten et al., 1993) as asymmetric models that perform more powerfully than the original GARCH. According to Hansen and Lunde (2005), the GARCH model performed more powerfully compared to other models when used for forecasting exchange rate volatility. The other models' outcomes are more powerful when measuring the effects of the leverage for stocks. Both Köksal (2009) and Hung and Jui (2010) approved the previous results through model testing.

Various studies have examined the issue of error generated by the GARCH model. Bollerslev (1986) introduced the use of the student's t distribution as an alternative to the Normal distribution, which was initially assumed by Bollerslev (1986) and Engle (1982), in order to address the error problem in the GARCH model. Nelson (1991) proposed the utilization of the Generalized Error Distribution (GED) as another density function that accounts for fat tails. Furthermore, Hung-Chun and Jui-Cheng (2010) conducted tests on different distributions, including the skewed generalized (SGT) distribution, which revealed its relevance in the GARCH model. The choice of error distribution impacts volatility forecasting, with the leptokurtic error distribution demonstrating improved performance compared to the normal distribution. In this study, three distributions, generalized error distribution, student's distribution, and normal distribution, are employed. The GARCH model proves to be the most suitable for non-stationary series data. Consequently, various spectral models like Wavelet Transform (WT) can be employed to render the data stationary and achieve smoother results.

2.5 Related Literature

2.5.1 Related Literature to GARCH Models

The financial markets stylized facts in the natural path of GARCH's application of symmetrical and asymmetrical GARCH (1,1) types of models to historical financial data. Symmetric and asymmetrical GARCH (1,1) models impose an autoregressive structure at the conditional variance of the financial time series. This enables volatility shocks to persist through time. The symmetric and asymmetric GARCH (1,1) models are considered Martingale variations, leaving unbiased predictions. GARCH (1,1) model can be used for conditional financial market volatility, which enables the prediction of future stock returns (Natsir, 2018). GARCH (1,1) can also be used to follow up on the volatility behaviour of the financial time series. The GARCH (1,1) model was found to suit both the individuals and indices stocks (Lamoureux and Lastrapes 1990). EGARCH (1,1) is the extended form of GARCH (1,1), which was developed by Nelson (Dritsaki, 2017). The stock returns are more practical to be modelled using the EGARCH (1,1). Using EGARCH (1,1) allows for a stopping signal to return in the asymmetry. The algorithms of EGARCH (1,1) make it possible to avoid non-negative conditions forcing on the parameters. The impacts of anomalies on assessment results are avoided (Abdulla et al., 2017).

According to Chen et al. (2019), another more critical group of homologous (1,1) GARCH models is the threshold conditional autoregressive (TGARCH) model. The model solves the problem of the probability that the conditional standard deviation of the EGARCH model is either exactly zero or very close to zero. Another drawback of the EGARCH model is its assumption that the effect of negative and positive volatility remains constant over time. The other limitation of the EGARCH model is that the linear model includes a moving average formula in the natural logarithm of squares conditional standard deviation process. It was noted that the TGARCH model is superior to the EGARCH model. By incorporating nonlinear effects into the conditional variance, the GARCH model maintains linearity when the data does not contain nonlinearity.

Alom et al. (2012) said that understanding the nature of fluctuations in commodity prices requires more attention because this type of volatility will often lead to increased production costs and opportunity opportunities, as well as accelerate uncertainty and risk. Contributes to a slowdown in economic activities. The study also investigated the asymmetry and continuity in the variability of the group of future cost returns for gasoline within a system of asymmetric conditional autoregressive (GARCH) models. The review by Alom et al. (2012) explicitly utilized threshold GARCH, exponential GARCH, asymmetric power ARCH, and component GARCH models to utilize day-to-day data from 1995 to 2010. The review discloses that: (1) Over the period 1995 to 2010, all future price returns show determined and uneven impacts of the shock wave to the instability. Yet, the degree of persistency and level of deviation varies from one item to another. (2) Throughout the period 1995–2001, persistency and asymmetry are evident for all series except for premium motor spirit future price returns. The recent subsample of 2002–2010 shows the persistent effect, and all series show ongoing effects of shocks to the volatility. In contrast, the asymmetry is supported in crude oil and propane only.

Kalyanaraman (2014) studied the market volatility and used the GARCH model for the daily data. He estimated the conditional volatility of the stock market by applying the AR(1)-GARCH(1,1) model to the daily stock returns from 2004-2013. He applied the following models to study the volatility: (1) The symmetric linear GARCH model

(1, 1) is suitable for estimating stock market volatility. (2) The stock market returns are characterized by volatility and an unusual distribution. The returns of the Saudi stock market showed erratic fluctuations all the time. It showed stability that can be expected. It was found that the previous fluctuations appear in the volatility of the current period. (3) Some markets are nervous in their reactions to market fluctuations. Coenrad et al. (2015) compared the variance deviations resulting from the use of the RNHD model in the BRIC countries resulting from the use of the E-GARCH and GJR-GARCH models. The study also investigated the effect of different interest rates on the implied volatility deviations of European call options.

The conclusion found that the two GARCH models produced similar results but differed significantly from the Risk Neutral Historic Distribution (RNHD) model. The argument that the RNHD model implicitly calibrates only one parameter of the historical return time series rather than the four parameters used by the GARCH models may mean that the GARCH models are more accurate than the RNHD model. The final section shows the fixed interest rates that GARCH models produce more accurate results than the RNHD model.

For the most part, two unique approaches exist for stock cost expectation utilizing ANNs. The general idea of stock price diversification as a time series and the future price of the price can be predicted by using the historical data for the stock. This approach involves ANNs as indicators. These forecast models endure constraints inferable from the tremendous commotion and high dimensionality of stock cost information. Subsequently, none of the current expectation models has acceptable execution. A second methodology for stock cost expectation has recommended some specialized files and subjective variables to be applied. Different endeavours have been made to figure out monetary business sectors that reach from customary time series ways to deal with man-made reasoning strategies, including ARCH-GARCH models, ANNs, and transformative calculation techniques.

Mubarok and Sutrieni (2021) studied the stock return volatility using the GARCH model. The study was applied to the Indonesian Stock Exchange Market from January 2014 to December 2019. The study applied the ARCH-GARCH model in volatility analysis. The testing was carried out in two stages. The first stage concentrated on the model specification, while the second stage concentrated on calculating parameters and reaching the variance model. The results showed that the GARCH model was suitable for measuring the volatility of returns.

The researcher Mubarok (2020) studied the volatility return pattern of an index stock using the GARCH model to know the behaviour of volatility patterns in combined stocks using the (GARCH) model. Data variability is observed using the GARCH model. The results of daily data estimates showed that stock volatility is affected by the error and return volatility of the previous day, indicated by the effecting of GARCH on each regression. The results also showed that the tested model GARCH passed the ARCH- Lagrange Multiplier test serial correlation, indicating that the GARCH model was correctly selected.

The extreme risk spillovers were used to investigate the role of gold as a haven and the US dollar (Xiaomeng, 2020). The value at risk was used to measure the extreme risk. The extreme risk was measured using the GIR-GARCH model that follows the skewed distribution. Extreme risk spillover was detected using one and two-way causality in risk. The study concluded that gold was used as a haven for the US dollar in times of oil shift in global markets before the financial crisis and failed after the global crisis. These conditions were not applied in the Japanese and American stock markets before and after the global crisis. As for the Chinese stock market, gold was a haven before the crisis but advanced slightly after the global financial crisis also contributed to an increase in the role of gold as a haven for stock markets. On the other hand, the effects of indirect risks are transmitted from the stock markets to the gold markets. It differed from the risks usually transmitted from the gold markets to the stock markets. Moreover, the study found that the US dollar was generally a weak haven for the Chinese market throughout the study, while it was effective in the Japanese and US stock markets before the crisis, and its impact decreased after the crisis. These findings have important implications for risk managers and international investors when reallocating portfolios from high-risk to low-risk assets during different market conditions.

Petri (2020) studied the characteristics of fluctuations in the Nordic countries (Finland, Sweden, Norway, Denmark and Sweden) and how the global financial crisis affected them. He also analyzed the natural developments of business sectors in the long run. The researcher broke down the daily proceeds of important files for countries addressing each other's monetary states from January 2006 to July 2011, which led to the worldwide monetary emergency. The researcher divided the study period into two sub-periods: the crisis and post-crisis time frame. They examine the effects of the crisis. Using a univariate EGARCH model, which allows model of the ling of conditional time series fluctuations and asymmetric responses to shocks. The study designed the conditional association with the ADCC-EGARCH model,

More about translation consequences of the review showed that there is a bunch of vacillations in every series and that the solidness coefficient, which was estimated and expanded after the emergency except for the instance of Iceland. The results of the study also showed the effect of leverage in each chain, which decreased after the crisis. They indicated that positive news had a greater impact on volatility. They found that the joint movements of countries vary over time and that the differences are sometimes relatively large. Nevertheless, the movements lasted only a short time, and it was found that the crisis did not affect the joint movement. The crisis contributed to an increase in volatility, but it did not affect the correlation.

Misha (2021) studied the relative performance in predicting volatility of the standard GARCH, EGARCH, GJR-GARCH, and TGARCH models in crisis periods. The daily price indices of the NASDAQ, Dow Jones and S&P500, indices were analyzed. The test periods consist of the Internet bubble, the financial crisis, and the COVID-19 crisis. The results of the study showed that the negative deviation of the data indicates the inconsistency of all data. It is expected that asymmetric models will be able to predict more accurately, especially during crisis periods. The asymmetric models also facilitate the modelling of large negative shocks associated with stock market crashes. On the other side, these capabilities are not comparable with that of the GARCH model, which is capable of outperforming the GJR-GRACH and TGARCH models in the three data sets. The results showed that they were inconsistent with the literature on the topic. Much research was done in the 1990s and early 2000s on the four models, meaning the current literature is outdated. However, all models are still frequently used, as they are easy to apply and understand. It also helps managers who decide which model to use base their decisions on historical research. It leads them to choose one of the asymmetric models. Since the accuracy of volatility predictions is most important in times of crisis, using an asymmetric model over the standard GARCH model may result in poor performance. The study's results also show that the GARCH model, assuming at distribution, provides more accurate predictions in times of crisis, particularly when it is contrary to previous beliefs.

2.5.2 Related Literature to Wavelet Transform

Through Al-Enezi (2021), the reasons for financial exchange instability and displaying of different conduct are additionally determined to address the exactness of assumptions and the level of potential dangers. By consolidating MODWT capabilities with the ANFIS model and utilizing measurable rules like MAE, RMSE, MSE, and MAPE, the gauging exactness is improved, and another estimating model is proposed. The model MODWT-LA8-ANFIS has been contrasted with customary models (ARIMA and ANFIS models*)*. The MODWT-LA8-ANFIS is more exact than conventional models. The new proposed anticipating model can be summed up to conjecture in other worldwide financial exchanges. Besides, this model is adequately strong to streamline business processes for the monetary improvement of a country.

Afshan et al. (2018) applied the wavelet approach to study the relationship between stock prices to exchange rates. Continuous WT was used to determine the causal relationship between the exchange rate and the stock market. The study was divided by time-frequency to study the causal relationship. For associations in the financial markets, the study indicated that some studies in the past used the temporal model's approach. It turns out that these correlations do not differ across frequencies, but they may change in the future. This method can support the extraction of economic-temporal frequency correlations that have not yet been captured.

The study showed the flexibility of the wavelet approach and its applicability to both fixed and non-stationary time series. The main drivers or processes within the data are largely preserved. The feature of the wavelet method is applied without any limitations. This is considered one of the main advantages of wavelet analysis in that it can perform local analysis, which is a local analysis of the sub-area of a larger image (or signal).

Therefore, it reveals some aspects of the data that other signal analysis techniques usually miss. Convolutional time series analysis of economics has been a longstanding challenge for academics and practitioners. Because historical data is the result of complex systems, structural changes, behavioural policy shifts, disproportionate linkages, crises, shocks, wars and volatility, these events lead to some of the key systemic facts in financial time series, including the presence of outliers, nonlinearity, fat tails, and asymmetry. Ignoring these irregularities during statistical modelling tasks can lead to misleading conclusions.

Yugiao Li et al. (2016) developed a hybrid forecasting system using multiple scales. It forms an integration method for prediction. The developed method utilized the decomposition of original data into multiple layers using wavelet transform. It is relevant to the division of multiple layers into low and high-frequency signal layers and intermediate frequencies. The ARIMA models are used to predict future values for the three types of frequencies. This model is considered effective in the field of predicting stocks' prices. According to Yugiao et al. (2016), the data of the stock markets is considered non-stationary and highly random, making much noise. The hybrid forecasting system was the solution for the stock market's high variations. The procedure applied in this method depended on decomposing the data into multiple layers of different frequency levels, followed by the application of ARMA models to predict the low frequencies layer. Kalman filter was used to predict the intermediate frequency layers, while Back Propagation (BP) was used for the high-frequency signal layers.

Limiao et al. (2015) proposed a frequency model. It has been proposed to predict key turning points in stock markets. This indicator has been successfully applied to the United States, and the System Adaptation Framework has an internal adaptive model for capturing fast and slow market dynamics, respectively. The remnants of the internal model were found to contain rich information about market cycles. To extract and recover useful frequency components, the multiple wavelet analysis, including time parameters to decompose these internal residuals, is already used. Then a demo indicator is proposed based on the retrieved signals to predict the turning points of the market. The study used an internal model that captures the dynamic characteristics of the money market and generates a rich residual of signals that help predict turning points. The MRA of DWT and MODWT is used to analyze internal residues 430 and extract more intermediate frequency signals. By analyzing the slope of the feedback, a tipping point prediction indicator is proposed. Comparing the results of DWT with MODWT, it was found that DWT performs better with this indicator.

Theo (2015) transforms the financial return series into an iteration-with-time model through wavelet decomposition to separate short-term noise from long-term trends and then assess the relevance of each iteration to the VaR. Moreover, he also calmly analyzed financial assets. The results showed that turbulence sometimes occurs in the market, and the daily percentage of forecast value at risk of 95% is mainly driven by volatility. It is captured by the first metrics that include the short-run data.

The researcher Tsung et al. (2011) combined wavelet transform and (RNN) because of (ABC) artificial bee colony algorithm (called ABC-RNN) is consolidated for the determining of stock price. The framework involves three phases. To start with, the wavelet transform utilizing the Haar wavelet is applied to break down the stock price time series and, in this manner, dispose of noise. Second, the RNN, which has a straightforward design and uses various essential and specialized pointers, is applied to develop the info highlights picked through stepwise regression-correlation selection (SRCS). Third, the algorithm of an artificial bee colony (ABC) is used to streamline the RNN biases and weights under a boundary space plan, for outline and assessment purposes. The conclusion from the study found that one model that might be more effective than others in stock return is the (ANN).

Ling et al. (2013) proposed a three-stage approach. First, use the wavelet transform. Through variable analysis to predict different functions and decomposition stages to obtain sub-series. Second, to identify the most important substring among the substrings obtained from the wavelet transform through the use of MARS. Third, applying the selected sub-series containing factors affecting prediction accuracy in SVR as new input variables to build a prediction model. This approach is to evaluate the performance of the proposed method and to compare the prediction accuracy. The result shows that the proposed Wavelet-MARS-SVR approach has better prediction accuracy and can not only solve the problem of variable selection only. It is to identify the most important periods that affect the rise and fall of the stock index. This study contributed to the relevant literature among three aspects: (1) Investigating the basic functions in generating specific sub-strings using the results and identifying the best wavelet rule functions in prediction. (2) Analyzing the significance of the selected important sub-series in relation to the stock price data to find out (time points) among the previous stock prices that significantly influenced the construction of the prediction model. (3) Among the important sub chain identified by MARS, the proposed Wavelet-MARS-SVR approach can build the prediction model more efficiently because the build time of Wavelet-MARS-SVR only includes two-thirds of Wavelet-SVR.

Ling et al. (2013) concluded that the proposed approach of the experimental study could not only solve the wavelet substring selection problem but also showed that it is superior to other competing models. According to the chosen sub-series, it is possible to select the special data (or time points) among the previous stock prices, which can have an impact on building the prediction model by the proposed approach.

Lahmiri's (2014) forecasting model integrates discrete wavelet transform (DWT) and inverse neural networks (BPNN). They are used for financial time series forecasting. The first presented model uses DWT to analyze financial time series data. Then, the obtained approximation (low frequency) and detail (high frequency) components predict future stock prices after analyzing the original time series as input variables. Indeed, while high-frequency components can capture discontinuities, tears, and singularities in the original data, low-frequency components characterize the coarse structure of the data to identify long-term trends in the original data. As a result, the high-frequency components act as a complement to the low-frequency components. The model was applied to seven data sets. Accuracy measures showed that the presented model is superior to the traditional model that uses low-frequency components, and the presented model is superior to both the well-known Autoregressive Moving Average (ARMA) model and the random walk (RW) process. The automated stock price prediction system consists of three steps: (1) the time series of the original stock price is processed through the use of a discrete wavelet transform (DWT); (ii) they extract the approximation coefficients a(t) and the details d(t) to form the main property vector characterizing the original time series; and (iii) the resulting characteristic vector feeds the input into a backpropagation neural network (BPNN).

The simulation results showed that the coupling of the low-frequency components with the high frequency led to a higher accuracy compared to the traditional model that uses low frequency to predict future stock prices. In addition, the current model outperformed the ARMA model and the random walk process. The current model is