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ORIGINAL PAPER

Estimating Fluctuating Volatility Using Advanced Garch Models: Evidence from Denmark Stock Exchange

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Abstract:
In the stock market, volatility is a term used to describe the degree to which the prices of assets oscillate and determines the level of risk or uncertainty. The foremost objective of the present analysis is to model the behaviour of the Denmark stock market using data from December 20, 2016, to September 20, 2023. Through the application of GARCH family prototypes which, include GARCH/TARCH, EGARCH, Component ARCH (1,1), and PARCH. The analysis used a sample number of 1668 daily observations for OMXC 25 or OMX Copenhagen 25 Stock Index representing the Denmark stock market. We used some statistical techniques such as Phillips-Perron and Augmented Dickey Fuller tests, Kwiatkowski-Phillips-Schmidt-Shin test statistic, The ARCH Lagrange Multiplier (LM) test, PARCH model. We utilized the E-Views 12 Econometrics package. This empirical investigation adds to the corpus of financial econometrics and emphasizes the importance of precisely and painstakingly modelling the behaviour of stock markets. Our ability to forecast market movements and make informed decisions in a turbulent financial climate will be improved by the findings and research methodologies covered in this paper, which will serve as a solid foundation for future investigations.

Keywords: *Volatility, Uncertainty, Forecasting, GARCH family prototypes, stock marketplace, heteroscedasticity.*

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Introduction

Kim & Won (2018) show that volatility in the stock market refers to how much the prices of assets—which are seen as unpredictable—variate and how much risk or uncertainty there is. Price fluctuations are brought on quickly by it (Badarla et al., 2021). A fortune may be made or lost in the blink of an eye in the complex and volatile world of global finance. In this erratic environment, the concept of stock market volatility is a critical factor in determining investment choices, risk, and mitigation tactics. It is crucial to quantify and examine volatility in the financial markets to appropriately mitigate against instability. It's also beneficial to comprehend the level of risk associated with any specific market (Badarla et al., 2021). In the financial markets, volatility is important for hedging techniques, portfolio risk management, and derivative pricing. As a result, accurate volatility prediction is paramount (Kim & Won, 2018). Since (Bollerslev, 1986) introduced model which is ARCH models, it is an econometrical prototype used to analyze leverage effect in time series to estimate future spillover. The parametric estimating approach is commonly used to estimate the parameters of the ARCH class models, if there exists a probability density function of the return's series. (Sun & Yu, 2019). Due to the capacity to capture spillovers persistence or clustering, the ARCH class prototypes are advantageous (Bollerslev, 1986; Vedat, 1989; Baillie, Bollerslev, & Mikkelsen, 1996). Nevertheless, some recent research has suggested that in order to get high predicting performance, the ARCH class models need to be modified. (Choudhry & Wu, 2008). For financial time series forecasting, researchers have recently coupled the GARCH model with computer AI intelligence-based methodologies. (Engle, 1982) Constructed on the hypothesis that the variance error is serially autocorrelated, the GARCH model is an econometrical prototype that is used to analyze time-series data.

The official securities market in Denmark is the Copenhagen Stock Exchange (CSE). In 1996, the CSE converted to a limited company and began trading shares, fixed income securities, and derivatives. Nasdaq Copenhagen, a division of Nasdaq Nordic, has the top-tier stock market index known as OMXC25, or OMX Copenhagen 25 Stock Index. The current project aims to mimic the Danish stock market's behaviour using data from December 20, 2016, until September 20, 2023. The thorough analysis for a certain market offers insightful information on past trends and volatility, assisting with any future decision-making. For predicting stock price volatility in the Danish stock market, we suggest using the generalized autoregressive conditional heteroscedasticity (GARCH) model.

Review Literature

Several studies have been carried out using different indices to assessment the instability of stock markets. (Birau et al., 2021) examined the Hong Kong and Spanish stock markets' GARCH-based behaviour. Furthermore, (Spulbar et al., 2020) used short-term momentum effects to study the dynamics of the Hong Kong stock market. (Meher et al., 2020) investigated the fluctuations in the marketplace throughout the COVID-19 epidemic outbreak. However, the adverse information has far stronger ramifications. (Sokpo, 2017). The analysis establish that the prototype series had strong perseverance, indicating that the market will be affected for some time by a positive or negative shock to the stock market yield series caused on by either good or bad news. According to (Spulbar et al., 2023) it is evident from the detrimental impacts of the world-wide financial crisis that investors were not able to make any significant profits from the Poland stock market. Moreover, negative shocks happen more often than positive ones

(Bonga, 2019). concluded that returns, risks, and volatility are positively correlated. The financial market gets more turbulent as market volatility rises.

Numerous studies carried out globally have investigated the volatility trends and dynamics of the stock marketplace through the application of the GARCH family model. Kumar et al. (2023) used the EGARCH, TGARCH, MGARCH, and PGARCH models to examine and find out the spillovers of the S&P / Toronto index. The outcome of the article indicates that the GARCH-GJR model is more appropriate. According to (Kumar et al., 2023) the IBOVESPA index's volatility is evaluated in this study using the GARCH (1,1), GJR-GARCH, EGARCH, M GARCH, and TGARCH models. Apart from that, this study evaluated the exactitude of spillovers projections using both univariate and multivariate models. The work by Maqsood et al. (2017) used GARCH-M (1,1), EGARCH (1,1), TGRACH (1,1), and PGARCH (1,1) to calculate the volatility of the Nairobi Securities Exchange. They concluded that the TGARCH (1,1) model is more suitable to capture the instability clustering and leverage impact of the NSE stock market out of various symmetric and asymmetric type heteroscedastic processes. The GJR-GARCH model was used by (Kumar et al. 2023) to assess the price volatility spillover transmission objectively or experimentally in the daily returns of the IPC Mexico index from the Mexican stock market. (Leite & Lima, 2023) shown the tremendous volatility of Brazil's spot pricing. This extreme volatility is a result of both institutional problems and the growing share of renewable energy in the electrical mix.
According to Birau et al. (2023) the perfect fit of the GARCH (1, 1) model, which accounts for the effects of both GARCH and ARCH, indicates that the volatility in the Sweden market has continued over time. (Bonga, 2019). Moreover, Trivedi et al. (2021) have also applied GARCH models in order to investigate the dynamics of the Indian emerging stock market. The GARCH family of prototypes is used to simulate the volatility of the Zimbabwean stock market. The EGARCH (1,1) model was determined to be the optimal model. It has been shown that the volatility that was noticed during the COVID-19 epidemic (Spulbar et al., 2022) formed a "V" shape array with an unanticipated, severe negative slope. Compared to the pattern established during the world-wide financial disaster, this was completely different. (Bonga, 2019) came to the conclusion that stock market returns are impacted differently by positive and negative shocks. To differing degrees, news that is both good and bad will increase the spillovers of stock marketplace yields.

Research Gap

This effort closes a large research gap in the field of financial econometrics. While an extensive amount of research has been done on forecasting stock market volatility, less focus has been placed on modelling and comparative analysis of volatility in Denmark. Furthermore, there is still a dearth of research on the use of complicated GARCH models, including TGARCH, EGARCH, and PARCH, in this particular setting. By bridging this gap, our study provides investors, policymakers, and financial analysts substantial understanding into the different dynamics and asymmetric volatility patterns within these two different markets.

Research Methodology

Using data from December 20, 2016, to September 20, 2023, the current effort concentrations on modelling the behaviour of the Danish stock market in order to apprehend fluctuations, spillover clusters, the suitability of econometric prototypes, and spillover patterns. We use GARCH models (Bollerslev, 1986). The study used a sample number of 1668 daily observations for OMXC25 or OMX Copenhagen 25 Stock Index representing the Denmark stock market. The time series data have been used for modelling volatility. The day-to-day returns were computed using the log of the first difference of the day-to-day closing prices. Before doing any of these tests, the daily returns were compiled since volatility has been evaluated on return (r_t). The log of first change of the daily closing price is used to compute the return series, which is as follows:

$$r_t = log\frac{P_t}{P_{t-1}}$$

Where,
r_t = Logarithmic daily return for time t,
P_t = Closing price at time t,
P_{t-1} = Corresponding price in the period at time $t - 1$.

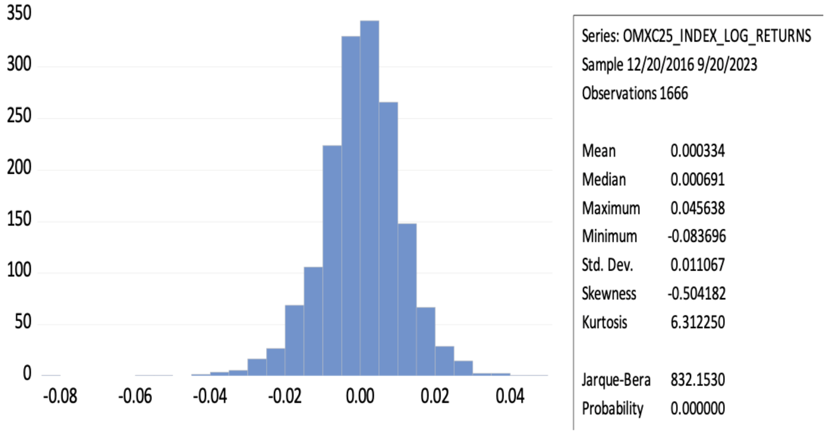
We utilized the E-Views 12 Econometrics package. This software package provides robust tools for econometric modelling and time series analysis. The selection of the most suitable GARCH prototype was based on the evaluation of four GARCH family models: GARCH/TARCH, EGARCH, Component ARCH (1,1), and PARCH models, all using the Student's Distribution.

Empirical Results and Discussion

In this paper, the day-to-day closing prices of the OMXC25 index, over the period from 20th December 2016 to 20th September 2023 resulted in total observations of 1666 excluding public holidays. Numerous descriptive statistics are computed and exhibited in Table 1 providing 0.000334 mean with 0.011067, degree of Standard Deviation. A high value of kurtosis 6.312250 which is greater than 3 indicates a leptokurtic distribution that is an apparent departure from normality while the skewness represents negative value it indicating data has long left skewed distribution.

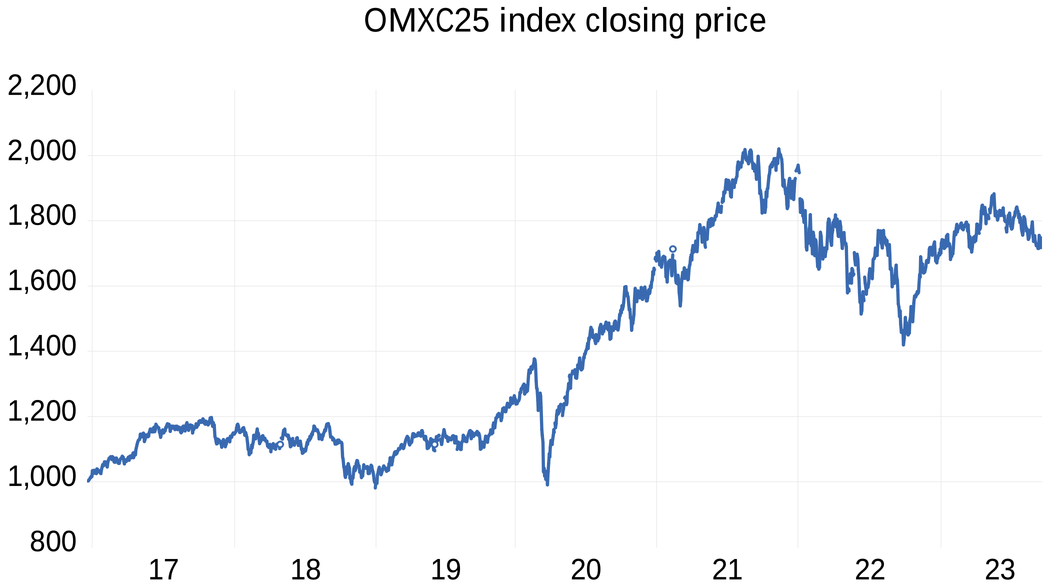
The Jarque-Bera statistic is a crucial normality test, the p-value of Jarque Bera is less than its critical value of 5% signifying the data is non-normal.

Graph 1: - Descriptive Statistics of the OMXC25 index



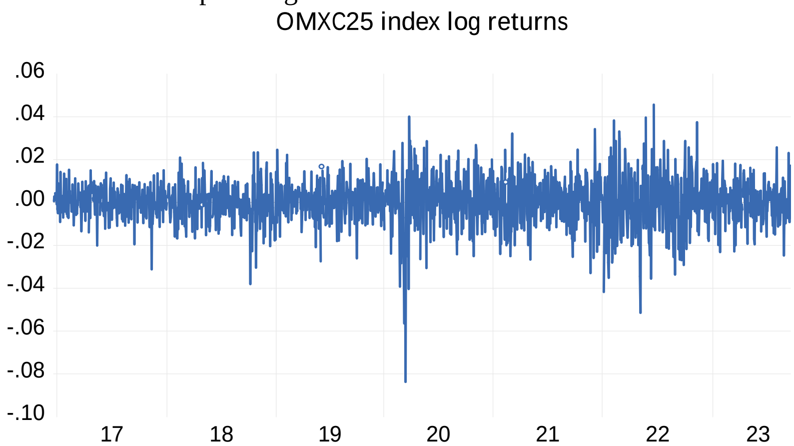
Source: Authors' Calculation using Eviews12

Graph 2: Movement Pattern of the OMXC25 Index



Source: Authors' Calculation using Eviews12

Graph 3: log returns of the OMXC25 Index



Source: Authors' Calculation using Eviews12

Graph 1 shows the movement patterns of the OMXC25 Index's Stationary Series during the hypothetical period from 20th December 2016 to 20th September 2023. Graph 3 shows the graphical presentation of the log returns of the presence of spillover clustering using the OMXC25 Index. In order to estimate the volatility of Denmark stock market, checking the stationary is the first step in the analysis of the return series (Maqsood, Safdar, Shafi, & Lelit, 2017). For this purpose, Augmented Dickey-Fuller (Dickey & Fuller, 1979) test, Phillips Perron test and Kwiatkowski-Phillips-Schmidt-

Shin experiment used to establish the stationarity of the OMXC25 index sample data series. The experiment results are presented with the help of following tables:
Table: 1: Unit root Test (Augmented Dickey-Fuller test, Phillips-Perron test and of OMXC25 index
Null Hypothesis: D(OMXC25_INDEX_LOG_RETURNS) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 13 (Automatic - based on SIC, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-19.84532	0.0000
Test critical values:	1% level	-3.963611	
	5% level	-3.412533	
	10% level	-3.128223	

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-40.63717	0.0000
Test critical values:	1% level	-3.963564	
	5% level	-3.412510	
	10% level	-3.128209	

Table: 2: Kwiatkowski-Phillips-Schmidt-Shin test of OMXC25 index

Null Hypothesis: D(OMXC25_INDEX_LOG_RETURNS) is stationary

Exogenous: Constant, Linear Trend

Bandwidth: 63 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.024117
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

Source: Authors' Calculation using Eviews12

Table 1 displays the Unit root Test (Augmented Dickey-Fuller test and Phillips-Perron test) of OMXC25 index. Table 2 shows the p values of Augmented Dickey-Fuller test and Phillips-Perron test and Kwiatkowski-Phillips-Schmidt-Shin test statistic are less than 0.05 which leads to reject the null hypothesis hence, the sample data were found to be stationary since the probability values are significant at 10%, 5%, and 1% levels.

Testing for ARCH Lagrange Multiplier Effect:

It is crucial to look at the residuals for signs of heteroscedasticity. If conditional heteroskedasticity is present, the results might be deceiving if it is not taken into consideration. (SOKPO, IOREMBER, & USAR, Inflation and Stock Market Returns Volatility: Evidence from the Nigerian Stock Exchange 1995Q1-2016Q4: An E-GARCH Approach, 2018). To ascertain whether heteroscedasticity is present in the residual of the return series, the ARCH Lagrange Multiplier (LM) test is utilized. It is necessary to test for conditional heteroskedasticity since adopting GARCH-type models would be incorrect if it were not included.

Table 3: Heteroskedasticity Test: ARCH

F-statistic	39084.87	Prob. F(1,1662)	**0.0000**
Obs*R-squared	1596.128	Prob. Chi-Square(1)	0.0000

Source: Authors' Calculation using Eviews12

Table 3 displays the result of the ARCH-LM test for OMXC25 index. It inferred that data is highly significant. The probability of F-statistic (0.0000) shows that p value is less than 0.05. The null hypothesis (i.e., no ARCH effect) is rejected at 1% level. The results support to estimate GARCH family models since, indicating the existence of ARCH effects in the residuals of time series models. This indicates the series under consideration is variable, requiring volatility modelling to account for volatility in the model.

Table 4: Selecting an appropriate model.

OMXC25 Index			
Estimated model	**Akaike info criterion**	**Schwartz criterion**	**Log Likelihood**
GARCH/TARCH	-6.354315	-6.334793	**5295.968**
EGARCH	-6.367335	-6.344559	**5307.806**
PARCH	-6.36757	-6.341539	**5309.002**
Component ARCH (1,1)	-6.355511	-6.32948	**5298.963**

Source: Authors' Calculation using Eviews12

Table 4 depicts four models of GARCH family models. PGARCH model with Student t's Distribution has the lowest Akaike info criterion with -6.36757 and Schwartz criterion with -6.341539 apart from that maximum Log Likelihood with 5309.002 when compared to the other three. As a result, this model is thought to be the best one. The results of the selected PARCH Model for the OMXC25 Index are shown in the table below.

Table 5: PARCH with Student's t distribution Error Construct of OMXC25 index
Dependent Variable: OMXC25_INDEX_LOG_RETURNS
Method: ML ARCH - Student's t distribution (BFGS / Marquardt steps)
Date: 10/18/23 Time: 07:06
Sample (adjusted): 12/22/2016 9/20/2023
Included observations: 1665 after adjustments
Convergence achieved after 153 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
@SQRT(GARCH)^C(7) = C(3) + C(4)*(ABS(RESID(-1)) - C(5)*RESID(-1))^C(7) + C(6)*@SQRT(GARCH(-1))^C(7)

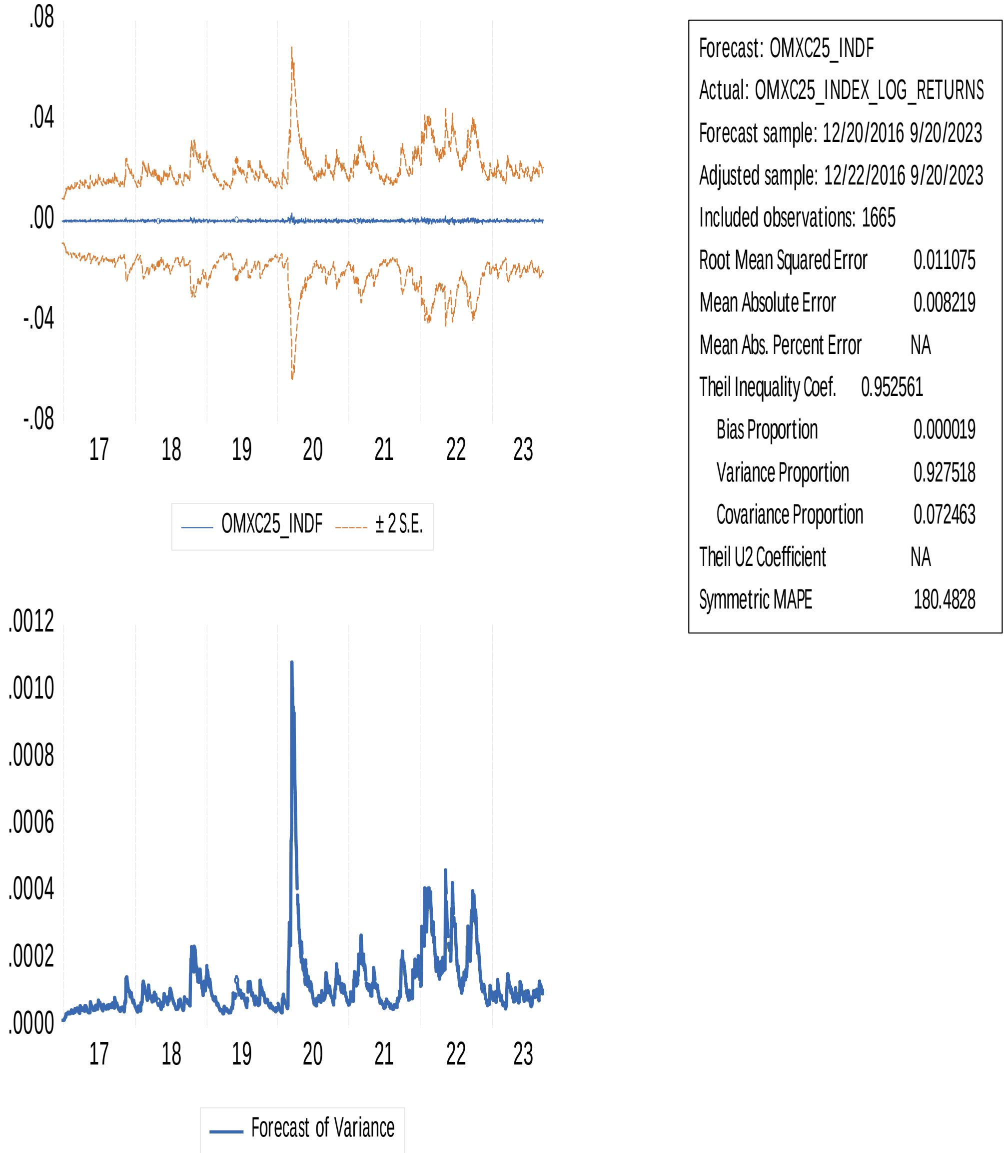
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000393	0.000228	1.725467	0.0844
OMXC25_INDEX_LOG_RETURNS(-1)	-0.036309	0.025492	-1.424320	0.1544
	Variance Equation			
C(3)	3.05E-05	4.47E-05	0.683013	0.4946
C(4)	0.043537	0.021799	1.997218	0.0458
C(5)	0.857876	0.484705	1.769894	0.0767
C(6)	0.937568	0.011279	83.12756	0.0000
C(7)	1.399207	0.309030	4.527743	0.0000
T-DIST. DOF	11.47747	2.548399	4.503797	0.0000

R-squared	-0.001326	Mean dependent var	0.000334
Adjusted R-squared	-0.001929	S.D. dependent var	0.011071
S.E. of regression	0.011081	Akaike info criterion	**-6.367570**
Sum squared resid	0.204213	Schwarz criterion	**-6.341539**
Log likelihood	**5309.002**	Hannan-Quinn criter.	-6.357923
Durbin-Watson stat	1.924286		

Source: Authors' Calculation using Eviews12

Above table are representing the PARCH model with Student's t distribution error construct of OMXC25 index. Since Probabilities are lower than 0.05, the constant (C) is considered significant.

Graph 4: Estimating volatility patterns using PARCH models of OMXC25 index



Source: Authors' calculation using Eviews12

We can forecast the volatility of the Denmark Stock Exchange composite indices using the aforementioned methodology using a data set of 1666 days. The Graph 4 demonstrates the anticipated uneven price changes of the Denmark Stock Exchange.

Conclusions

To forecast variance using financial time series data, we used model i.e., GARCH, which is specifically designed for spillover forecasting. The foremost purpose of the present analysis is to model the behaviour of the Denmark stock market using data from December 20, 2016, to September 20, 2023.Through the application of GARCH family prototypes which, incorporate GARCH/TARCH, EGARCH, Component ARCH (1,1), and PARCH models. The analysis cantered on log returns derived from the OMXC25 Index. We used some statistical techniques to evaluate stationarity.

The Augmented Dickey Fuller test, and Phillips-Perron test, and Kwiatkowski-Phillips-Schmidt-Shin test statistic. Findings indicating that the sample data were stationary. The ARCH Lagrange Multiplier (LM) test was employed to investigate the presence of heteroscedasticity in the residual series of the return data. The results of this test revealed the presence of ARCH effects in the residuals of our time series models. The selection of the most suitable GARCH model was based on the evaluation of four GARCH family models that is GARCH/TARCH, EGARCH, Component ARCH (1,1), and PGARCH using Student t's distribution.

As a result, PARCH Model were selected with the help of the lowest Akaike info criterion, Schwartz criterion and maximum Log Likelihood. As demonstrated in Table 5, the outcomes of the PARCH model's application yield important insights into the dynamics of the OMXC25 Index. Our ability to forecast market movements and make informed decisions in a turbulent financial climate will be improved by the findings and research methodologies covered in this paper, which will serve as a solid foundation for future investigations. This work adds to the area of analysis in financial econometrics and emphasizes the importance of precisely and methodically modelling stock market behaviour. We have gained valuable insights into the US and Austrian stock markets using complex GARCH models and extensive statistical studies. These insights have improved our understanding of the intricate subject of stock market volatility prediction.

Authors' Contributions:

The authors contributed equally to this work.

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