Revista de Științe Politice. Revue des Sciences Politiques • No. 78 • 2023: 50 – 59

ORIGINAL PAPER

Estimating volatility patterns using GARCH models: A case study on Swedish stock market

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Abstract:
The main aim of this research paper is to estimate volatility patterns using GARCH models based on a case study on Swedish stock market. The selected time period covers the long time interval from December 2008 to December 2022. In other words, the analyzed period includes certain extreme events such as global financial crisis of 2008 and COVID-19 pandemic which had a significant impact on most stock markets in Europe. The econometric framework includes GARCH family models. This empirical research study contributes to the existing literature on the behavior of the developed stock market from Sweden.

Keywords: *volatility patterns, GARCH models, developed stock market, abnormal returns, investor, random walk.*

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1. Introduction

FTSE Russell recently published, in September 2022, the last official report on FTSE Equity Country Classification of Markets and highlighted the following four main market categories, like : developed, advanced emerging, secondary emerging and frontier markets. Considering the criteria used by FTSE Russell, the selected stock market in Sweden is included in the leading category of developed markets. According to the official website of Trading Economics, the OMX Stockholm 30 index represents a main index, but also free float and capitalization weighted stock market index on the Stockholm Stock Exchange. The OMX Stockholm 30 Index also covers the performance of a certain number of 30 stocks with the largest volume of the trading on the Sweden stock market.

Tarczyński et al. (2021) revealed the existance of particular stock market disturbances generated due to the absence of complete market information. Moreover, Engle (2001) argued that both ARCH and GARCH models consider heteroskedasticity as a variance which is to be modeled. Xie et al. (2020) revealed that the benefits of the international diversification of the portfolio are highlighted when they have an effect on the level of portfolio risk based on the strategy to compose the portfolio by adding financial assets from certain stock markets characterized by weak correlations.

Umlauf (1993) investigated the effect of transaction taxes on the dynamics of the stock market in Sweden for the sample period 1980–1987 and concluded that volatility is not affected by the regulation of new taxes, however in contrast to the behavior of stock prices and turnover in this regard. Adenomon and Idowu (2022) argued that COVID-19 pandemic determined significant breakdown the case of most economies based on the dynamics of Gross Domestic Product also known as GDP, but the financial markets were also massively affected.

2. Literature review

Burdekin and Harrison (2021) considered that the COVID-19 pandemic constitutes the most severe health crisis since the previous Spanish Flu of 1918–1919. Trivedi et al. (2022) revealed the effect of COVID-19 pandemic on stock markets due to a severe distress based on unpredictable uncertainty. Tarczyński et al. (2021) discussed the classical finance theory approach which is based on the assumption that all market participants are rational focused on profit maximization which refers to the high efficiency of the stock market. Spulbar et al. (2022) analyzed the long-term behavior of the stock market developed in Japan by applying GARCH family models for the sample period from July 1998 to January 2022. Badarla et al. (2022) investigated volatility patterns using GARCH models for a cluster of stock markets such as: Switzerland, Austria, China and Hong Kong for the selected period from January 2003 to September 2021. Adenomon and Idowu (2022) provided relevant information on the impact of the COVID-19 pandemic on the volatility behavior of the Nigerian stock markets using certain sectorial stocks based on GARCH models.

Engle (1982) designed “a new class of stochastic processes” also known as autoregressive conditional heteroscedastic (ARCH) processes. Moreover, Engle (2001) suggested that ARCH and GARCH models represent “standard tools” of applied econometrics in terms of the rigorous understanding of volatility behavior. Nelson (1991) generated the exponential GARCH model, also known in as the EGARCH model. Furthermore, Glosten et al. (1993) devised the GJR model, which gets its name from Glosten, Jagannathan, and Runkle. On the other hand, Hamori (2003) claimed that the exponential GARCH or EGARCH models do not benefit from applying non-negative constraints on model parameters when the log volatility value is used as an explanatory variable.

The Engle-created ARCH model is represented by the generalised version known as generalised autoregressive conditional heteroscedastic. In this situation, ARCH models function as a function of prior volatility, as Sultonov (2020) highlighted in a previous research study. ARCH models are used to estimate future volatility. Another reason is that GARCH (1, 1) model combines one ARCH effect with one GARCH effect. Since conditional variance in the EGARCH specification is an exponential function, non-negative limitations that were previously restricted in GARCH specifications can now be rejected. EGARCH model uses an exponential function for conditional variance, in contrast to prior GARCH model specifications, which prevented rejection of non-negative limitations. Furthermore, Muguto and Muzindutsi (2022) have conducted a complex research study on stock return volatility based on a cluster of stock markets, such as the developed G7 stock markets and the emerging BRICS stock markets by using GARCH models.

3. Research methodology and empirical analysis

We took into account the Sweden stock market major index known as OMX index. The empirical analysis is based on daily closing price values for the sample period from December 18, 2008 to December 23, 2022, which includes a number of 3516 observations (OBS). In order to apply the GARCH class models, the initial databases have been converted into log returns and the first log difference was taken into account. The statistical summary shows that for the chosen time period, returns were negatively skewed and had an excessive amount of kurtosis. The GARCH (1,1) model, which has the effects of (1) GARCH and (1) ARCH models, fitted exactly and indicates that volatility in the Sweden market is enduring through time.

Many theories and models have been devised to forecast the future of the stock market, and extensive research has been done on the feasibility of predicting the future value of financial instruments.

We use series returns in order to apply Bollerslev's (1986) GARCH (1,1) model comparative volatility estimation. The data is logged into returns using the algorithm below, accounting for the initial log difference.

$$Log\ Return = ln(\frac{P_t}{P_{(t-1)}}) * 100$$

Further to test the normality, Augmented Dickey Fuller test is used. Conditional variance is modelled by the Bollerslev (1986) model, which was initially put forth in 1986. According to the ARCH coefficient (a1), volatility shocks from the previous period had a significant impact on the current period. While the other GARCH coefficient I evaluates the impact of prior period variance on current volatility and reflects the presence of volatility clustering in series returns. Using the following examples, Bollerslev's GARCH (1,1) model is demonstrated;

Formula process contains mean equation and variance equation represented as the following;

$$h_t = \omega + \alpha_1 u_{t-1}^2 + \beta_1 h_{t-1}$$

Mean equation is the following :

$$rt = \mu + \varepsilon t$$

Variance equation is the following :

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

The GARCH (1, 1) model analyses volatility dynamics and postulates that if the product of the coefficients for ARCH and GARCH is equal to 1, then any shock, whether positive or negative, can permanently alter all future values. In the absence of this, conditional variance shock will be categorised as persistent in nature. Graphs with explanations of the specifics are used to depict actual series returns, volatility shocks, and comparative asset returns for Sweden stock market OMX.

Conditional variance, an exponential function in the EGARCH specification, permits the rejection of non-negative limitations, which were prohibited in the original GARCH model specification.

EGARCH model:

$$log(\sigma_t^2) = \omega + \sum_{j-i}^{p} \beta i \, log(\sigma_{t-i}^2) + \sum_{j-1}^{q} \alpha i \left(\frac{\varepsilon i - t}{\sigma}_{i-t} \left| \frac{-\sqrt{2}}{n} \right| - \gamma i \frac{\varepsilon i - t}{\sigma i - t} \right)$$

GJR GARCH model:

$$ht = \delta + \alpha_1 e_i^2{}_1 + \gamma d_{i-1} e_t^2{}_1 + \beta_i h_{i-1}$$

ADF process

Augmented Dickey-Fuller (ADF) regression process is managed using the following:

$$\Delta y_t = c + \beta \cdot t + \delta \cdot y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \varepsilon_t$$

Augmented Dickey-Fuller test for fist difference of OMX, testing down from 4 lags, criterion AIC with sample size daily observations 3514, unit-root null hypothesis: a = 1 indicates that with including 0 lags of (1-L), the model: (1-L)y = b_0 + (a-1)*y(-1) + e, estimates estimated value of (a - 1): -1.0436 which is significant at 1% where the asymptotic p-value 0.0001. However, with using 4 lags, the asymptotic p-value 6.573e-111 which is even indicates strong significance less than 1% level. The summary of statistics exhibited in Table 1 suggesting merely zero mean returns for the selected time period with negatively skewed returns and excess kurtosis (4.62) than the normal movement of (3).

Table 1. Summary Statistics, using the observations 2008-12-18 - 2022-12-23 for the variable d_l_OMX index closing price (3515 valid observations)

Mean	Median	Minimum	Maximum
0.00031780	0.00067856	-0.11173	0.068491
Std. Dev.	C.V.	Skewness	Ex. kurtosis
0.012656	39.824	-0.39742	4.6263
5% Perc.	95% Perc.	IQ range	Missing obs.
-0.020732	0.019881	0.012914	1

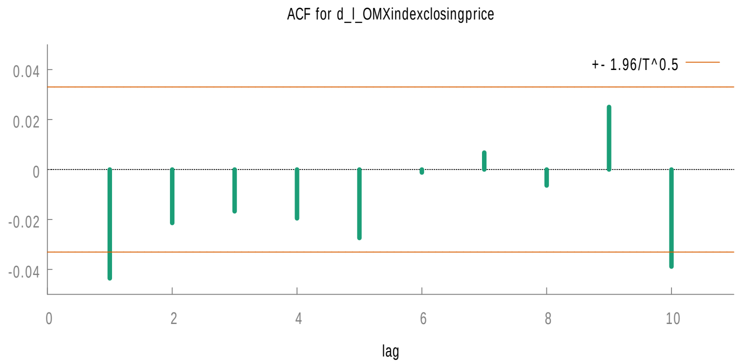
Source: Author’s computation using first difference of daily observations

Table 2 exhibits the property of ACF and PACF considering the 10 lags at significance indicate significance at the 1%, 5%, 10% levelsusing standard error 1/T^0.5.

Table 2. Autocorrelation function for d_l_OMX index closing price
***, **, *

LAG	ACF	PACF	Q-stat. [p-value]
1	-0.0436***	-0.0436 ***	6.6860 [0.010]
2	-0.0214	-0.0234	8.2999 [0.016]
3	-0.0167	-0.0187	9.2851 [0.026]
4	-0.0196	-0.0217	10.6317 [0.031]
5	-0.0274	-0.0302 *	13.2801 [0.021]
6	-0.0012	-0.0051	13.2853 [0.039]
7	0.0068	0.0044	13.4468 [0.062]
8	-0.0064	-0.0076	13.5916 [0.093]
9	0.0251	0.0234	15.8045 [0.071]
10	-0.0389 **	-0.0379 **	21.1368 [0.020]

Source: Author’s computation using first difference of daily observations



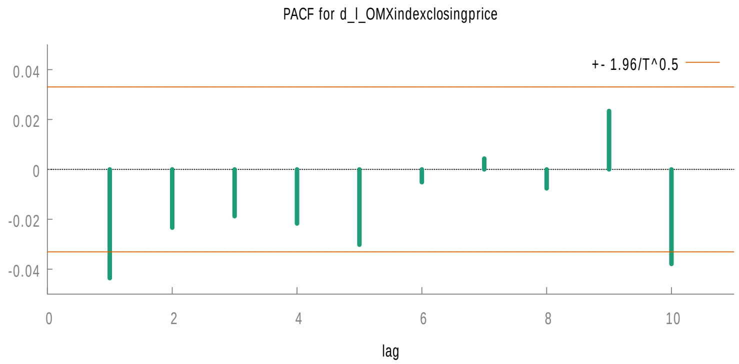


Figure 1. Autocorrelation function ACF and PACF property
Source: Author’s computation using first difference of daily observations

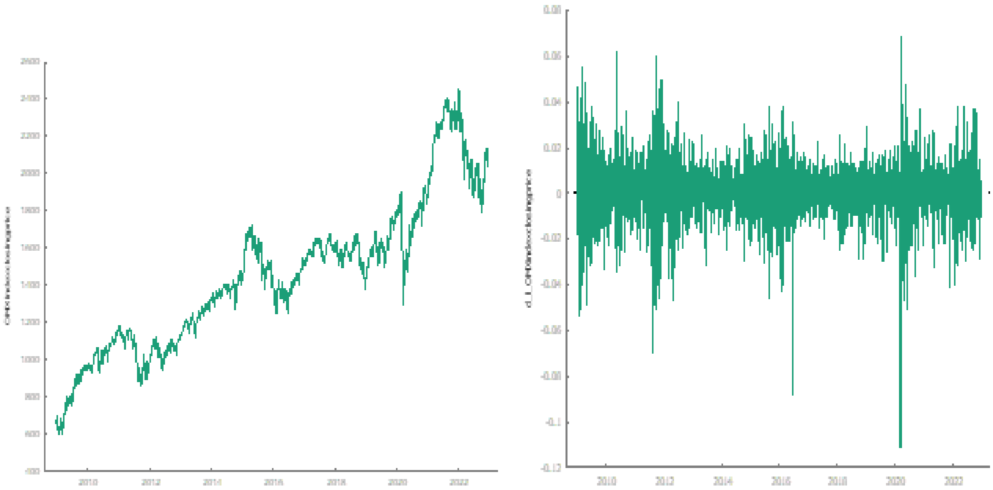


Figure 2. Random walk (Series movement) and Stationary returns
Source: Author's computation using actual series returns and first difference of log returns

The random walk movement (see Fig 2, first part) shows the aggressive movement of index soon after the global financial crisis impact whereas the second part of the (Fig 2) demonstrates volatility sketches over the time. The COVID 19 impact clearly exhibits the strongest negative shock.

Table 3. Model: GARCH(1,1) [Bollerslev] (Normal)*, Dependent variable: OMX. Sample: 2008-12-19 -- 2022-12-23 (T = 3515), VCV method: Robust

Conditional mean equation					
	coefficient	std. error	z	p-value	
const	0.000523811	0.000167619	3.125	0.0018	***
Conditional variance equation					
	coefficient	std. error	z	p-value	
omega	2.52985e-06	7.41748e-07	3.411	0.0006	***
alpha	0.0903323	0.0153907	5.869	4.38e-09	***
beta	0.894049	0.0167827	53.27	0.0000	***
Llik: 10837.70444		AIC: -21667.40887			
BIC: -21642.74970		HQC: -21658.61022			

Source: Author's computation using first difference of daily observations

Table 4. Model: EGARCH(1,1) [Nelson] (Normal) Dependent variable: OMX, Sample: 2008-12-19 -- 2022-12-23 (T = 3515), VCV method: Robust

Conditional mean equation

	coefficient	std. error	z	p-value	
const	-6.96717e-06	0.000144853	-0.04810	0.9616	

Conditional variance equation

	coefficient	std. error	z	p-value	
omega	-0.279928	0.0496391	-5.639	1.71e-08	***
alpha	0.126061	0.0169931	7.418	1.19e-013	***
gamma	-0.122576	0.0149278	-8.211	2.19e-016	***
beta	0.979632	0.00476282	205.7	0.0000	***

Llik: 10901.11660 AIC: -21792.23320
BIC: -21761.40923 HQC: -21781.23488

Source: Author's computation using first difference of daily observations

Table 5. Model: GJR(1,1) [Glosten et al.] (Normal)*
Dependent variable: OMX
Sample: 2008-12-19 -- 2022-12-23 (T = 3515), VCV method: Robust

Conditional mean equation

	coefficient	std. error	z	p-value	
const	0.000113685	0.000161666	0.7032	0.4819	

Conditional variance equation

	coefficient	std. error	z	p-value	
omega	2.72695e-06	6.87026e-07	3.969	7.21e-05	***
alpha	0.0433684	0.0114340	3.793	0.0001	***
gamma	0.935969	0.213929	4.375	1.21e-05	***
beta	0.901574	0.0141502	63.71	0.0000	***

Source: Author's computation using first difference of daily observations

Discussion

We considered the daily closing prices for Sweden index OMX from December 18, 2008 to December 23, 2022 (OBS 3516). The data converted to log returns and first log difference considered to build the GARCH class models. The summary of statistics indicates negatively skewed returns with excess degree of kurtosis over the selected period of time. The GARCH (1, 1) model with (1) GARCH and (1) ARCH effect fitted perfectly and suggests that volatility in the Sweden market is persistent over the period of time. The exponential GARCH model or EGARCH (1,1) model was noticed with the conditional mean equation property, however the results for the conditional mean variances are significant at the level of 1% and indicates that there is a presence of leverage effect in the series returns. GJR model further confirms the presence of leverage effect in the model with degree of (α) at 4.33% with the positive (γ) of 93.59% indicating the presence of asymmetry in the series returns. It means that the OMX index tends to react stronger and for the longer period of time in case of negative movements than the positive movements.

Conclusions

Forecasting for volatility on most financial markets have a tendency to average out over time, or mean aversion. Some assets, however, could exhibit volatility that is less mean-reverting and doesn't necessitate term structure convergence. According to the statistical summary, returns for the chosen time period were negatively skewed and had an excessive amount of kurtosis. The perfect fit of the GARCH (1, 1) model, which includes the effects of (1) GARCH and (1) ARCH, indicates that the volatility in the Sweden market is ongoing over time. The second half of the movement depicts volatility sketching over time, while the random walk movement displays the aggressive movement of the index shortly following the effect of the global financial crisis.

The strongest negative shock is readily visible in the COVID-19 pandemic impact. The statistical summary showed that there were only zero mean returns for the chosen time period, with negatively skewed returns and excess kurtosis (4.62) compared to the usual movement of (3). The returns of OMX index are persistent to high volatility and investors and traders may find the appropriate opportunity for the higher returns but with considerable degree of risk. Very low evaluated loss values, as shown by EGARCH model, demonstrate that anticipated volatility is typically close to experienced volatility. However, the conditional mean equation property for both the asymmetric GARCH class models i.e. EGARCH and GJR models revealed insignificant and found to be exposed considering the optimum (4) lags selection.

Acknowledgement

This work was partially supported by the University Constantin Brancusi of Targu Jiu (grant number 22/20.03.2023).

Authors' Contributions:

The authors contributed equally to this work.

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Article Info

Received: January 16 2023
Accepted: May 20 2023

How to cite this article:
Birau, R., Trivedi, J., Baid, R., Florescu, I., Simion, M.L. (2023). Estimating volatility patterns using GARCH models: A case study on Swedish stock market. *Revista de Științe Politice. Revue des Sciences Politiques,* no. 78, pp. 50 – 59.