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ORIGINAL PAPER

Investigating volatility patterns for a cluster of developed stock markets including Austria, France, Germany and Spain by using GARCH models

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Abstract:
The main aim of this research article is to investigate the volatility patterns for a cluster of stock markets including Austria, France, Germany and Spain by using GARCH models.All the selected stock markets are developed markets from member states of the European Union. The selected financial databases covered the sample period from January 2007 to November 2022 so as to include certain extreme events such as the global financial crisis of 2007-2008 and the COVID-19 pandemic. Our empirical findings revealed the impact of negative shocks on sample stock markets and differentiate returns from the sample period.

Keywords: *volatility clustering, GARCH models, stylized facts, uncertainty, developed stock market, extreme events, volatility transmission patterns*

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1. Introduction

The accuracy of the selected model is very important in achieving significant and robust results. Duttilo et al. (2021) argued that volatility represents the predominant measure of risk.Sen and Subramaniam (2019) suggested that the most frequent stylized facts encountered in empirical studies on stock markets are the following “heavy tails, volatility clustering, slow decay of auto-correlation in absolute returns and leverage effect”.In addition, Black (1976) identified at the pioneering level the existance of leverage effect which implies that the volatility of stocks tends to increase when the prices of traded financial assets decrease.Engle (1982) developed the GARCH model, which was later expanded by Bollerslev (1986), Nelson (1991) and Glosten et al. (1993) considering the GJR-GARCH model. Moreover, Engle (2001) discussed about GARCH parameterization developed by Bollerslev (1986).

According to the latest report released by FTSE Russell on FTSE Equity Country Classification of Markets which was published in September 2022, there are the following essential categories of stock markets, such as: developed, advanced emerging, secondary emerging and frontier markets.Consequently, considering the criteria that are the basis of the previous classification the selected stock markets of Austria, France, Germany and Spain are all included in the category of developed markets.

2. Literature review

Spulbar et al. (2022) examined volatility patterns in the case of Japanese stock market based on GARCH models for long time interval from July 1998 to January 2022.Duttilo et al. (2021) suggested that volatility modeling provides certain attractive opportunities for financial investors such as identifying potential risks and investment benefits.Badarla et al. (2022) have conducted an empirical study for a cluster of stock markets including Switzerland, Austria, China and Hong Kong, using GARCH models during the period from January 2003 to September 2021.

Engle (2001) provided a complex framework on volatility by using ARCH and GARCH models in applied econometrics considering the implications of heteroskedasticity. Trivedi et al. (2022) argued that financial markets highlight the ability to recover from unexpected turbulence.Nogueira and Madaleno (2022) investigated volatility effects on certain sustainability index in the context of COVID-19 pandemic using Multivariate Generalized Auto-Regressive Conditional Heteroskedasticity (MGARCH) models for the sample period from 2000 to 2022.

Tilfani et al. (2020) investigated the behaviour of certain stock markets and concluded that that there is a certain level of comovement between Germany and certain other member states of the European Union (most Eurozone) but the Brexit process affected this linkage.Trivedi et al. (2021) considered that volatility clustering generates two significant scenarios, respectively the potential for higher losses but also the potential for higher financial stock returns.

3. Research methodology and empirical analysis

We randomly selectedcertain financial databases samples of European stock markets in order to capture the changes in volatility clusters, changes in volatility pattern, and influence on volatility shocks during the global financial crisis of 2007-2008 and COVID-19 pandemic era on the daily sample of the developed stock markets from Austria, France, Germany and Spain. The data captures the daily closing adjusted prices from January 2007 to November 2022. Sample stock market indices contain the following: ATX index, CAC40 index, DAX index and IBEX index for the selected stock markets of Austria, France, Germany and Spain. For comparative volatility estimation, we apply GARCH (1,1) model to sample financial series returns and asymmetric GARCH model, such as Exponential GARCH model by developed Nelson (1991).

In the EGARCH specification, conditional variance is an exponential function, which allows rejection of non-negative restrictions that were restricted in earlier GARCH specifications. EGARCH, unlike earlier GARCH specifications, allows rejection of non-negative restrictions by using an exponential function for conditional variance. In the EGARCH specification, conditional variance is an exponential function that allows rejection of non-negative restrictions, which were restricted in the earlier GARCH specification. Thus, shock in ε_{t-1} has the same effect regardless of whether $\varepsilon_{t-1} > 0$ or $\varepsilon_{t-1} < 0$. By ensuring that variance is always positive, Nelson's EGARCH (1991) model captures the asymmetric reactions of time-varying variances to volatility shocks.

We apply the GARCH (1,1) model provided by Bollerslev (1986) on selected financial time series returns for comparative volatility estimation.

The selected databases have been transformed into log returns and first log difference. The following formula is used to log the data into returns and take into account the initial log difference examined using following formula:

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

Further to test the normality, Augmented Dickey Fuller test is used.

$$(1 - L)yt = \beta 0 + (\alpha - 1)yt - 1 + \varepsilon i$$

The Bollerslev model, first proposed in 1986, represents conditional variance as a linear function of lags. The ARCH coefficient (a1) indicates a considerable influence of volatility shocks from the prior period on the current period. Whereas the other GARCH coefficient I reflects the presence of volatility clustering in series returns and assesses the influence of prior period variance on current volatility. The Bollerslev's GARCH (1, 1) model is illustrated by the following;

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

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

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 studies the dynamics of volatility and hypothesises that any shock, whether positive or negative, can cause permanent change in all future values if the product of the coefficients for ARCH and GARCH is equal to 1. If not, conditional variance shock will be classified as persistent in nature. Actual series returns, volatility shocks, and comparative asset returns for Austria, France, Germany and Spain are displayed in graphs with explanations of the specifics.

The exponential GARCH or EGARCH model proposed by Nelson (1991) that captures the asymmetric impact in the series returns.

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

4. Empirical findings

This model adopts a lengthy form and includes an additional term for the leverage impact, which we refer to as the asymmetric effect. Because ht= exp (R.H.S.) > 0 is a constant and Vt-1 accounts for asymmetric effect, this model ensures positive variance.

Table 1 exhibits results for Augmented Dickey Fuller and confirms that the data is now stationary.

Variable	EV (a - 1)	t-statistic	p-value
ATX	-0.9302	-58.5961	0.0001
DAX	-1.0008	-63.5491	0.0001
CAC 40	-1.0778	-38.7118	0.0000
IBEX	-1.0370	-38.1867	0.0000

Source: Author's computation

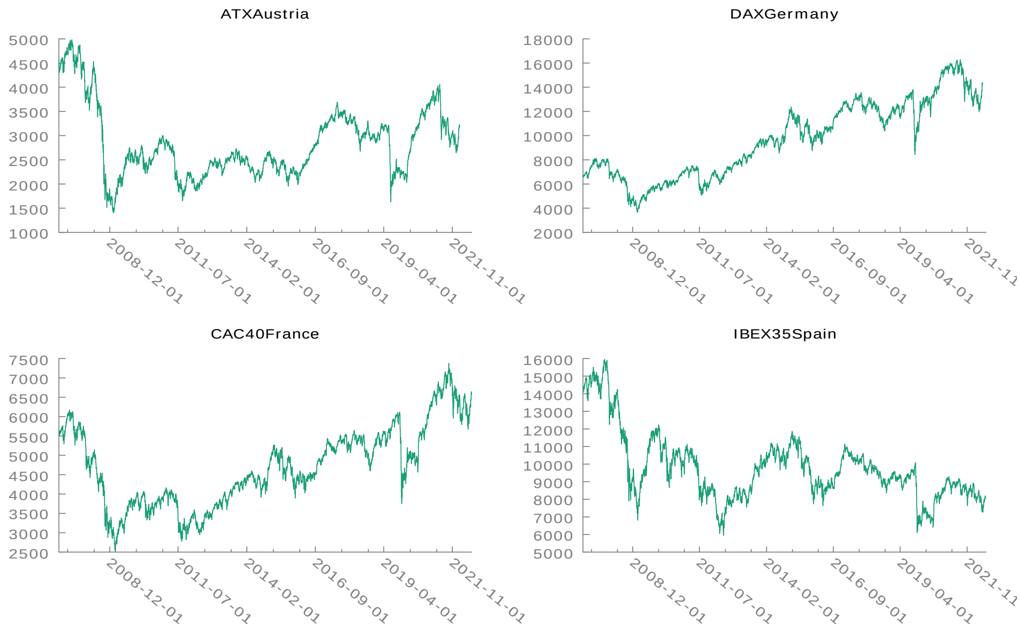

Figure 1. Random-walk pattern - sample from Austria, Germany, France and Spain
Source: Author's computation

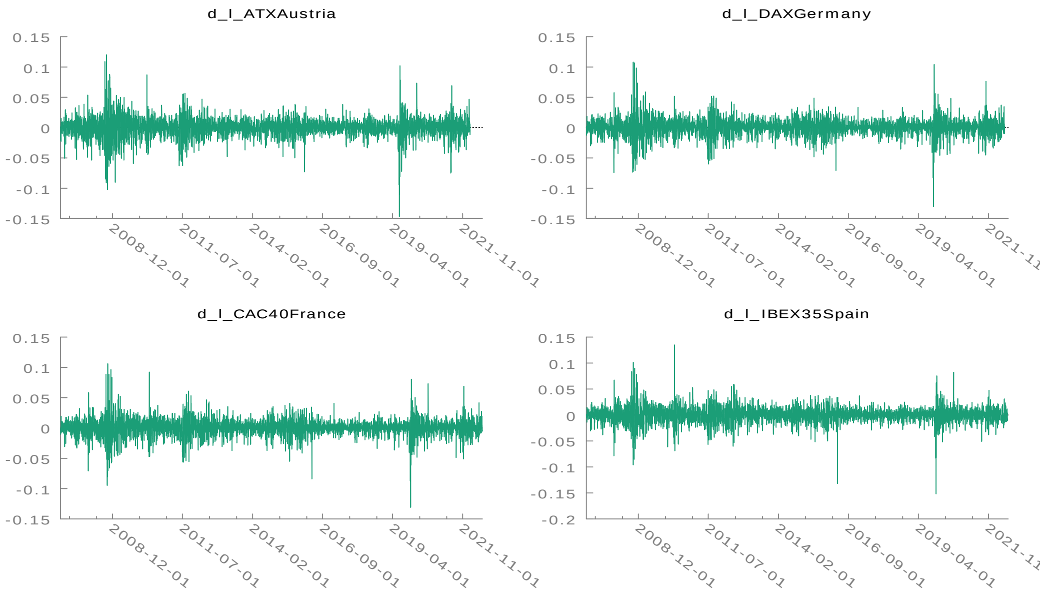

Figure 2. Stationary Log-Returns –Shocks, sample from Austria, Germany, France and Spain

Source: Author’s computation

The selected stock market indices' reactions to the global financial crisis of 2007-2008 are shown in Figures no.1 and no.2, along with the impact of COVID-19 pandemic, which is evident in the stationary representative charts' volatility clusters and the line-clearly chart's negative slope. The graphic shows that Austria and Spain, which were determined to have not recovered from the shocks of the global financial crisis, as the indexes are trading 3.57 times and 2.67 times lower than before the effect of the global financial crisis. In contrast to the performance of ATX index (Austria) and IBEX index (Spain), the selected stock indices of France and Germany stock markets, have attained far higher trading levels than during the global financial crisis.

Table 2 Summary of Descriptive Statistics

Variable	Mean	Std. Dev.	Skewness	Kurtosis
ATX	-8.71E-05	0.016	-0.47	7.79
DAX	0.0001	0.014	-0.19	7.79
CAC 40	4.48E-05	0.014	-0.25	7.86
IBEX	-0.0001	0.015	-0.35	9.22

Source: Author’s computation

By using the ADF test, we have proven that the ARCH effect is there. It confirms at a 1% level. Our models are now applicable to every time series. We point out that a negative value for the correlation coefficient, particularly for the GARCH and E-GARCH models, gives evidence for potential leverage effects. We can look at used models and research it in the ways listed below (Table 3).

Table 3 Estimations for GARCH and EGARCH models

Variable	Model	Mean Equ.	Omega	Alpha	Gamma	Beta	P-Value
ATX	GARCH	0	4.64E-06	0.1125	NA	0.8685	1% all
	EGARCH	5.00E-05	-0.3371	0.15887	-0.1103	0.9753	IS/1%
DAX	GARCH	0.0006	4.09E-06	0.1059	NA	0.8729	1% all
	EGARCH	0.0001	-0.3487	0.1298	-0.1312	0.9719	IS/1%
CAC40	GARCH	0.0005	4.72E-06	0.1296	NA	0.8488	1% all
	EGARCH	-5.35E-05	-0.3448	0.1169	-0.1608	0.9712	IS/1%
IBEX	GARCH	0.0002	5.26E-06	0.1207	NA	0.8585	IS/1%
	EGARCH	-0.0003	-0.3231	0.1452	-0.1211	0.9755	10% & 1%

Source: Author's computation

The lagged conditional variance coefficient (β_1) in the GARCH (1, 1) model deviates significantly from zero. This suggests that all four-time series show evidence of volatility clustering. The fact that the sum of the ($\alpha_1 + \beta_1$) coefficient is a unity indicates the importance of shocks to the conditional variance. The ARCH effect is represented by (1) while the GARCH effect is represented by (β_1). For the stock markets of Austria, Germany, France, and Spain, we create the equation ($\alpha_1 + \beta_1$). The results of the computation of ($\alpha_1 + \beta_1$) using a simple calculator are Austria's ATX (0.981), Germany's DAX (0.978), France's CAC 40 (0.974), and Spain's IBEX (0.979). The figure that is the closest to zero indicates that a heavy blow's strong shock is attenuated at a relatively modest speed. GARCH model fitted to all the mean variances except for the Spain stock market where only conditional variance equation provides the significance at degree of 1%. The conditional mean variance is not delivering significant values. However, for the asymmetric EGARCH, the conditional variance equation provides the information at 1% significance level and contrasting with the results of GARCH estimates, the conditional mean variance are insignificant for all the sample markets.

Here, we see that the value of (γ)is not zero and that the exponential GARCH (EGARCH) confirms the existence of leverage (asymmetry) in the volatility of closing stock indices in the sample of Austria, Spain, Germany and France. It implies that the volatility of the selected European stock markets found with the asymmetric impact and negative news has a stronger impact on volatility than positive news. In other words, stock markets of Austria, France, Germany and Spain tend to respond to more shocks during the non-positive event than the positive events. In essence, the EGARCH model depicts the log of the variance or standard deviation as a function of the lagged logarithm of the variance or standard deviation and the lagged absolute error from the regression model. This paradigm enables an unequal response to the lagged error. This indicates that selected samples of European stock markets i.e. Austria, Germany, France and Spain, all have the asymmetric behaviour pattern indicating that these stock markets tend to be more volatile during the negative shocks and forward the impact for the longer period than the positive tendency of movements.

Conclusions

This empirical study investigates the changes in volatility and persistent of volatility in selected sample of European developed stock market based on GARCH (1,1) and EGARCH (1,1) models. Results indicate that volatility is more persistent in the case of stock market in Austria compared to the rest sample markets. Further, we find presence of asymmetric effect in all sample markets indicating that the negative shocks will invite more negative shocks compared with positive shocks. All selected sample market provided volatility clustering evident during global financial crisis of 2007-2008 and COVID-19 pandemic. The sample stock markets from Austria and Spain have not yet recovered the returns since the global financial crisis as the trading levels are still at lower level that were being traded before the global financial crisis events. In addition to that we find all sample market creating leptokurtic effect where the returns demonstrated left fat tails. Moreover, negative shocks occur more frequently than positive ones.

Authors' Contributions

The authors contributed equally to this work.

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