ISSN 0323-9004

Economic Archive

Svishtov, Year LXXIX, Issue 3 - 2026

Green Banking as a catalyst for Sustainable Development – Evidence from the Banking Sector

A Coefficient-Based Method for the Allocation of Indirect Costs

Fiscal and Distributional Effects of the Change in the Social Security Model for Civil servAnts in Bulgaria

Forecasting the Volatility of Leading Banking Institutions Using the EGARCH (1.1) Model

Measuring Regional Economic Opportunities: A New Approach Through the Regional Economic Opportunities Index and the Regional Deficit Coefficient

D. A. TSENOV ACADEMY OF ECONOMICS
SVISHTOV

Народностопански архив
Година LXXIX книга 3 - 2026
Year LXXIX, Issue 3 - 2026
Economic Archive

EDITORIAL BOARD:
Prof. Teodora Dimitrova, PhD – Editor-in-chief
Prof. Svetoslav Iliychovski, PhD – Deputy Editor
Assoc. Prof. Mihail Chipriyanov, PhD
Assoc. Prof. Zhelao Vytev, PhD
Assoc. Prof. Iskra Panteleeva, PhD
Assoc. Prof. Plamen Yordanov, PhD
Assoc. Prof. Plamen Petkov, PhD
Assoc. Prof. Anatoliy Asenov, PhD
Assoc. Prof. Sergey Radukanov, PhD

INTERNATIONAL BOARD:
Prof. Mihail A. Eskindarov, DSc (Econ) –Financial University under the Government of the Russian Federation, Moscow (Russia).
Prof. Grigore Belostechnik, DSc (Econ) – Moldovan Academy of Economic Studies, Chisinau (Moldova).
Prof. Mihail Zveryakov, DSc (Econ) – Odessa State Economic University, Odessa (Ukraine).
Prof. Andrey Krisovatiy, DSc (Econ) – Ternopil National Economic University, Ternopil (Ukraine).
Prof. Ken O'Neil, PhD – University of Ulster (Ireland)
Prof. Richard Thorpe, PhD – Leeds University (Great Britain)
Prof. Olena Nepochatenko, DSc (Econ) – Uman National University of Horticulture, Uman (Ukraine)
Prof. Dmytro Lukianenko, DSc (Econ) – Kyiv National Economic University named after Vadym Hetman, Kyiv (Ukraine)
Assoc. Prof. Maria Cristina Stefan, PhD – Valahia University of Targoviste (Romania)
Assoc. Prof. Anisoara Duica, PhD – Valahia University of Targoviste (Romania)
Assoc. Prof. Vladinir Klimuk, PhD – Baranovichi State University, Branovic (Belarus)

Support Team
Elena Petkova – Technical Secretary
Anka Taneva – Bulgarian Copy Editor
Ventsislav Dikov – Senior Lecturer in English – Translation from/into English
Margarita Mihaylova, PhD – Senior Lecturer in English – Translation from/into English

Editorial address:
2, Emanuil Chakarov street, Svishtov 5250
Prof. Teodora Dimitrova, PhD – Editor-in-Chief
☎ (++359) 631 66 201
Elena Petkova – technical secretary
☎ (++359) 631 66 201, e-mail: nsarhiv@uni-svishtov.bg
Blagovesta Borisova – computer graphic design
☎ (++359) 882 552 516, e-mail: b.borisova@uni-svishtov.bg
Milena Aleksandrova – computer graphic design
☎ (++359) 888 303 402, e-mail: m.aleksandrova@uni-svishtov.bg

In 2026, the journal will be printed using a financial grant from the Scientific Research Fund – Agreement № KP-06-NP7-66 from Bulgarska Nauchna Periodika – 2026 competition.

© Academic Publishing House "Tsenov" – Svishtov
© D. A. Tsenov Academy of Economics – Svishtov

ECONOMIC ARCHIVE

YEAR LXXIX, BOOK 3 – 2026

CONTENTS

Mihail Chipriyanov, Mario Stephan Hopfner
Green Banking as a catalyst for Sustainable Development – Evidence from the Banking Sector / 3

Rosen Iliyanov Kolev
A Coefficient-Based Method for the Allocation of Indirect Costs / 23

Teodor Nenov, Ivaylo Kanev
Fiscal and Distributional Effects of the Change in the Social Security Model for Civil servAnts in Bulgaria / 34

Petar Georgiev Dzhelepov
Forecasting the Volatility of Leading Banking Institutions Using the EGARCH (1.1) Model / 47

Stefka Chilova
Measuring Regional Economic Opportunities: A New Approach Through the Regional Economic Opportunities Index and the Regional Deficit Coefficient / 72

FORECASTING THE VOLATILITY OF LEADING BANKING INSTITUTIONS USING THE EGARCH (1.1) MODEL

Petar Georgiev Dzhelepov
D. A. Tsenov Academy of Economics – Svishtov
Department of Finance and Credit

Abstract: This study focuses on the analysis and forecasting of stock price volatility among leading banking institutions using the EGARCH (1,1) model. In a dynamic and often volatile financial environment, the accurate modeling of market risk is of critical importance to both investors and financial institution management. The EGARCH model is particularly suitable for capturing asymmetric effects in volatility, whereby negative market shocks exert a stronger impact on volatility than positive shocks of comparable magnitude.

The study examines twenty of the largest banks worldwide selected based on their market capitalization and analyzes the dynamics of their realized and conditional volatility over the period 2020–2025. The results indicate that the EGARCH (1,1) model effectively captures the key characteristics of the volatility process, including volatility clustering and the persistence of risk, although it exhibits a tendency to smooth extreme observations. Overall, the findings suggest that the EGARCH (1,1) model constitutes a robust and reliable tool for analyzing and forecasting market volatility in the context of the global banking sector.

Key words: volatility, EGARCH model, market risk, conditional variance, financial time series, banking sector, volatility clustering, asymmetric effects.

URL: nsarhiv.uni-svishtov.bg
DOI: https://doi.org/10.58861/tae.ea-nsa.2026.3.04.en
JEL: G17, C22, G21.

* * *

Introduction

In the conditions of increasing uncertainty and heightened volatility in global financial markets, issues related to the measurement and forecasting of volatility have become increasingly relevant. Volatility has emerged as a key indicator of market risk, reflecting not only the magnitude of price fluctuations but also investors' expectations and the degree of uncertainty prevailing in the economic environment (Cont, 2001; Tsay, 2010). Accurate modeling of market risk is therefore of critical importance to both investors and the management of financial institutions (Radukanov, 2017). The heightened sensitivity of financial markets to macroeconomic, geopolitical, and institutional factors further underscores the need for reliable econometric models capable of capturing the complex dynamics of market risk.

The **object** of the present study is a sample of leading banking institutions worldwide, examined from the perspective of the market volatility of their stocks. The **subject** of the study is the modeling and forecasting of stock market volatility using the EGARCH (1,1) model, which takes into account asymmetric effects in response to market shocks.

The primary **objective** of the study is to assess the applicability and effectiveness of the EGARCH model in describing the dynamics of volatility in the banking sector. To achieve this objective, several research tasks are undertaken, including an examination of the theoretical foundations of the model, its empirical application to data from leading banks, and an assessment of its ability to capture key characteristics of the volatility process, such as volatility clustering, persistence, and asymmetric responses to market shocks.

Thus, the study aims to contribute to a deeper understanding of market risk in the banking sector and to highlight the potential of the EGARCH model as a reliable analysis and forecasting tool.

1. Theoretical presentation of the EGARCH model

The Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model was proposed by Nelson (Nelson, 1991) as an extension of the standard GARCH model, with the aim of providing a more accurate representation of asymmetric volatility responses to market shocks. Traditional GARCH models assume a symmetric response to market movements in which positive and negative returns have effects of equal magnitude on volatility (Bollerslev, 1986; Engle, 1982). In actual market dynamics, however, a phenomenon known as a leverage effect is frequently observed,

whereby negative shocks lead to a greater increase in volatility than positive shocks of the same magnitude (Nelson, 1991; Brooks, 2019).

The EGARCH model addresses this limitation by introducing a logarithmic specification of the conditional variance, thereby ensuring its positivity without imposing additional restrictions on the model parameters. This formulation allows for a more flexible and realistic representation of volatility dynamics, particularly during periods of heightened market uncertainty and pronounced price fluctuations. Owing to this structure, the EGARCH model has become a widely used tool for analyzing financial time series characterized by asymmetric volatility responses and persistent risk dynamics.

The EGARCH model describes the dynamics of conditional volatility through a logarithmic transformation of the conditional variance. The general specification of an EGARCH (p, q) model is given by:

$$\ln(\sigma_t^2) = \omega + \sum_{i=1}^{q} \beta_i \ln(\sigma_{t-1}^2) + \sum_{j=1}^{p} \alpha_j \left(\frac{|\varepsilon_{t-j}|}{\sigma_{t-j}} - E\left[\frac{|\varepsilon_{t-j}|}{\sigma_{t-j}} \right] \right) + \sum_{j=1}^{p} \gamma_j \frac{\varepsilon_{t-j}}{\sigma_{t-j}},$$

where:

σ_t^2 : the conditional variance of asset returns at time t;

ω : the baseline or constant long-term volatility;

β_i : measures how past volatility persists into the future (memory effect);

α_j : captures the effect of the absolute magnitude of shocks;

γ_j: captures the asymmetry, i.e. the difference of the effects of positive and negative shocks;

ε_t: a random error term, typically with a mean of zero and unit variance.

The logarithmic specification of the EGARCH model ensures that the conditional variance remains positive, regardless of model parameter values. This is a significant advantage over the standard GARCH model, which requires parameter restrictions, such as като $\alpha, \beta \geq 0$ to ensure a valid conditional variance. Moreover, the asymmetry parameter γ (gamma) enables the model to capture the leverage effect, whereby negative shocks result in a larger increase in volatility than positive shocks of the same magnitude.

The economic rationale underlying the EGARCH model is based on the assumption that market participants respond more strongly to adverse events than to favorable events of comparable magnitude. This phenomenon, commonly referred to as the leverage effect, reflects the tendency for volatility to increase more following a decline in asset prices than following an equivalent increase. The parameter γ captures the magnitude and direction of this asymmetry. Under the conventional EGARCH specification, a negative value

of γ indicates that negative returns generate a stronger volatility response than positive returns, a pattern frequently observed in equity markets.

Using a logarithmic format, the EGARCH model not only ensures a positive conditional variance but also provides greater flexibility in capturing the dynamics of financial markets, where investor responses to positive and negative shocks may be asymmetric (Tsay, 2010; Alexander, 2008). This makes the model particularly suitable for analyzing the volatility of stocks, market indices, and derivatives, where market disturbances may produce disproportionately stronger effects following adverse events.

The EGARCH model has several advantages that distinguish it from the standard GARCH approach. Its most significant advantage is its ability to account for asymmetric volatility responses to positive and negative shocks. This feature is particularly relevant in financial markets, where adverse news and negative market shocks typically generate disproportionately larger increases in risk. Another important advantage is the logarithmic specification of the conditional variance, which ensures that the variance remains positive without requiring parameter restrictions to impose non-negativity. Furthermore, the model provides greater flexibility in analyzing financial data characterized by pronounced volatility dynamics, including periods of heightened uncertainty and abrupt changes in the behavior of returns.

Despite these advantages, the EGARCH model also has certain limitations. The estimation of its parameters is relatively more complex and computationally demanding, which may present challenges when applying the model to large datasets or in real-time environments. Moreover, although the model can capture asymmetric volatility responses, it may not always adequately account for extreme market events or structural changes over longer time horizons. In such cases, more advanced extensions or hybrid approaches may be employed, including combinations of EGARCH with stochastic volatility models or higher-order conditional heteroskedasticity specifications.

The EGARCH model has been widely applied in the management of market risk within global banking institutions, as it provides a more flexible representation of volatility dynamics under conditions of rapidly changing and frequently asymmetric financial markets. Its ability to model differentiated volatility responses to adverse market events is particularly relevant to the assessment of potential losses and the management of regulatory capital requirements under the Basel III and Basel IV standards. By capturing the leverage effect and the asymmetric relationship between returns and risk, the EGARCH model can provide informative inputs for stress-testing and market-risk assessment, including the estimation of Value at Risk (VaR) and Conditional Value at Risk (CVaR) (Jorion, 2007; McNeil et al., 2015). The continued development of market-risk measurement methodologies has also encouraged

the adoption of more advanced approaches, including applications in foreign exchange markets (Todorov, 2018).

In the practice of large international banks, EGARCH models are used as part of internal systems for volatility forecasting and capital buffer management, particularly for portfolios comprising derivatives, equities, and foreign exchange instruments (Hull, 2018). These models support decision-making processes related to hedging, exposure mitigation, and risk optimization. Because of their adaptability, EGARCH models can also be incorporated into scenario analysis and stress-testing frameworks, providing valuable insights into the behavior of market risk under different macroeconomic conditions. In this context, it is also important to emphasize that issues related to risk assessment and the reliability of model parameters are highly relevant to the analysis of financial derivatives, including foreign exchange options, where parameter accuracy can have a substantial impact on modeling outcomes (Todorov, 2018).

2. Risk forecasting using the EGARCH model

The present study examines the twenty largest banking institutions worldwide selected based on market capitalization as of 14 October 2025. The market data used in the analysis cover the period from 14 October 2020 to 14 October 2025 (see Table 1).

The selection of market capitalization as the primary criterion for identifying the banks included in the sample is based on several important considerations. First, market capitalization represents an aggregate market-based measure of the scale, perceived stability, and economic significance of a financial institution, as it reflects investors' expectations regarding its future cash flows and risk profile. In this respect, it incorporates information relating both to financial performance and to perceived market risk. Second, the use of this criterion facilitates the construction of a sample comprising globally significant banking institutions with highly liquid traded securities, thereby enhancing the reliability of the empirical analysis. Furthermore, market capitalization enables meaningful comparisons among banks from different geographical regions while maintaining a relatively high degree of homogeneity in terms of the scale of their operations.

Table 1

Banking institutions subject to the study

N	Bank
1	JPMorgan Chase
2	Bank of America
3	ICBC
4	Agricultural Bank of China
5	China Construction Bank
6	Wells Fargo
7	Morgan Stanley
8	Goldman Sachs
9	HSBC
10	Bank of China
11	Royal Bank of Canada
12	Commonwealth Bank
13	HDFC Bank
14	Citigroup
15	Mitsubishi UFJ Financial
16	Charles Schwab
17	CM Bank
18	Santander
19	Toronto Dominion Bank
20	Capital One

Source: *Author's compilation.*

A relatively strong correspondence is observed between the realized and modeled volatility. The model successfully captures the main periods of heightened market activity, responding clearly to volatility clustering and abrupt market shocks (see Figure 1).

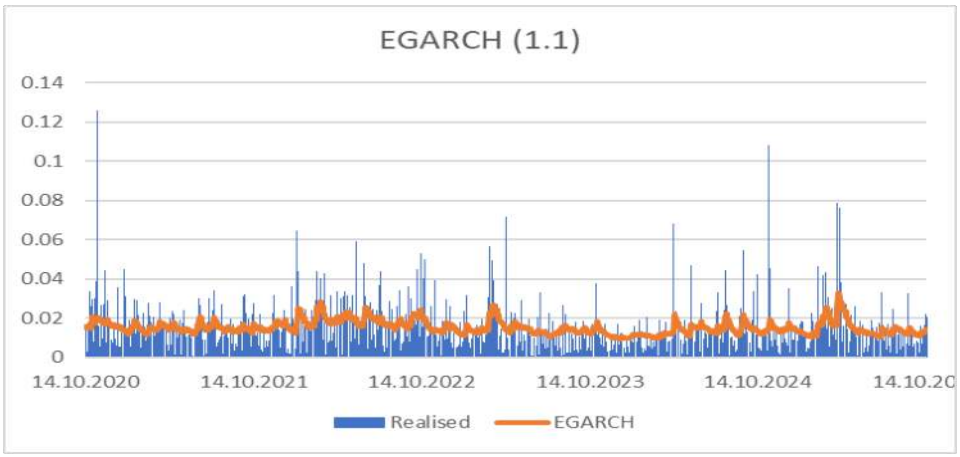

Figure 1. ***EGARCH (1.1) results for JPMorgan Chase***

A distinct feature of the EGARCH specification is its ability to capture asymmetric effects; whereby negative market events exert a stronger influence on volatility than positive events of comparable magnitude. This is supported by the model's observed responses to extreme observations, particularly during periods of heightened market instability, when conditional volatility increases more sharply.

Nevertheless, some degree of smoothing of peak values can be observed, suggesting that the model tends to underestimate the most extreme market movements. Despite this limitation, the EGARCH (1,1) model demonstrates a high degree of sensitivity to changes in risk dynamics and provides a more adequate representation of asymmetric effects. These characteristics make it a suitable tool for analyzing and forecasting market volatility in the context of large global banking institutions.

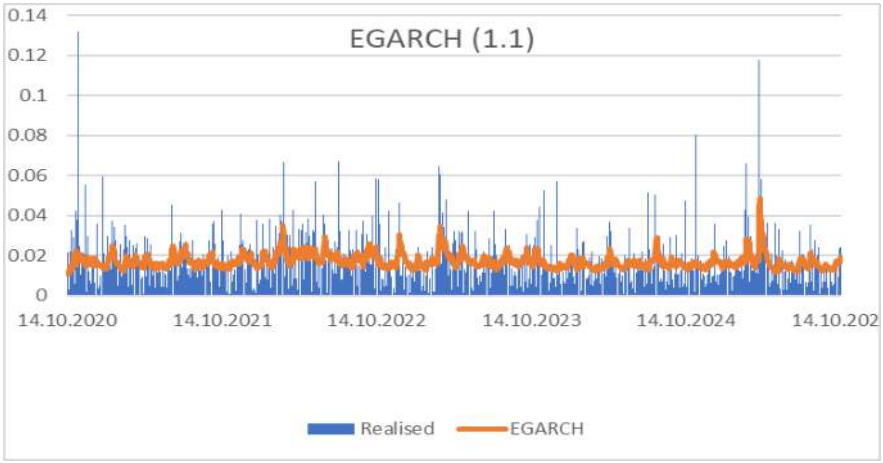

Figure 2. ***EGARCH (1.1) results for Bank of America***

Figure 2 presents the results obtained from the application of the EGARCH (1,1) model to Bank of America. A relatively strong correspondence between realized and modeled volatility can be observed over most of the study period. The model successfully captures the underlying dynamics of volatility, including volatility clustering and periods of heightened market uncertainty.

The response of the EGARCH model to extreme market events is particularly evident toward the end of the study period, where substantial volatility spikes are observed. This finding corroborates the model's ability to capture asymmetric effects and to respond more sensitively to negative shocks. Nevertheless, as is the case with other volatility models, some degree of smoothing of the highest volatility values can be observed, suggesting a partial underestimation of extreme market movements.

Overall, the EGARCH (1,1) model demonstrates good adaptability to changes in market conditions and provides a relatively realistic representation of conditional volatility.

Figure 3 illustrates the results obtained from the application of the EGARCH (1,1) model to Industrial and Commercial Bank of China (ICBC). Compared with the institutions analyzed previously, the conditional volatility exhibits relatively stable dynamics. Realized volatility displays more moderate fluctuations, which is also reflected in the smoother trajectory of the modeled volatility.

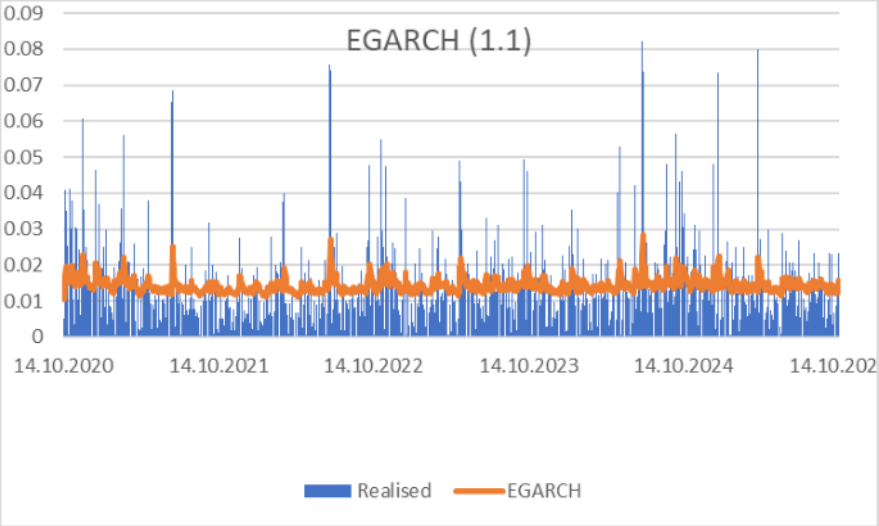

Figure 3. ***EGARCH (1.1) results for ICBC***

The EGARCH model successfully captures the presence of volatility clustering and responds appropriately to individual market shocks, although their intensity is comparatively less pronounced. This implies a relatively lower

sensitivity of the analyzed institution to extreme market events, potentially reflecting characteristics of the institutional and regulatory environment of the Chinese banking sector.

Despite the overall good correspondence between realized and modeled volatility, some degree of smoothing of the peaks can be observed, which is a common feature of volatility models and may result in a partial underestimation of the most extreme observations. Nevertheless, the EGARCH (1,1) model demonstrates a high degree of adequacy in modeling conditional volatility and provides a useful basis for assessing market risk in the context of ICBC.

Figure 4 presents the results obtained from applying the EGARCH (1,1) model to the stock volatility of Agricultural Bank of China. A pronounced clustering of volatility can be observed, with periods of relatively low variability alternating with episodes of heightened instability, particularly toward the end of the study period (Cont, 2001). The EGARCH-estimated volatility broadly follows the dynamics of realized volatility, successfully capturing the main trends and persistent changes in the risk level.

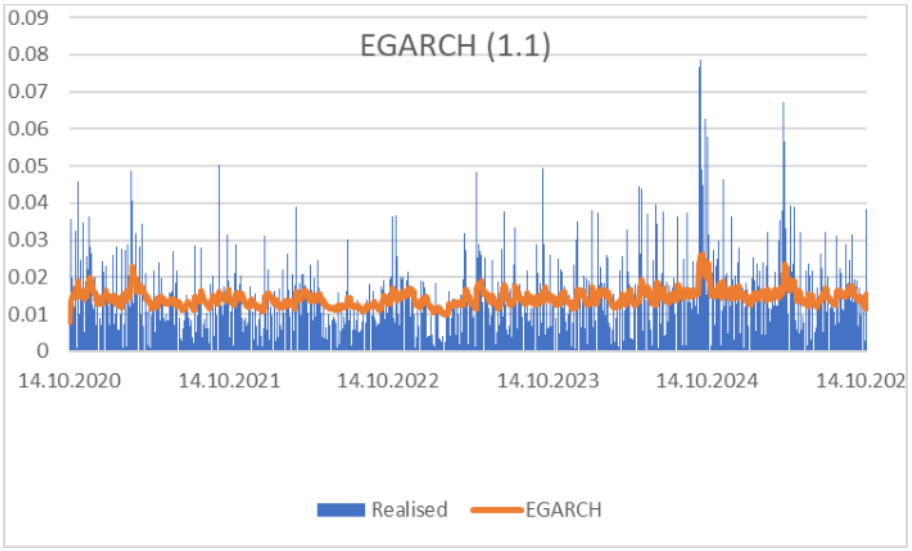

Figure 4. ***EGARCH (1.1) results for Agricultural Bank of China***

At the same time, some degree of smoothing of extreme values can be observed, with the model not fully reproducing the sharp peaks evident in the realized data. Such behavior is typical for the EGARCH specifications, which prioritize capturing the dynamics of conditional variance and the asymmetric effects of shocks rather than precisely reproducing individual extreme events. Overall, the results confirm the applicability of the model for volatility analysis

while also highlighting its limitations in capturing and interpreting sudden market disruptions.

Figure 5 presents the results obtained from applying the EGARCH (1,1) model to the stock volatility of China Construction Bank over the study period. A relatively low and stable level of conditional volatility can be observed, with the model-estimated volatility remaining within a narrow range and exhibiting a smooth trajectory over time. At the same time, realized volatility is characterized by several sharp spikes, particularly during the later part of the study period, indicating episodic market disruptions.

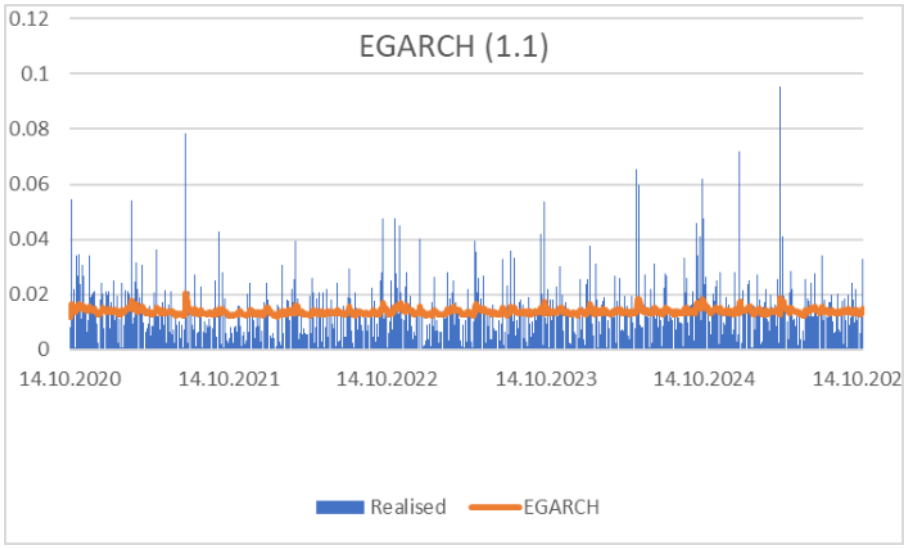

Figure 5. ***EGARCH (1.1) results for China Construction Bank***

The EGARCH (1,1) model successfully captures the overall level and trend of volatility as well as the presence of volatility clustering. However, like in the previous case, it smooths extreme observations and does not fully express the intensity of sudden volatility spikes. This behavior is consistent with the theoretical characteristics of the model, which is designed to capture the dynamics of conditional variance and asymmetric responses to shocks rather than precisely reproduce individual extreme observations. Overall, the results support the adequacy of the EGARCH (1,1) model for describing the volatility of this banking asset, while also highlighting its limitations in the presence of pronounced short-term fluctuations.

The realized volatility of Wells Fargo is higher and more dynamic than that observed for the previously analyzed banks, with frequent and pronounced volatility spikes, particularly at the beginning and toward the end of the study period.

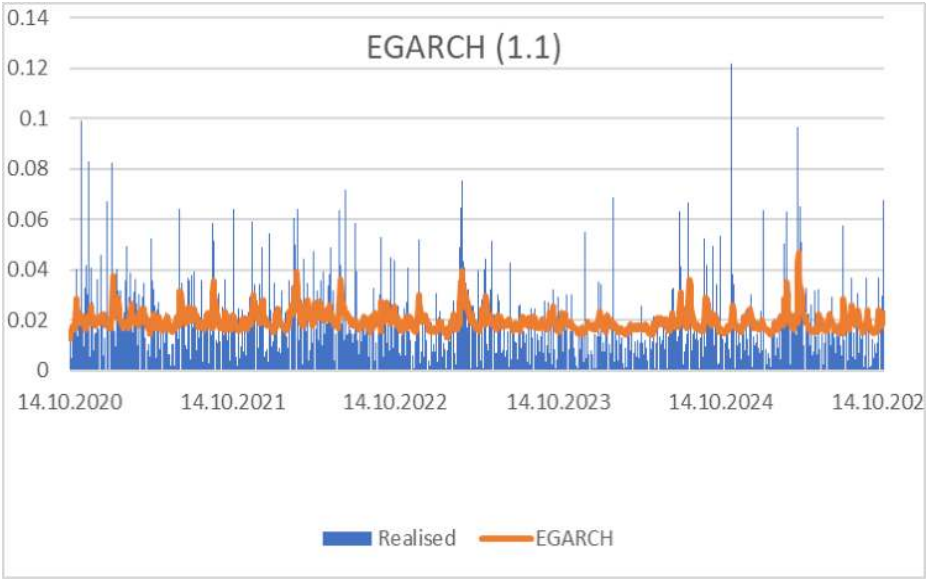

Figure 6. ***EGARCH (1.1) results for Wells Fargo***

The model-estimated volatility follows the overall trend of realized volatility and clearly reflects the presence of volatility clustering, with conditional variance increasing after periods of heightened instability. Nevertheless, as observed in the other cases examined, the EGARCH (1,1) model smooths extreme observations and does not fully reproduce the amplitude of the sharpest fluctuations, resulting in some degree of risk underestimation during periods of severe market shocks. This behavior is consistent with the characteristics of the model, which focuses on the capture of persistent changes in volatility and asymmetric responses to shocks. Overall, the model demonstrates a good ability to describe the dynamics of Wells Fargo's stock volatility, while also exhibiting limitations in capturing short-term extreme movements.

Figure 7 illustrates the results obtained from applying the EGARCH (1,1) model to the volatility of Morgan Stanley's stock and provides a clear visual comparison between realized volatility and the estimated conditional volatility. The time-series dynamics reveal typical episodes of relative market calm that are abruptly interrupted by periods of heightened instability. Realized volatility is characterized by sudden and often short-lived spikes, reflecting the sensitivity of market prices to new information and external shocks.

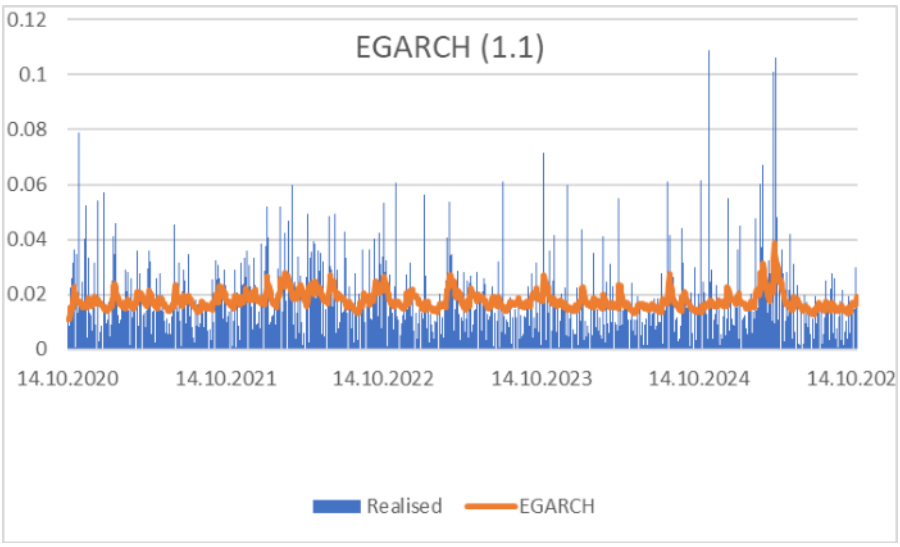

Figure 7. ***EGARCH (1.1) results for Morgan Stanley***

Against this background, the EGARCH model produces a smoother and more persistent trajectory that follows the overall level of volatility without responding excessively to individual extreme observations. This behavior makes it possible to identify the underlying trend in volatility while retaining sensitivity to periods of risk accumulation. An increase in volatility can be observed during the later stages of the study period, which the model captures through a gradual increase in its estimates, indicating the presence of persistent volatility clusters.

Overall, the figure demonstrates that the model successfully captures the key characteristics of Morgan Stanley's volatility, including its persistence and asymmetric response to market shocks. Consequently, the EGARCH (1,1) specification provides a useful basis for a more in-depth analysis of market risk and financial market dynamics.

Figure 8 presents the relationship between realized volatility and the estimated conditional volatility of Goldman Sachs. The figure reveals the characteristic heterogeneity of financial market volatility, with relatively calm periods alternating with sudden and pronounced spikes reflecting market responses to significant events and information shocks.

Realized volatility exhibits substantial variability and several extreme observations, particularly toward the end of the study period, when some of the largest amplitudes are observed. At the same time, the EGARCH model generates a smoother trajectory that follows the overall level of volatility while attenuating sharp deviations. This feature highlights its ability to capture the

persistent components of volatility without responding excessively to short-lived fluctuations and isolated extreme observations.

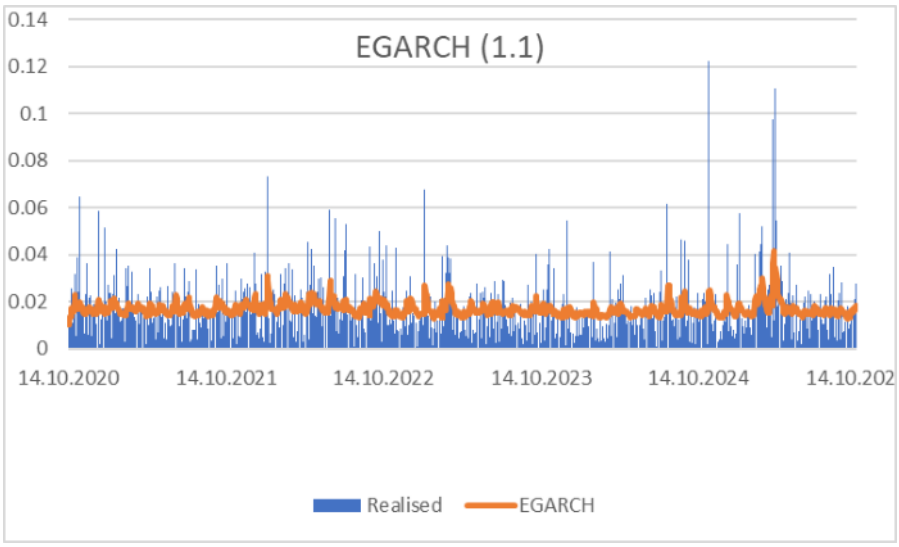

Figure 8. ***EGARCH (1.1) results for Goldman Sachs***

Over the studies period, an increase of volatility clustering is observed, with periods of heightened instability tending to occur in clusters rather than as isolated events. The model responds to this pattern with a gradual increase in its volatility estimates, indicating its ability to adapt to changing market conditions.

The results indicate that the model successfully captures the main characteristics of Goldman Sachs' volatility, including its persistence and tendency to exhibit asymmetric responses to market shocks, thereby providing a useful framework for the analysis and interpretation of market risk.

Figure 9 presents the results obtained from applying the model to the stock volatility of HSBC. Once again, the analysis reveals the characteristic dynamics of financial markets, with periods of relative calm alternating with sudden episodes of heightened instability. Realized volatility exhibits pronounced variability, with numerous short-lived spikes distributed throughout the study period, suggesting the occurrence of frequent, although not necessarily persistent, episodes of market disturbances.

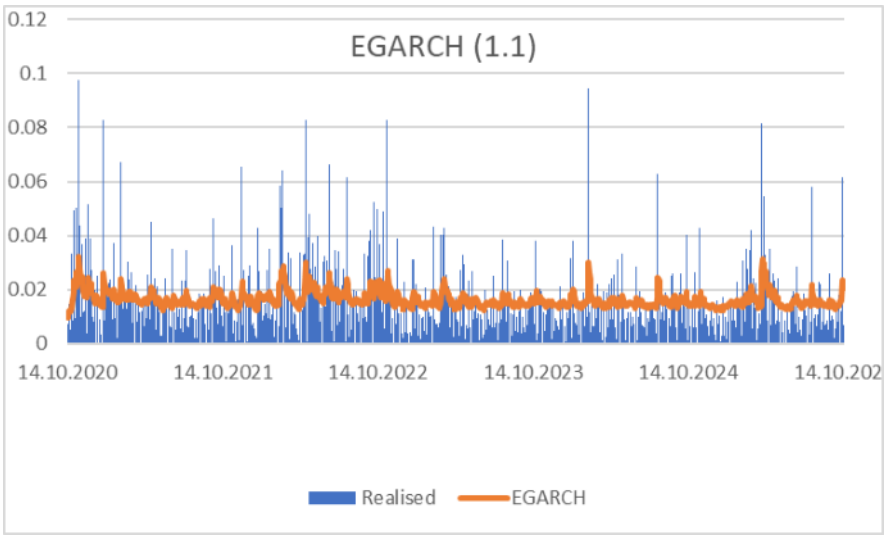

Figure 9. ***EGARCH (1.1) results for HSBC***

Against this background, the EGARCH model estimates follow a considerably smoother trajectory, capturing the overall level of volatility and its longer-term fluctuations. Although the model does not fully reproduce the amplitude of the most extreme observations, it responds to them through a moderate increase in conditional volatility, indicating the presence of volatility clustering and persistence of the volatility trend.

It is noteworthy that, throughout most of the study period, volatility fluctuation is relatively moderate, with no prolonged phases of extreme instability such as those observed for some of the other financial institutions analyzed. Nevertheless, individual spikes, particularly during the later stages of the study period, highlight the market's sensitivity to specific events, with the model gradually adapting its estimates to these changes.

Figure 10 presents the results obtained from applying the model to the stock volatility of Bank of China, clearly revealing a comparatively lower and more stable baseline fluctuation level than that observed for the previously analyzed institutions. Realized volatility is characterized by distinct spikes that occur sporadically and are often associated with specific market events and prolonged periods of relative calm between them.

The EGARCH model estimates follow the same pattern, producing a smooth trajectory that captures the underlying level of volatility and responds moderately to sharp increases in market instability. Notably, even in the presence of individual pronounced spikes in realized volatility, the model maintains a relatively restrained response, highlighting its ability to filter short-lived noise and emphasize the more persistent elements of the volatility trend.

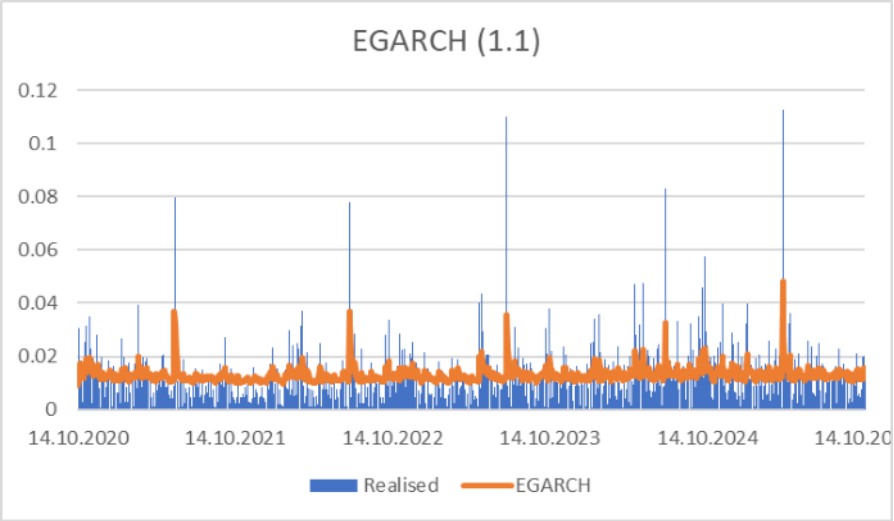

Figure 10. ***EGARCH (1.1) results for Bank of China***

In the course of time, an increase in the frequency and amplitude of volatility spikes becomes apparent, particularly during the later stages. This pattern may indicate heightened market sensitivity to external shocks. The EGARCH model reflects this tendency through a gradual increase in conditional volatility and a more pronounced response during periods characterized by clustered shocks, indicating the presence of volatility persistence and clustering.

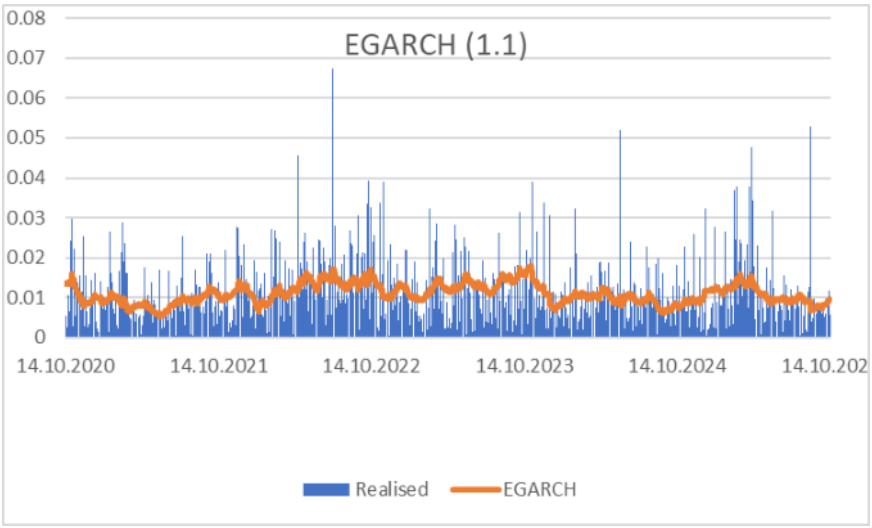

Figure 11. ***EGARCH (1.1) results for Royal Bank of Canada***

Figure 11 presents the results obtained from applying the model to the stock volatility of Royal Bank of Canada over the study period. A moderate

level of realized volatility can be observed, accompanied by distinct but relatively infrequent extreme observations compared with those recorded for some of the other institutions in the sample. The model-estimated volatility has a smooth curve and successfully captures the main trends, including the presence of volatility clustering, while responding to periods of heightened instability with a gradual increase in conditional variance.

At the same time, the characteristic smoothing of sharp volatility spikes associated with the EGARCH specification is evident, with the model not fully reproducing the amplitude of extreme fluctuations in realized volatility. This behavior demonstrates the model's ability to capture persistent changes in volatility and asymmetric responses to market shocks, while also highlighting its limitations in capturing sudden and short-lived market disruptions.

Commonwealth Bank's realized volatility remains at a relatively low to moderate level, accompanied by several distinct spikes reflecting short-lived episodes of market stress. The model-estimated volatility follows a stable and smooth trajectory, successfully capturing the underlying level of risk and the presence of volatility clustering over time.

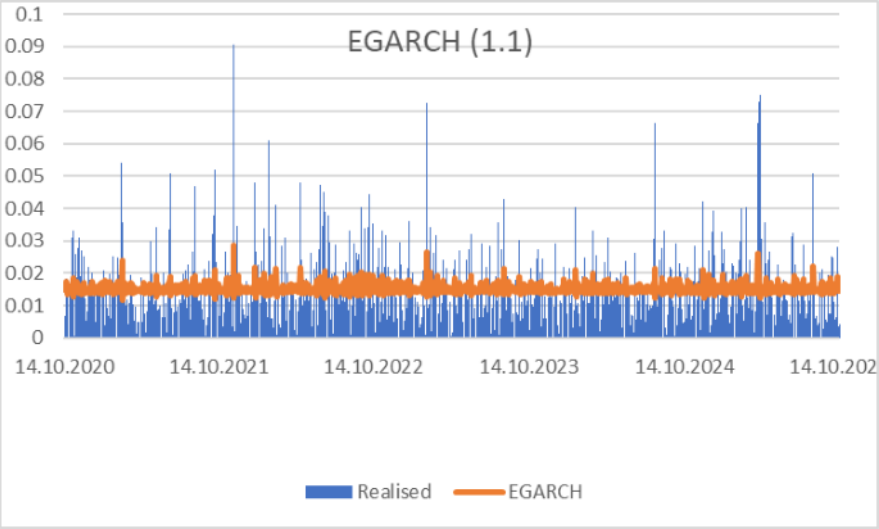

Figure 12. ***EGARCH (1.1) results for Commonwealth Bank***

Nevertheless, consistent with the findings for the other banks analyzed, the EGARCH (1,1) model exhibits a tendency to smooth extreme observations and does not fully reproduce the amplitude of the sharpest fluctuations in realized volatility. This behavior is consistent with the theoretical characteristics of the model, which emphasizes the dynamics of conditional variance and asymmetric responses to shocks. Overall, the model provides an adequate representation of the volatility dynamics of Commonwealth Bank's stock while

also highlighting its limitations in capturing sudden and pronounced market movements.

Figure 13 presents the results obtained from applying the model to the stock volatility of HDFC Bank over the study period. Realized volatility exhibits a moderate level with periodic sharp spikes reflecting short-lived market disturbances, particularly during the middle and later stages of the period. The model-estimated volatility follows a relatively smooth and persistent trajectory, successfully capturing the main trends and the presence of volatility clustering.

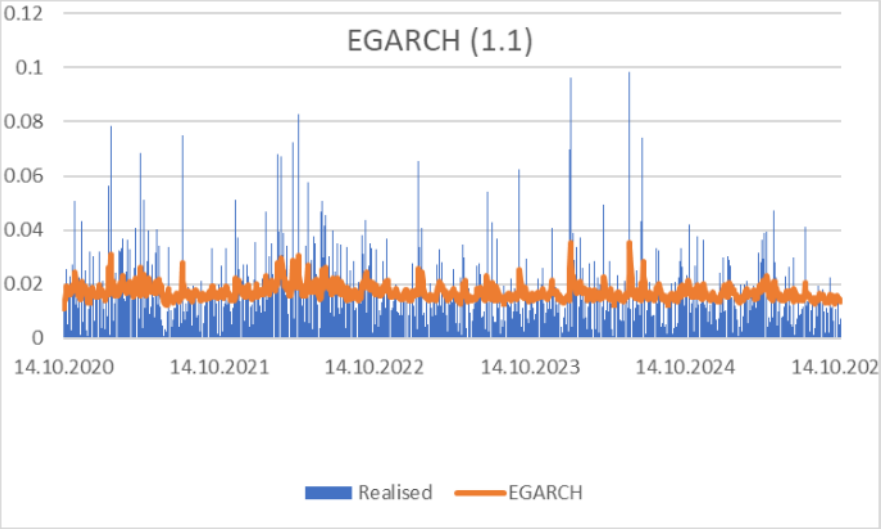

Figure 13. ***EGARCH (1.1) results for HDFC Bank***

The model exhibits an appropriate response for periods of greater instability, reflected in a gradual increase in conditional variance, although it does not fully reproduce the amplitude of extreme observations. This smoothing is a characteristic feature of the EGARCH (1,1) specification, which emphasizes the capture of asymmetric responses to shocks and the longer-term dynamics of risk. Overall, the model provides a reliable representation of HDFC Bank's stock volatility while exhibiting limited sensitivity to isolated extreme fluctuations.

Figure 14 presents the results obtained from applying the EGARCH (1,1) model to the stock volatility of Citigroup, clearly illustrating the complex and dynamic nature of market fluctuations. At the beginning of the study period, relatively high levels of realized volatility are observed, followed by periods of relative stabilization, creating a characteristic pattern of alternating instability and consolidation.

Realized volatility exhibits a pronounced tendency toward sharp spikes occurring at irregular intervals, with several particularly prominent extreme

observations appearing in the middle and toward the end of the study period. These episodes may reflect the impact of significant market events or temporary increases in market stress, resulting in short-lived but pronounced price movements.

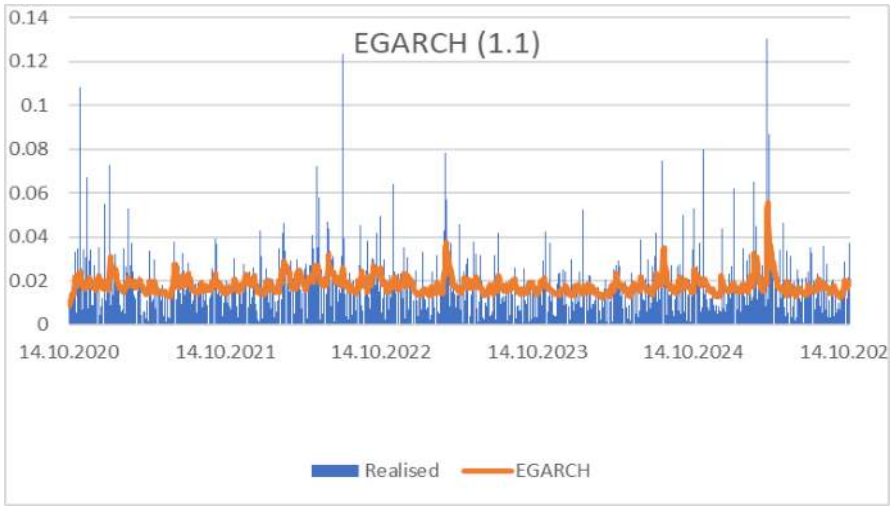

Figure 14. ***EGARCH (1.1) results for Citigroup***

Against this background, the EGARCH model produces a smoother trajectory that follows the overall pattern of volatility while attenuating extreme fluctuations. Its response to sudden spikes is moderate and gradual, allowing longer-term changes in the level of risk to be identified. At the same time, a clear volatility-clustering effect can be observed, with periods of heightened instability occurring in clusters rather than as isolated events. The model captures this persistence through higher volatility estimates that remain elevated over the subsequent periods.

Overall, the figure indicates that the model provides a reliable representation of volatility dynamics for Citigroup, combining sensitivity to market shocks with the smoothing of short-lived extreme movements. This makes the EGARCH (1,1) specification a useful tool for analyzing market risk in the context of highly integrated financial institutions that are sensitive to global market factors.

The results for Mitsubishi UFJ Financial Group reveal a relatively balanced pattern with periods of moderate stability and individual episodes of heightened market uncertainty (see Figure 15). Realized volatility is characterized by frequent but generally moderate fluctuations, among which several more pronounced spikes stand out at irregular intervals.

Visually, the most pronounced volatility episodes appear to be concentrated at specific points in time, potentially reflecting the market's response to

certain economic or financial events. During most of the study period, however, volatility dynamics remain relatively moderate. The EGARCH model presents this pattern as a smooth trajectory that captures the underlying level of volatility and responds gradually to increases in market stress.

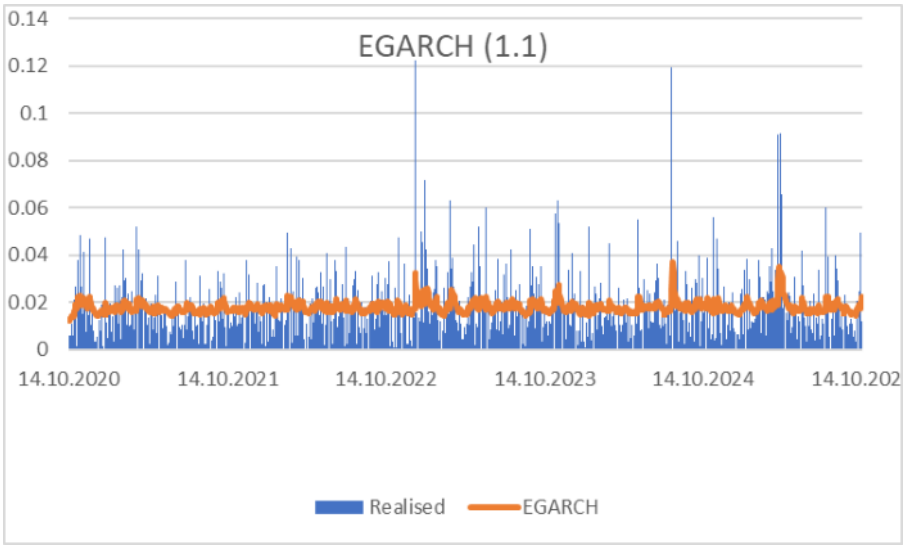

Figure 15. ***EGARCH (1.1) results for Mitsubishi UFJ Financial***

The model's response to volatility clustering is particularly interesting - following increases in realized volatility, the estimates of conditional volatility also rise and remain elevated for a certain period before gradually returning to lower levels. This behavior indicates the model's ability to capture persistence in the volatility process without being excessively influenced by isolated extreme observations.

Overall, the figure indicates that the EGARCH (1,1) model provides an adequate and stable representation of volatility for Mitsubishi UFJ Financial Group, combining sensitivity to market shocks with the smoothing of short-lived fluctuations. In this way, the model provides a useful basis for interpreting market risk in the context of the Japanese banking sector.

Distinct volatility spikes are already evident at the beginning of the study period, followed by a pattern characterized by alternating periods of moderate volatility and sudden episodes of heightened instability (see Figure 16).

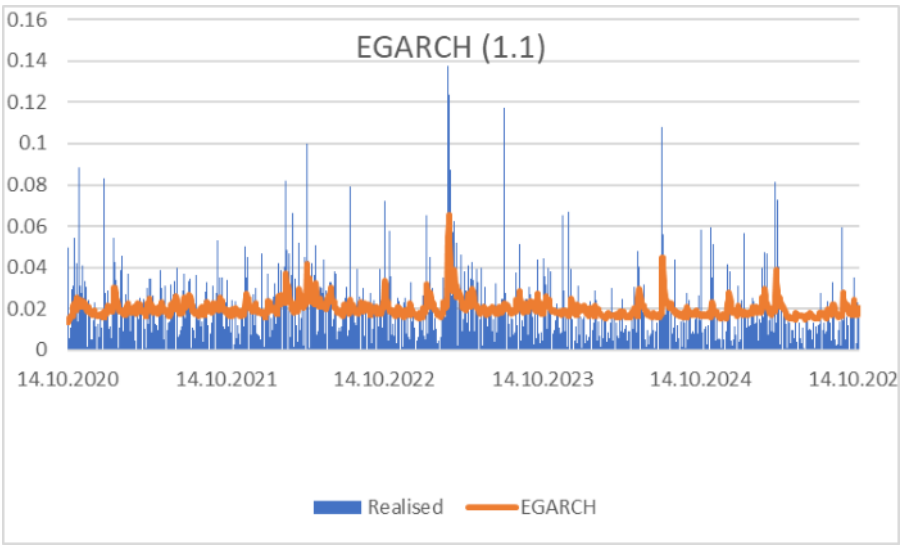

Figure 16. ***EGARCH (1.1) results for Charles Schwab***

Obviously, realized volatility tends to spike, particularly during the middle phase of the period, when some of the highest volatility spikes in the sample are observed. These movements may indicate periods of heightened market stress and increased sensitivity to external factors. At the same time, the EGARCH model follows the overall trend with a smoother trajectory, responding to these events with a gradual increase in conditional volatility without fully reproducing their magnitude.

As the study period progresses, a pronounced volatility-clustering effect becomes evident, with periods of heightened instability occurring in clusters and persisting for some time. The model successfully captures this persistence by maintaining higher levels of conditional volatility even after the most extreme spikes have subsided, which is consistent with the dynamic characteristics of the EGARCH specification.

Overall, the figure indicates that the EGARCH (1,1) model provides a reliable and informative representation of volatility dynamics for Charles Schwab Corporation. The model captures significant market disturbances while smoothing short-lived extreme fluctuations, making it a useful tool for market risk analysis in a dynamic financial environment.

Figure 17 presents the dynamics of realized and modeled volatility for CM Bank, clearly illustrating how the model captures the key characteristics of market uncertainty. Realized volatility has pronounced short-term fluctuations and several distinct spikes, reflecting periods of heightened financial market stress. Against this background, the volatility estimated by the EGARCH (1,1)

model follows the overall trend but does so with a smoother trajectory and more moderate amplitude, which is characteristic of this type of volatility model.

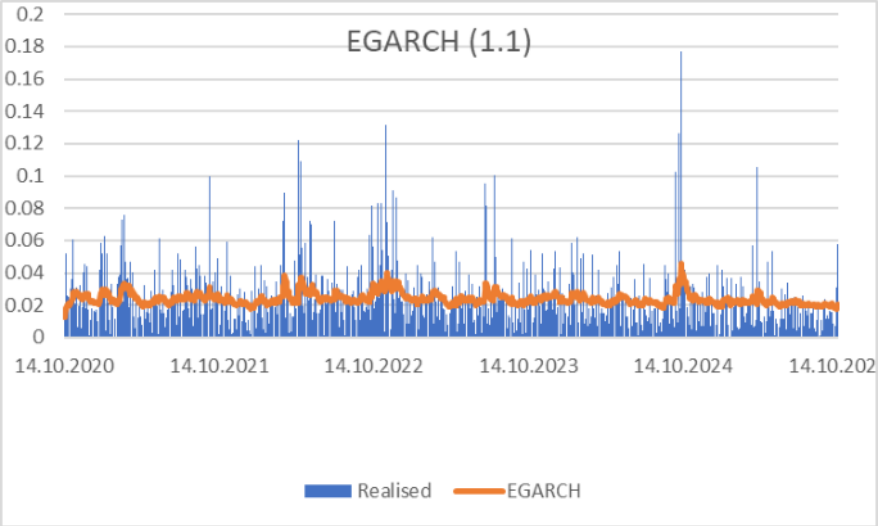

Figure 17. ***EGARCH (1.1) results for CM Bank***

During periods of sharply increased market activity (particularly around 2021 and 2023) realized volatility reaches substantially higher levels, whereas the model responds more moderately and with a slight lag. This divergence is consistent with the smoothing properties of EGARCH models, which are designed to capture the underlying dynamics of conditional volatility rather than reproduce every short-term fluctuation in realized volatility. Nevertheless, the model clearly captures the presence of volatility clustering and provides asymmetric responses to market shocks, including stronger responses to negative shocks, which is typical for financial time series.

Over the longer term, the figure indicates a gradual decline in volatility following 2023, a pattern that is also reflected in the EGARCH (1,1) estimates. This suggests that the model can not only capture short-term responses to market shocks but also more persistent changes in the volatility environment. Although it does not fully reproduce the extreme values observed in realized volatility, it provides a stable estimate of conditional volatility, supporting its use in market-risk analysis and forecasting.

For Banco Santander's conditional volatility dynamics is characterized by periods of heightened market instability (see Figure 18). Realized volatility has several distinct spikes, which the model captures to a large extent, although the extreme observations are subject to the characteristic smoothing effect of the EGARCH specification.

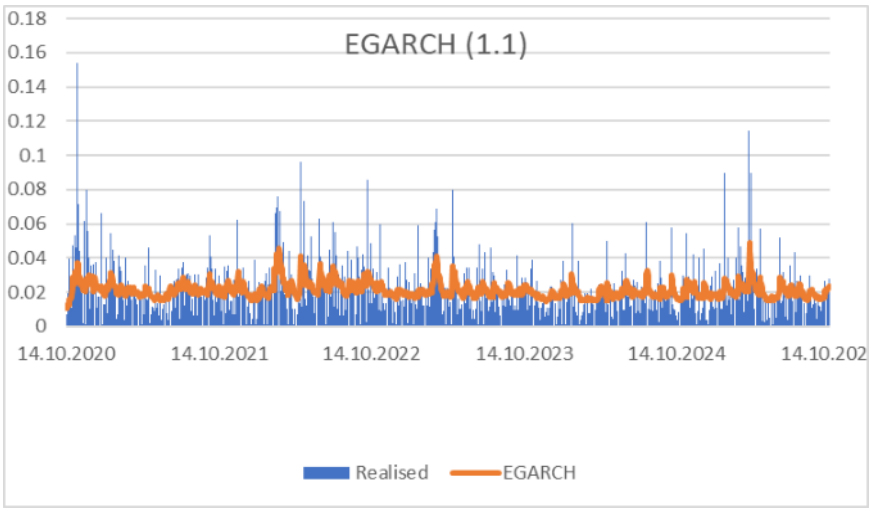

Figure 18. ***EGARCH (1.1) results for Santander***

The model effectively captures volatility clustering, with periods of persistently higher and lower market activity clearly distinguishable in the time series. This finding is consistent with the dynamic nature of risk associated with the institution under consideration. The presence of asymmetric responses can also be inferred from the model's stronger response to pronounced increases in volatility, which is consistent with the theoretical characteristics of the EGARCH specification.

Compared with the banks analyzed previously, Santander exhibits relatively greater volatility amplitude, which may indicate a higher sensitivity to external market factors.

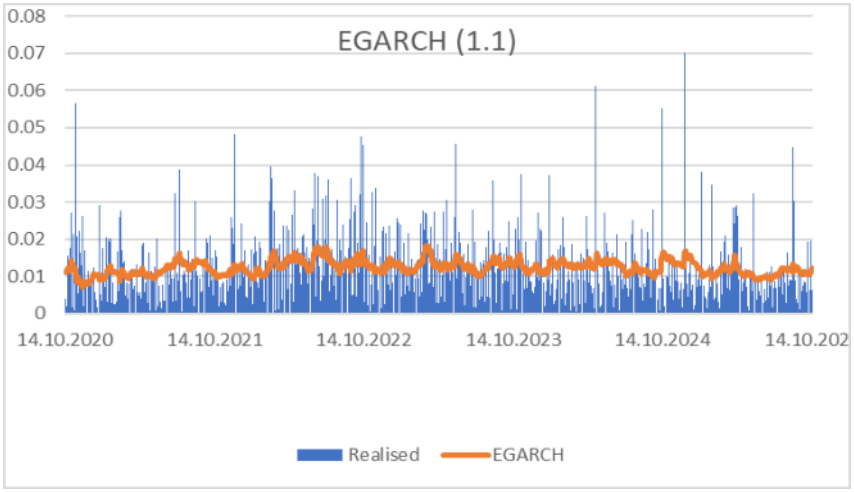

Figure 19. ***EGARCH (1.1) results for Toronto Dominion Bank***

A relatively stable pattern of conditional volatility with moderate fluctuations can be observed in Figure 19. Realized volatility exhibits several distinct spikes, although these are less pronounced than those observed for some of the other institutions analyzed. This is also reflected in the smoother trajectory of the model-estimated volatility.

The EGARCH model successfully captured the main characteristics of the volatility process, including volatility clustering and periodic increases in market uncertainty. The model responds appropriately to more significant shocks through an increase in conditional volatility, although some smoothing of extreme observations is evident.

Comparatively, Toronto-Dominion Bank has a relatively lower intensity of volatility fluctuations, which may indicate a relatively more stable volatility profile.

The institution's realized volatility under consideration exhibits relatively greater variability compared with some of the other institutions analyzed. Several distinct spikes are observed, reflecting periods of heightened market instability, while the model successfully tracks the overall dynamics of these fluctuations.

The EGARCH (1,1) model demonstrates a good ability to capture volatility clustering, responding appropriately to the accumulation of market shocks. The results are also consistent with the asymmetric response characteristic of its specification, whereby adverse market events result in stronger volatility responses. Nevertheless, some smoothing is observed at the most extreme values, suggesting that the model may partially underestimate the highest levels of observed risk.

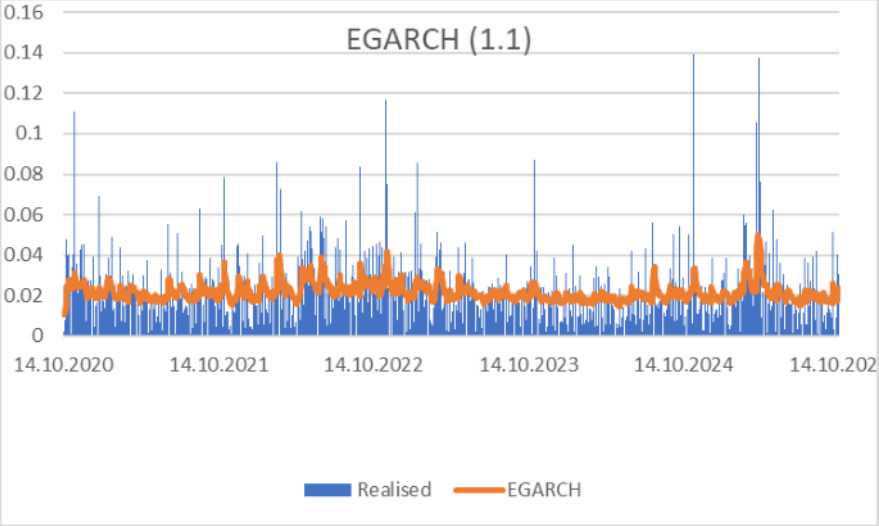

Figure 20. ***EGARCH (1.1) results for Capital One***

Comparatively, Capital One has more pronounced volatility dynamics than the institutions characterized by relatively more stable volatility patterns, which may be attributed to differences in business models and market exposure. Nevertheless, the EGARCH (1,1) model provides a robust and adaptable framework for risk analysis, successfully capturing the key characteristics of the volatility process.

Conclusion

The present study focused on the analysis and forecasting of stock volatility among leading banking institutions using the EGARCH (1,1) model with a particular emphasis on its ability to capture the dynamics of market risk in the contemporary financial environment. The empirical results provide a basis for several broader conclusions regarding the applicability and effectiveness of the econometric approach employed.

First, the empirical analysis confirms that the stock volatility of large banking institutions is characterized by pronounced volatility clustering and persistence, whereby periods of relatively low instability alternate with periods of heightened market activity. This behavior is consistent with established theoretical findings concerning financial time series and underscores the importance of employing models capable of capturing such dependencies.

Second, the EGARCH (1,1) model demonstrates a good ability to reproduce the principal characteristics of the volatility process (Brooks, 2019; Tsay, 2010). The model successfully captures volatility clustering and responds to market shocks while allowing for asymmetric effects, whereby negative events may have a stronger impact on volatility than positive events of comparable magnitude. This feature makes the model particularly suitable for the analysis of financial markets, where such asymmetries are frequently observed empirically.

Nevertheless, the results reveal certain limitations of the model as well. Most notably, a systematic smoothing of extreme observations in realized volatility can be observed, resulting in some degree of risk underestimation during periods of severe market shocks. This finding suggests that, when the primary focus is on extreme events, the use of complementary models or hybrid approaches may be appropriate in order to improve the accuracy of volatility estimates and risk assessment.

The comparative analysis across the individual banks reveals substantial differences in volatility dynamics, which may be associated with variations in their business models, geographical exposure, and degree of integration into global financial markets. Some institutions exhibit greater sensitivity to external shocks, whereas others display relatively more stable volatility patterns.

Overall, the findings indicate that the EGARCH (1,1) model represents a useful and applicable tool for the analysis and forecasting of volatility in the banking sector. It provides valuable information on the dynamics of market risk and can support risk-management processes, investment planning, and financial analysis. Future research could examine the application of more advanced volatility models or hybrid approaches in order to capture extreme market movements and structural changes in volatility more precisely.

REFERENCES

Todorov, T. (2018). Иновативни методи за измерване на пазарния риск на „FOREX“ пазара. Народностопански архив, бр. 4, с. 44–65.

Todorov, T. (2018). Тестване обективността на прецизиращите параметри на валутните опции. *Годишен алманах научни изследвания на докторанти на СА „Д. А. Ценов“*, Бр. 11, Кн. 14, с. 97–122.

Alexander, C. (2008). Market risk analysis, volume II: Practical financial econometrics. Wiley.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. Journal of Econometrics, 31(3), 307–327.

Brooks, C. (2019). Introductory econometrics for finance (4th ed.). Cambridge University Press.

Cont, R. (2001). Empirical properties of asset returns: Stylized facts and statistical issues. Quantitative Finance, 1(2), 223–236.

Engle, R. F. (1982). Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation. Econometrica, 50(4), 987–1007.

Hull, J. C. (2018). Options, futures, and other derivatives (10th ed.). Pearson.

Jorion, P. (2007). Value at risk: The new benchmark for managing financial risk (3rd ed.). McGraw-Hill.

McNeil, A. J., Frey, R., & Embrechts, P. (2015). Quantitative risk management: Concepts, techniques and tools. Princeton University Press.

Nelson, D. B. (1991). Conditional heteroskedasticity in asset returns: A new approach. Econometrica, 59(2), 347–370.

Radukanov, S. (2017). Market Risk Assessment under Value at Risk (VaR) Methodology – Specifications and Application. *Sotsialno-ikonomicheski analizi*, Book 2, VTU “St. Cyril and St. Methodius”, pp. 182–194.

Tsay, R. S. (2010). Analysis of financial time series (3rd ed.). Wiley.

Petar G. Dzhelepov is a Doctoral Candidate at the Department of Finance and Credit at D. A. Tsenov Academy of Economics – Svishtov, Bulgaria. **Scientific interests:** financial markets, market risk, banking institutions.