Revista de Științe Politice. Revue des Sciences Politiques • No. 79 • 2023: 46 – 56

ORIGINAL PAPER

Temporal Analysis of Mexico Stock Market Index Volatility using GJR-GARCH model

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Abstract:
Stocks play a crucial role in the stock market, which is at the very core of every nation's economic growth. Investors, analysts, and others in related fields have turned their attention to stock price analysis. This study empirically investigates the conditional variance (volatility) or empirically estimates the price volatility spillover transmission in the daily returns of IPC Mexico index from Mexico stock market, for the long period January 1993 - July 2023 (which is more than 30 years daily data) using the GJR- GARCH model. There are 7661 daily observations included in the study. The recurrence of outcomes had leptokurtosis, were skewed to the left, and were not normally scattered; there was also confirmation of ARCH effects. The insights of the symmetric GARCH model showed confirmation of volatility clustering and endurance; the results of the GARCH-GJR model demonstrated the leverage impact and volatility clustering in the sample index. Favorable events alter the conditional variance (volatility), resulting in significant asymmetric GJR-GARCH values. This leads to the conclusion that favorable information has greater effects on index return volatility than adverse information. The results of this research constitute vital information for financiers, risk analysts, and regulators.

Keywords: *GJR-GARCH model, Mexican Stock Market, Volatility, Forecasting, Stock index, conditional variance, extreme events.*

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1. Introduction

The dynamic and often unpredictable nature of financial markets has been a subject of intense research and analysis for decades. Understanding the patterns and determinants of volatility is of paramount importance for investors, policymakers, and financial analysts seeking to make informed decisions in an ever-evolving global economy(Chang et al., 2012). Among the numerous tools and methodologies utilized to comprehend market volatility, the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model has gained widespread popularity for its ability to capture time-varying volatility patterns(Palm, 1996)(Hou et al., 2022).

This research paper highlights the realm of financial econometrics to analyze the volatility of the Mexico Stock Market Index, also known as the IPC (Índice de Precios y Cotizaciones), utilizing the GJR-GARCH (Generalized Autoregressive Conditional Heteroskedasticity with Asymmetry and Leverage) model. The Mexican stock market has been a crucial player in the Latin American financial landscape (Kyaw et al., 2006, Lahrech & Sylwester, 2011, Hogenboom, 2012), and understanding its volatility dynamics can provide valuable insights into the region's overall economic stability and investment climate.

The GJR-GARCH model, an extension of the traditional GARCH model, explicitly accounts for asymmetric volatility, which is prevalent in many financial markets(Peng et al., 2018). Asymmetry refers to the phenomenon where positive and negative shocks have differing effects on volatility. Moreover, the model incorporates leverage effects, where large negative returns tend to lead to higher future volatility(Pilbeam & Langeland, 2015). By incorporating these factors, the GJR-GARCH model can provide a more robust and accurate representation of market volatility, particularly in periods of economic instability or financial crises(Bouri, 2015).

The objectives of this research paper are twofold: first, to empirically investigate the volatility patterns of the Mexico Stock Market Index, and second, to assess the performance of the GJR-GARCH model in capturing and forecasting volatility in this particular market context. To achieve these objectives, we will use a comprehensive dataset comprising daily or high-frequency returns of the IPC, spanning a considerable time horizon.

The paper will follow a systematic approach, commencing with a comprehensive literature review to provide an overview of the existing research on market volatility, GARCH models, and their applications in various financial markets. Subsequently, the methodology section will expound on the theoretical framework of the GJR-GARCH model, along with a detailed description of the dataset and variables used in the analysis.Furthermore, the empirical analysis will present the findings obtained from estimating the GJR-GARCH model on the IPC data, focusing on the model's ability to capture asymmetry and leverage effects. Robustness checks and diagnostic tests will be employed to validate the model's efficacy and identify potential shortcomings. The discussion section will delve into the implications of the research findings and their significance for investors and policymakers in Mexico and the broader Latin American context.

2. Review of literature

Many scholars have sought to abstract variations in volatility while taking into account diverse marketplaces. Much data can be gleaned from the returns of past financial series in the current literature, such as whether or not the leverage effect is present. Spulbar et al. have developed the study of volatility pattern using GARCH family model for USA and Netherland. Moreover, Spulbar et al. (2023b) have developed the study of volatility pattern using GARCH family model for grouping of advanced stock markets that includes Austria, France, Germany, and Spain, (Meher et al., 2023)have developed the study of volatility analysis of OMX Tallinn Index in the case of Estonia's new and promising stock exchange using PARCH model, (Kumar et al., 2023)have developed the an empirical case study of volatility analysis of Toronto Stock Exchange using PGARCH Model. Spulbar et al. (2023c) have have developed the study of volatility pattern using GARCH family model for Italy and Poland.

Guesmi et al. (2019) look into the legitimacy of Bitcoin in the market for financial services. because of the significance of geopolitical risk and its potential to predict oil price volatility.(Liu et al., 2019)intend to conduct a quantitative study of geopolitical risk (GPR), and more specifically, serious geopolitical risk (GPRS), in predicting oil volatility. (Troster et al., 2019)modeling and predicting bitcoin yields and risk requires performing a general GARCH and GAS analysis. (Bangar Raju et al., 2020)the use of EGARCH models to investigate and analyze market volatility in GOI and GOFI countries. Focusing on measuring the inherent correlation (Sun et al., 2020)to settle the heated argument over whether or not the maritime industry is exposed to extreme risk from the commodity market, a GARCH-Copula-CoVaR analysis is recommended. Other influential work includes (Gronwald, 2019, Pal & Mitra, 2019).

2.1. Research Gap

While there have been considerable efforts in the field of financial forecasting using various econometric models, a significant research gap persists concerning the application of the GJR-GARCH model specifically to predict the volatility of the Mexico Stock Market Index. While GARCH models have been widely used in financial econometrics for volatility modeling, the GJR-GARCH extension, which incorporates asymmetric effects of positive and negative shocks on volatility, remains underexplored in the context of the Mexican market. The Mexico Stock Market Index is known for its unique characteristics and susceptibility to external economic and political factors. Hence, applying the GJR-GARCH model to this specific market could offer valuable insights into the behavior of volatility under asymmetric conditions, enabling investors to make more informed decisions. Addressing this research gap will contribute to the understanding of the Mexico Stock Market's dynamics and provide a more accurate framework for risk management and investment strategies.

2.2. Significance of the Study

The study aims to contribute to the existing body of knowledge on financial market volatility and GARCH modeling, with a specific focus on the Mexico Stock Market Index. By uncovering the volatility patterns and leveraging the GJR-GARCH model's power, this study endeavors to enhance our understanding of the dynamics of the Mexican stock market, providing valuable insights for investors, risk managers, and policymakers operating in the region's financial landscape.

3. Materials and Methods.

Data Description

This work analyses conditional variance objectively or empirically estimates the price volatility spillover transmission in the daily returns of IPC Mexico index from Mexico stock market, for the long period January 1993 - July 2023 (which is more than 30 years daily data) using the GJR- GARCH model. The price return series of the weekly series has been used for subsequent calculations, as the manifestation of price volatility is assumed to be the square of the price return.

GARCH Models

ARIMA is a method based on linearity that cannot resolve the nonlinear dynamics of a time series. A fundamental assumption of this model is homoscedasticity in error variance. The ARCH model is presented(Kumar et al., 2023) by loosening the linear and homoscedasticity assumptions and taking into consideration large autocorrelations inherent in the quadratic residual series, the nonlinear characteristics of a time series are reflected. There are various GARCH models comes under the basket of GARCH family model. The GJR-GARCH model was developed to accommodate asymmetric volatility. The model's advantage is that the variance is directly modelled rather than using the natural logarithm like the EGARCH model does. This means that the GJR- GARCH model is simpler to implement in practices(Taylor, 1987). Several GARCH models have been studied, and the GJR-GARCH model has been found to be the most accurate in forecasting volatility and estimating VaR (variance in risk)(Hawaldar et al., 2022).

The GJR- GARCH (1, 1) model is stated in the equation below(Cristi, Birau, Trivedi, Simion, et al., 2023):

$$\sigma_t^2 = \omega + \alpha_1 n_{t-1}^2 + \alpha_2 I_{t-1} n_{t-1}^2 + \beta \sigma_{t-1}^2$$

Variables of the GJR-GARCH model are explained:

σ_t^2: is the projected variation in conditions.

ω : is the variance's intercept.

$\alpha_1 n_{t-1}^2$: is the amount of variation that is affected by preceding lag error terms.

α_2 : is the magnitude of the asymmetric volatility.

I_{t-1} : is a spurious parameter.

β: is the value of the coefficient for the predicted variation from yesterday.

σ_{t-1}^2 : The expected variance from yesterday.

$I_{t-1}$is a dummy imaginary variable that is only triggered if the previous shock was unfavorable ($n_{t-1} < 0$), thereby permitting the GJR-GARCH model to account for the leverage effect into consideration(Bollerslev, 1986).

Validation of Forecasts

Using the following formula, the anticipated reliability of multiple dispersion algorithms was evaluated in terms of root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE).

$$RMSE = \left(\frac{1}{T}\sum_{i-1}^{T} (y_i - Y_i)^2\right)^{1/2}$$

$$MAE = \frac{1}{T}\sum_{t=1}^{T} | yt \quad Yt |$$

$$MAPE = \frac{1}{T}\sum_{i-1}^{T} \frac{| y_t \quad Y_t |}{yt} X100$$

Where T is the number of instances used for confirmation, yt is the value that was observed, and yt is the value that was forecast.

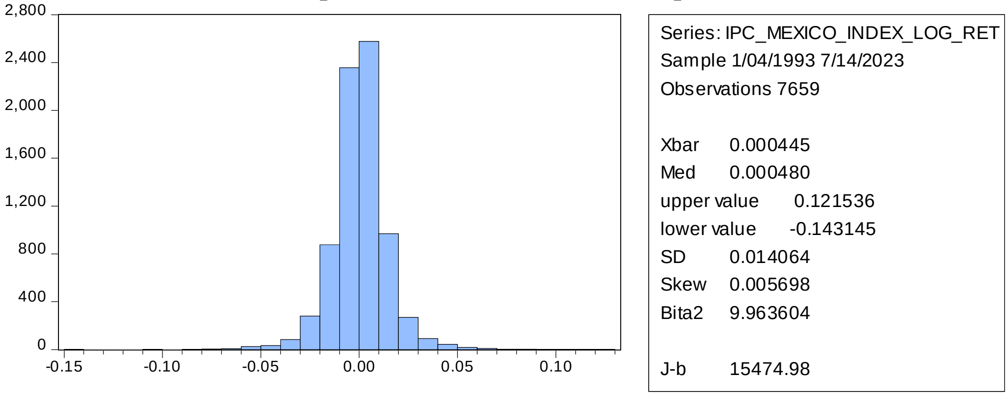
4. **Results and Discussion**

Models of prediction and estimation Volatility is crucial in establishing the cost of capital for financial securities, as well as evaluating leverage and investment decisions that will effect business performance and continuity. The Mexican IPC index (IPC) is a widely recognized index of stock markets that monitors the stock market performance of noteworthy Mexican Stock Exchange companies. It is made up of shares that are indicative of all the shares listed on the market from all sectors of the economy.

Descriptive statistics

Chart (1) with statistical observation mention in the below for selected sample index price provides the descriptive statistics. The price series of selected index is skewed towards right and leptokurtic. The presence of the ARCH effect in the data was validated using the ARCH - LM test.

Chart 1 Results of descriptive statistics of selected sample of Mexican IPC index.



Source: own computation using EViews

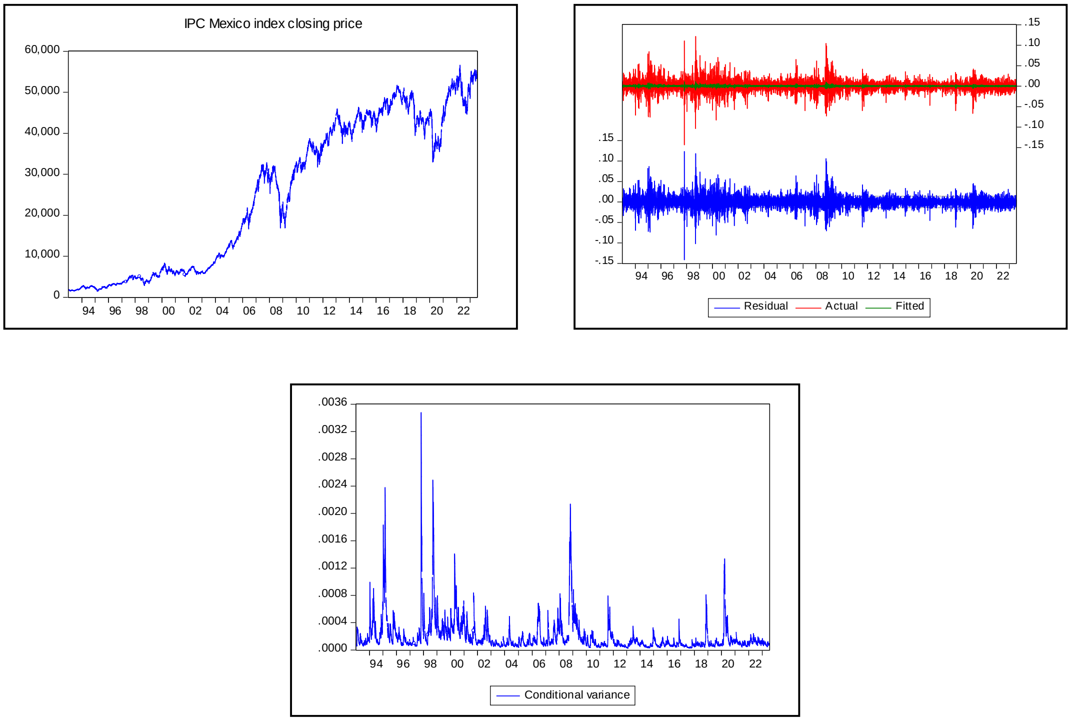
Table 1 – Unit root test

Null Hypothesis: D(IPC_MEXICO_INDEX_CLOSING_PRICE) has a unit root				
			t-Statistic	*Prob.*
ADF test outcomes			-83.26185	Significant* at 1%
critical values of results:	At 0.01level		-3.431027	
	At 0.05 level		-2.861724	
	At 0.10 level		-2.566910	
PP test outcomes			-83.18401	Significant* at 1%
critical values of results:	At 0.01level		-3.431027	
	At 0.05 level		-2.861724	
	At 0.10 level		-2.566910	

Source: own computation using statistical tools EViews

The stationary behaviour of the data is examined in Table 1 applying the Augmented Dickey Fuller (ADF) test and the Phillip Perron Test (PP), and the experiment's outcomes demonstrate that the prices of stocks are not stationary at level prices and stationery at first differencing. It indicates that the daily closing prices of the selected index are stable, rejecting the null hypothesis of unit root at 0.01 significance. The next graphic (chart 2) shows the cluster volatility effect of selected sample index returns.

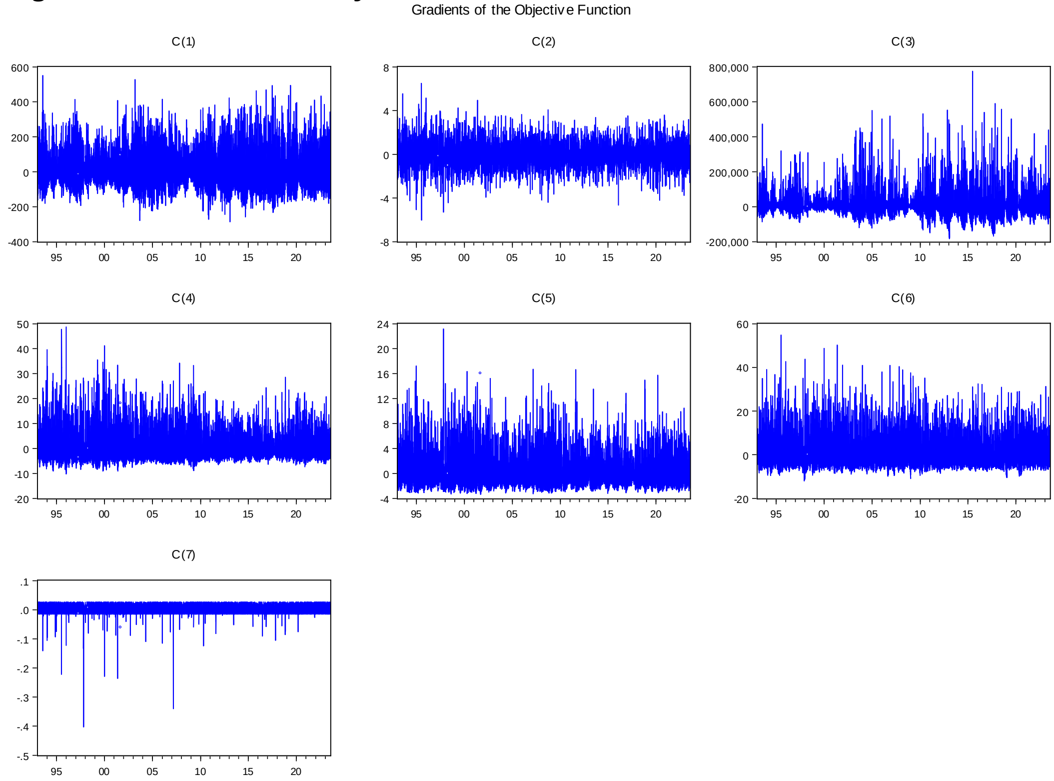
Chart 2 CLUSTERING VOLATILITY EFFECT OF RETURNS



Source: own computation using statistical tools EViews

The samples in Figure 2 have high volatility and great amplitude, and they exhibit volatility clustering characteristics. g. Furthermore, Figure 1 depicts three large-range volatilities experienced by the Mexico stock over the last 30 years, occurring in 1997-98, 2008-2010, and 2020-2022. The volatility that happened between 2020 and 2022 is particularly intense, with significant rewards and hazards. The final section of Figure 2 shows the conditional variance of the sample stock exchange. And further, following (3) figure show the Gradients of the objective function.

Figure 3: Gradients of the objective function



Source: own computation using statistical tools EViews

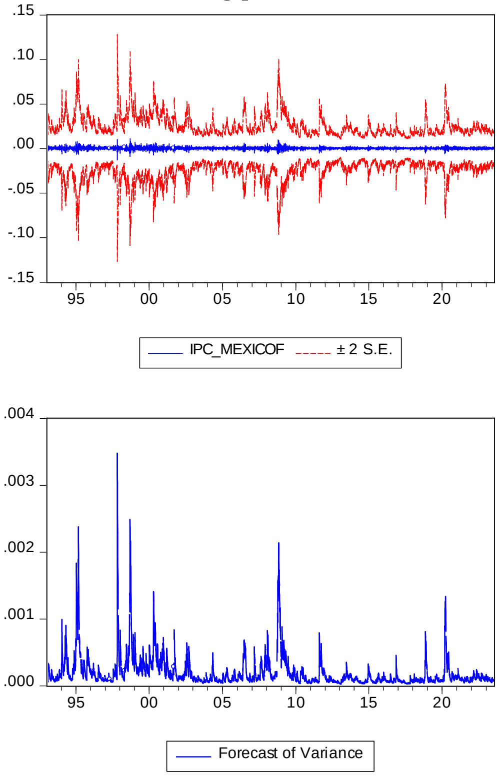
Implementation of Various GJR- GARCH family Models for the IPC Mexico index from Mexico stock market.

Models	C	ω	α	β	γ
GJR-GARCH (Gs')	0.000237 (0.0438)**	0.097087 (0.0000)**	0.115185 (0.0000)**	0.899480 (0.0000)**	0.035824 (0.0000)**
GJR-GARCH (St)	**0.000353 (0.0018)****	**0.090192 (0.0000)**	**0.109014 (0.0000)**	**0.903302 (0.0000)**	**0.034609 (0.0000)****
GJR-GARCH (Ged)	0.000322 (0.0040)**	0.090003 (0.0000)**	0.111585 (0.0000)**	0.900651 (0.0000)**	0.035657 (0.0000)**

Notes: the bracketed numbers are the p value of the estimations.
Source: own computation using statistical tools EViews

The IPC Mexico index from the Mexican stock market is depicted in the table below as the output of the GJR-GARCH model using three distinct constructs. The table above demonstrates that in all three experiments of the DJR-GARCH model with normal, student t's distribution error construct, and generalized error distribution (GED). When compared to the other models, the model with Student t's Distribution had the lowest AIC (-6.086400) and SIC (-6.080054). Similarly, based on the log likelihood value, that model has the greatest Log Likelihood (23311.83), followed by the results from the generalized error distribution. As a result, this model is believed to be the best.GJR-GARCH models confirmed the leverage impact in The IPC Mexico index from Mexico stock market series returns for the sample period. This suggests that the stock returns followed long memory across the sample period and demonstrated history in future returns. The GJR-GARCH model's significance indicates that volatility remained stable across the sample period (0.109014 + 0.903302). It indicates that the return will have a greater impact on the unconditional variance in future trades. In the last following chart (figure 4)highlights the forecasting evaluation of the IPC Mexico index from Mexico stock market series returns for the sample period.

Chart4: Forecasting performance evaluation.



Forecast: IPC_MEXICOF
Actual: IPC_MEXICO_INDEX_LOG_RETURNS
variable sample: 1/04/1993 7/14/2023
total observations: 7658
RMSE 0.014001
MAE 0.009709

TIC 0.909362
BP 0.000012
VP 0.834910
CP 0.165078

SyMAPE 172.0236

Source: own computation using statistical tools EViews

5. Conclusion

This empirical investigation provides to the current body of research by researching the very long-term (over 30 years) behaviors of the IPC Mexico index from the Mexican stock market, with a focus on modelling the behavior to capture changes, volatility clusters, econometric model fitness, and changes in volatility patterns during economic slowdown periods. The GARCH-GJR model was fitted for mean and variance equations on the series stock exchange returns with a significance of 1%. The empirical findings revealed that more than 10% of the stock exchange is dominated by past volatility, and around 90% of the stock exchange is took precedence by future volatility.The observational data verifies the occurrence of the leverage effect, but also shows that the sample stock returns are volatile and persistent. The return is skewed positively, resulting in a leptokurtic impact and exhibiting the long fat right tail. The degree of standard deviation approaches 0.014, and the total of + shows greater than one, showing that the return is consistent for the sample index from January 1993 to July 2023. According to the empirical data, the developed symmetric GJR-GARCH with student distribution construct model is the best fit for Volatility predicting and modelling for the proposed sample. The attribute of the asymmetric GARCH model for variance equations (GJR and EGARCH models) shows that the data series continue to recognize leverage impact and keep pattern of repeating more negative shocks than positive shocks. The scientific findings will be useful those making decisions in government, stakeholders, and regulators of financial institutions. Furthermore, we may try conducting an analysis using different models, such as DCC-CARR and DCC-RGARCH, to achieve more precise variance and correlation estimations.

Authors' Contributions:
The authors contributed equally to this work.

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Article Info

Received: July 24 2023
Accepted: August 30 2023

How to cite this article:
Kumar, S., Anand, A., Birau, R., Meher, B.K., Kumar, S., Florescu, I. (2023). Temporal Analysis of Mexico Stock Market Index Volatility using GJR-GARCH model. *Revista de Științe Politice. Revue des Sciences Politiques,* no. 79, pp. 46 – 56.