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Predictive Analysis of Volatility for BSE S&P GREENEX index using GARCH Family Models: A case study for Indian stock market

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Abstract:
The research paper aims to examine the BSE GREENEX index, which was developed to monitor and assess the performance of environmentally conscious companies based on carbon emissions. This index, created in collaboration with IIM Ahmedabad, is a valuable tool for companies aiming to enhance their carbon performance. It facilitates the creation of eco-friendly financial products like mutual funds, exchange-traded funds (ETFs), and structured funds. The study spans 2014 to 2024, utilizing quantitative data and various econometric tools to analyze price movements. With a dataset comprising 2485 observations of S&P BSE-GREENEX spanning from February 28, 2014, to March 15, 2024, the research explores the application of different GARCH models, including GARCH, EGARCH, IGARCH, TARCH, APARCH, and PARCH, across various distributions. By evaluating criteria such as AIC, SC, and Log Likelihood values, the APARCH (1,1) model with a t-distribution emerges as the optimal choice. The study's findings reveal the presence of volatility clustering, leverage effects, and log memory volatility within the BSE S&P GREENEX index. Furthermore, the analysis suggests that macroeconomic fluctuations have led to intermittent declines in volatility. Employing econometric and statistical methodologies, the paper endeavors to comprehensively elucidate these phenomena and their implications.

Keywords: *BSE, CARBONEX, GREENEX, Sustainability, GARCH, APARCH, Volatility, Green Finance*

JEL Code: C1, C32, C51, G13, Q5

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Predictive Analysis of Volatility for BSE S&P GREENEX index using GARCH Family Models: A case study for Indian stock market

Introduction

Green companies, also referred to as environmentally friendly or sustainable businesses, are entities that operate in a manner that reduces their negative impact on the environment."Sustainability" and "sustainable development" frequently lack clear and consistent definitions despite their widespread usage(Azevedo et al., 2017). Sustainability managers spearhead initiatives to make their companies' products and services more environmentally friendly (Kurland & Zell, 2011). Despite the challenges posed by the vague and widespread nature of sustainability risks, corporations are compelled by growing regulatory and societal demands to integrate social and environmental responsibility into their strategies and management systems(Giovannoni & Fabietti, 2013).Green finance aims to boost financial support for eco-friendly projects, advancing sustainable development goals(Kitakogelu & Ozili, n.d.).Going eco-friendly for businesses is complex, and there are many ways to become more sustainable. The key for environmentally conscious companies is to adopt at least one "4 Rs": reduce, reuse, recycle, and recover. (Čekanavičius et al., 2014).In order to achieve the GDP target projected for 2030, an annual growth rate of 8.58% is deemed necessary. To effectively realize this goal within the stipulated timeframe, it is imperative to attain growth rates of 10.67% and 3.55% in distinct periods(I. Ali et al., 2021).Sustainable investing, evolving from the 1980s, is now termed ESG investing, prioritizing Environmental, Social, and Governance factors and integrating societal impact into the financial decision-making frameworks (Meher, Hawaldar, Mohapatra, Spulbar, et al., 2020).

BSE launched two indices, BSE-GREENEX and BSE-CARBONEX, on February 22nd and November 30th, respectively, 2012(Seth & Singh, n.d.).India has four sustainability indices: S&P BSE GREENEX, S&P BSE CARBONEX, S&P BSE 100ESG, and Nifty 100 ESG.GREENEX is an index tracking environmentally sustainable companies' performance, aiding investors in aligning portfolios with sustainability goals. It offers a benchmark for evaluating financial performance, managing risk, and identifying investment opportunities in green sectors. By monitoring GREENEX, investors gauge market trends, assess returns, and make informed decisions about portfolio allocations. GREENEX is crucial in integrating environmental considerations into investment strategies while considering financial performance and risk management.The S&P BSE GREENEX is a real-time index that evaluates the performance of the leading 25 companies within the S&P BSE 100 index, focusing on their carbon efficiency.Quantitative environmental data disclosed voluntarily under the Carbon Disclosure Project (CDP) are drawn from companies listed in the BSE 100 index(Maji & Mondal, n.d.) It considers factors such as greenhouse gas emissions, market capitalization, and liquidity to gauge their environmental impact and financial strength**.**The BSE-GREENEX marks a significant initial stride towards establishing an inclusive market mechanism to foster energy-efficient practices among major corporate players in India.

BSE developed the GREENEX index, which focuses on tracking and evaluating the performance of companies based on carbon emissions that are environmentally conscious, in collaboration with IIM Ahmedabad to assist companies in improving their carbon performance. Index can utilized to create eco-friendly financial products such as mutual funds, exchange-traded funds (ETFs), and structured funds.The index is specifically created for investors who are socially conscious and gracious for society, ethical, and environmental factors while making investment decisionsInvestors are inclined to pay a premium for green companies to get better returns. The performance can observed by the focus on the potential benefits of ESGs. (Sharma, 2022).

Previously, investment decisions were only for monetary benefits, but in modern investment, companies take the society along with the profit (*Grnex*, n.d.). Technology continually shapes finance, driving efficiency, accessibility, and innovation in financial services and operations(Meher et al., 2024). Need for empirical analysis is necessary to conduct a data-driven study to observe the effectiveness of sustainable index in the Indian capital market. (Gurung & Sarkar, 2023).Assessing the volatility of GREENEX enables investors to make informed decisions and manage risk effectively in their sustainable investment portfolios.

Literature Review

In the present era, stock markets have become an integral part of a country's economy, playing a vital role in its growth and development. Observing the performance of a financial market requires considering its volatility. A market with low volatility is generally considered safer than a highly volatile market.

Much progress has been made in studying the volatility of stock indices.For the sake of convenience, the literature review has been divided into four different categories.The first category responds to the studies related to GREENEX companies. The second category responds to volatility. The next category responds to the GARCH family. And the last category responds to the APARCH

GREENEX companies and their objectives

BSE-GREENEX is the indicator used to predict carbon emissions by companies listed by BSE and suggests that investors should invest in companies that are a lesser threat to the environment.(Chowdhury et al., 2023). BSE-GREENEX is the initial stage for establishing mechanisms to encourage energy-efficient practices (Bhattacharya et al., 2013).GREENEX's launch signals growing environmental consciousness in the Indian investing community, fostering eco-friendly investment choices(V. Tripathi & Bhandari, 2014).Significant investment in these funds propels the market's progression of green and sustainable stocks (Babu et al., 2022). This increases the funds available in the US surged by nearly 400% (Babu et al., 2022). As GREENEX has low volatility, conscious investors are slightly more focused on it(Chowdhury et al., 2023)**.**Research has been conducted and found that BSE-CARBONEX has a positive relation with BSE-Energy and BSE-GREENEX has a positive relation with industrial production (“SUSTAINABLE ENVIRONMENT, MANIFESTATION AND AUGMENTATION,” 2023).BSE GREENEX gives equal importance to both energy efficiency and profitability (Maji & Mondal, n.d.).GREENEX and CARBONEX are described as emerging indices despite this, they are in the early stages of development(Chowdhury et al., 2023).

Volatility

Volatility refers to rapid and unpredictable changes in value, often used in finance to describe investment price fluctuations(Babu et al., 2022).Recentadvancements in financial econometrics enable more accurate volatility predictions,this has caught the eye of investors and decision-makers(Kumar, Meher, Birau, et al., n.d.).One can predict market directions by studying volatility, providing insights into economic expectations, and facilitating informed decisions about future economic trends(Meher, Hawaldar, Mohapatra, & Sarea, 2020). Comprehending volatility patterns and determinants is crucial for investors, policymakers, and financial analysts in making informed decisions(Kumar, Anand, et al., n.d.).Analyzing and predicting the stock prices and their return volatility of companies listed in sustainable indices is essential.Time series analysis predicts trends by analyzing past data, uncovering patterns to forecast future developments accurately, and effectively informing decision-making(Meher et al., 2021). Since December 2019, the COVID-19 epidemic has caused turbulence in global financial markets. It has been found that all major US stock market indexes are significantly impacted by conditional volatility due to COVID-19 (Babu et al., 2022). There are no asymmetric volatility transfers between the Green Bond and Equity Markets(A. Tripathi, 2022).It is important to consider the distribution of innovations when modelingand forecasting volatility, as it cannot be assumed to be normal(Erkekoglu et al., 2020).

GARCH family model

The GARCH model is an addition of ARCH. GARCH is the statistical model that assesses volatility and predicts future volatility. GARCH models are not just for forex markets but are also useful for stock markets (Erkekoglu et al., 2020).GARCH models are commonly utilized in volatility prediction because they possess a knack for encapsulating the evolving dynamics of volatility over time (Kumar, Meher, et al., n.d.)In 1982 Robert F. Engle broke the ARCH model (Autoregressive Conditional Heteroskedasticity). However, this model has major limitations, which were identified by Bollerslev in 1986 and introduced a generalized form of ARCH known as GARCH(Generalized ARCH) that provides resilience to the lag structure (Erkekoglu et al., 2020).GARCH-based models are more appropriate when considering the skewness and asymmetry in time series data. GARCH volatility focuses on the conditional variance of returns over a while (Bangur & Bangur, 2023). The maximum likelihood method typically estimates GARCH-type model parameters, including GARCH and IGARCH, using standard statistical software for normal or t-distributed errors(So & Yu, 2006).Many researchers worldwide have used the GARCH model to analyze the stock market volatility pattern. Volatility focuses on how the conditional variance on returns over a while.

APARCH Model

APARCH (Asymmetric PARCH) extends the ARCH and GARCH models. APARCH models enable the different effects of both positive and negative shocks on volatility within financial time series data. The APARCH model has two parameters based on the GARCH model. The leverage effect is measured by one of the parameters (DING, 2011).The APARCH model is flexible as it measures skewness and leverage effect.Ding, Granger, and Engle's APARCH model (1993) consolidates diverse univariate parameterizations, enriching volatility analysis in financial time series(Bollerslev, n.d.).

PARCH (Power ARCH) model is a statistical model to assess the volatility of foreign exchange markets as well as the volatility of financial assets. It is widely used to categorize volatility patterns witnessed in financial time series data.Building on the GARCH model, PARCH integrates an additional term to capture how volatility reacts. Volatility leads to more price drops compared to price increases. (alam & Rahman, 2012).PARCH is a GARCH-like model that allows for positive and negative parameters.The APARCH model stands as a broad category encompassing ARCH and

GARCH models, thus providing a comprehensive framework for volatility analysis in financial modeling(G. Ali, 2013).

Research Gap

In financial modeling, especially in the context of BSE-GREENEX, a significant research gap knuckles down when applying GARCH models. While accessible in the literature, it explored various methodologies for volatility, but it remains incompetent to be understood. This research attempts to understand BSE-GREENEX volatility using GARCH models; the study aims to provide a more specific volatility forecast.

Objectives of the study

1. To study the volatility of BSE GREENEX from 2014 to 2024.
2. To find and study volatility using appropriate GARCH models.

Research Methodology

Data used in this research are quantitative, andGARCH Family models are used to determine price movements. There are 2485 data points of S&P BSE-GREENEX ranging from 28/02/2014 to 15/03/2024. The study was done to know the volatility using GARCH models with Gaussian normal distribution, student's t distribution, generalized error distribution (GED), t distribution, and GED distribution with parameters. Logarithm returns are calculated to make data stationary and it was observed that data shows clustering in it for this ARCH LM test was applied to test heteroskedasticity in residual series of return. Various models from the GARCH model are used (GARCH, IGARCH, TGARCH, EGARCH, PARCH, and APARCH) across various distributions for volatility analysis. The software package used was EViews 10.

Significance of study

As climate change becomes increasingly urgent, exploring sustainability's impact across different sectors is crucial. Rising awareness has sparked a surge in investment in green projects, reflecting a collective effort to address environmental degradation and promote a sustainable future. This research offers significant benefits to understanding the financial market dynamics. Much work has not been done at the individual level, and as everyone wants to make sustainable investments, a knowledge gap exists. For this, it is important to know the volatility by taking a sustainable index in the market and academic field. This study tries to understand BSE-GREENEX volatility.

Limitations of study

Despite conducting a thorough time series analysis with a substantial dataset, the results remain incomplete due to a lack of regression analysis on the indicator. While APARCH is a sophisticated and adaptable model within the GARCH family, it may not fully capture all volatility-influencing variables. Limited institutional support and resources hinder in-depth exploration.

Analysis, estimation and results

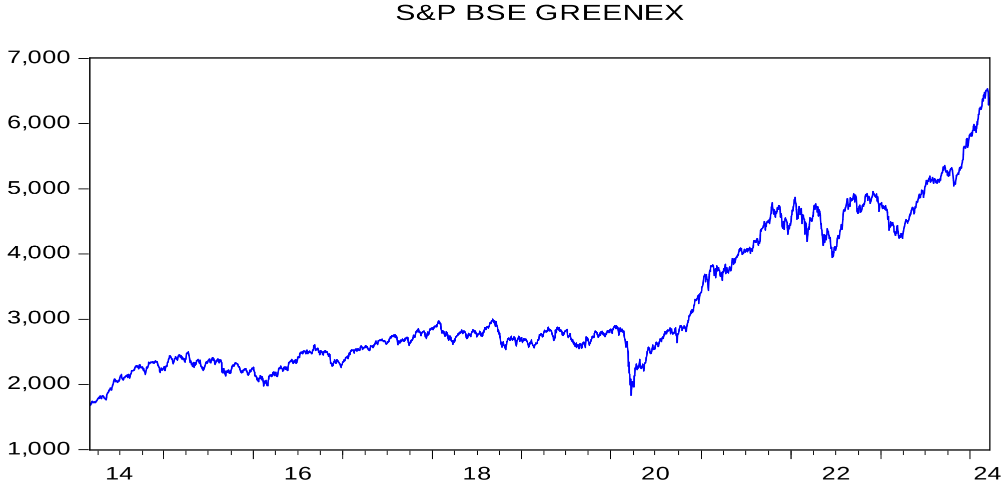


Figure 1 The trend of daily closing price of the index
Source: Author’s computation using EViews 10.

The above graphical representation is of S&P BSE GREENEX. It shows that the market was not very volatile between 2014 and 2018, but after 2019, there was high volatility due to factors like COVID-19 and other financial problems. Between 2022 and 2024, the graph does not show volatility.

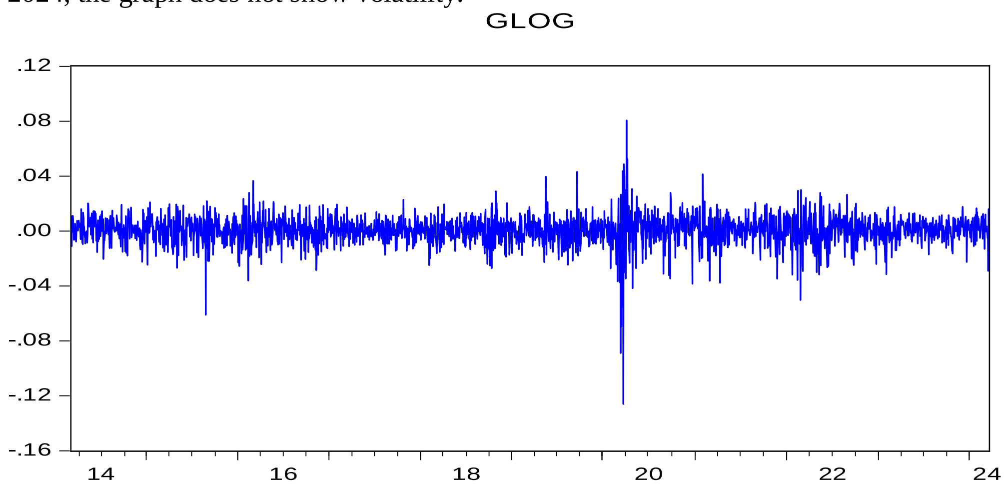


Figure 2 Log Return Graph
Source: Author’s computation using EViews 10

Log return is calculated to make returns stationary. The above graphical representation is the log return of S&P BSE GREENEX. As discussed above, because of COVID-19 and other financial problems, the graph shows a sharp dip in 2019. Due to the heteroscedastic nature of data, it is important to analyze the stationarity test.

Null Hypothesis: GREENEXLOG has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=26)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-49.19577	0.0001
Test critical values:	1% level	-3.432790	
	5% level	-2.862504	
	10% level	-2.567328	

*MacKinnon (1996) one-sided p-values.

Table 1 Augmented Dickey-Fuller (ADF) TEST
Source: Author's computation using EViews 10

Test of stationarity

The test above is the Augmented Dickey-fuller (ADF) test. As it can be observed, the probability value is less than 0.05, here we reject the Null Hypotheses test, and the data has no unit root and the data is stationary.

Descriptive Statistics

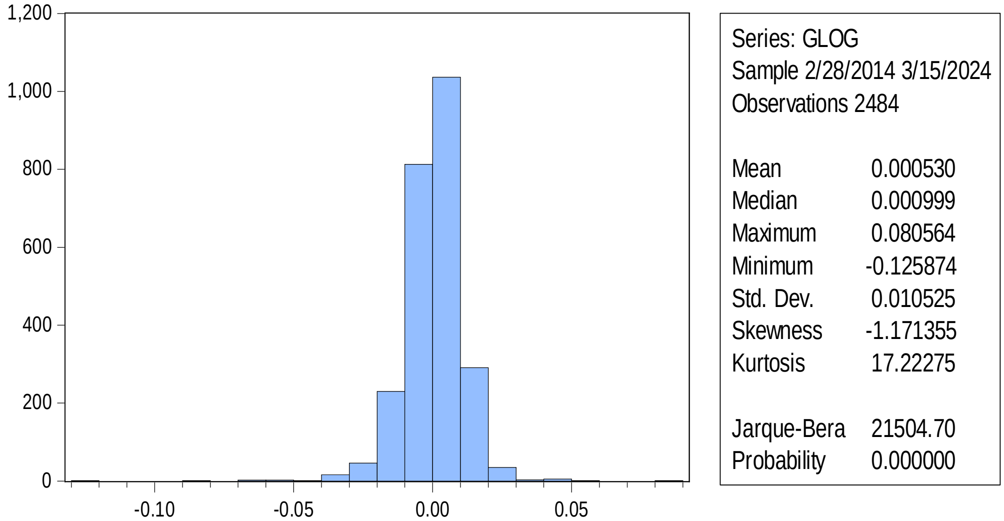


Figure 3 Test Distribution Analysis
Source: Author's computation using EViews 10

For analysis of the log return, we have the above test statistics. The Standard deviation is very low, which signifies that most of the dataset is around the mean value and less deviation. The skewness suggests that data is left-tailedand meaning data is clustered towards the higher values. The data is leptokurtic, suggesting higher peaks, volatility, and maybe asymmetry. To analyze further we need to check the ARCH effect on the data through the ARCH LM Test.

Heteroskedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	34.60165	Prob. F(1,2480)	0.0000
Obs*R-squared	34.15304	Prob. Chi-Square(1)	0.0000

Table 2 ARCH effect test

Source: Author's computation using EViews 10

From the test results above it is very evident that the P-values are below 0.05, we conclude there exists an ARCH effect on the data. We will be using the GARCH model against ARCH due to its limitations of weights.

		GARCH	IGARCH	TARCH	EGARCH	PARCH	APARCH
Normal Distribution	Akaike info criterion	-6.508132	-6.482558	-6.538223	-6.534819	-6.507343	-6.539838
	Schwarz criterion	-6.496418	-6.475529	-6.524166	-6.520763	-6.493286	-6.523438
	Log Likelihood	8084.846	8051.096	8123.204	8118.978	8084.866	8126.209
	ARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	Autocorrelation	No	No	No	No	No	No
	ARCH LM-Test	No	No	No	No	No	No
	GARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	significant coefficient	Yes	Yes	Yes	Yes	Yes	Yes
Student's T	*Akaike info criterion*	-6.554916	-6.536444	-6.578931	-6.576542	-6.554255	-6.57999
	Schwarz criterion	-6.540859	-6.527073	-6.562532	-6.560142	-6.537855	-6.561247
	Log Likelihood	8143.928	8118.995	8174.743	8171.777	8144.107	8177.057
	ARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	Autocorrelation	No	No	No	No	No	No
	ARCH LM-Test	No	No	No	No	No	No
	GARCH significant	Yes	Yes	Yes	Yes	Yes	Yes

	significant coefficient	Yes	Yes	Yes	Yes	Yes	Yes
	Akaike info criterion	-6.547456	-6.529809	-6.570602	-6.5677	-6.54668	-6.571438
	Schwarz criterion	-6.533399	-6.520438	-6.554202	-6.551301	-6.53028	-6.552695
	Log Likelihood	8134.667	8110.758	8164.403	8160.8	8134.703	8166.44
	ARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	Autocorrelation	No	No	No	No	No	No
	ARCH LM-Test	No	No	No	No	No	No
	GARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
Generalized Error	*significant coefficient*	Yes	Yes	Yes	Yes	Yes	Yes
	Akaike info criterion	-6.546573	-6.536444	-6.577877	-6.575258	-6.552013	-6.579021
	Schwarz criterion	-6.534858	-6.527073	-6.56382	-6.561201	-6.537956	-6.562621
	Log likelihood	8132.57	8118.995	8172.434	8169.183	8140.325	8174.855
	ARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	Autocorrelation	No	No	No	No	No	No
	ARCH LM-Test	No	No	No	No	No	No
	GARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
T distribution (Parameter)	*significant coefficient*	Yes	Yes	Yes	Yes	Yes	Yes
	Akaike info criterion	-6.552716	-6.529809	-6.57078	-6.567778	-6.545784	-6.571702
	Schwarz criterion	-6.541002	-6.520438	-6.556723	-6.553721	-6.531727	-6.555303
	Log Likelihood	8140.197	8110.758	8163.624	8159.896	8132.59	8165.769
	ARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	Autocorrelation	No	No	No	No	No	No
Generalised Error (Parameter)	*ARCH LM-Test*	No	No	No	No	No	No

	GARCH significant	Yes	Yes	Yes	Yes	Yes	Yes
	significant coefficient	Yes	Yes	Yes	Yes	Yes	Yes

Table 3 Decision Table
Source: Authors's tabulation using MS Office

After implementing GARCH, IGARCH,TARCH, EGARCH, APARCH, and PARCH among Gaussian Normal Distribution, Student's t distribution, Generalized Error distribution(GED), t distribution, and GED with fixed parameter, from the table it can be concluded that APARCH student's t distribution is most suitable model due to lowest Akaike info criterion(-6.57999), lowest Schwarz criterion(-6.561247) and highestlog-likelihood(8177.057)

Dependent Variable: GLOG
Method: ML ARCH - Student's t distribution (BFGS / Marquardt steps)
Sample (adjusted): 3/04/2014 3/15/2024
Included observations: 2483 after adjustments
Convergence not achieved after 500 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
@SQRT(GARCH)^C(7) = C(3) + C(4)*(ABS(RESID(-1)) - C(5)*RESID(
-1))^C(7) + C(6)*@SQRT(GARCH(-1))^C(7)

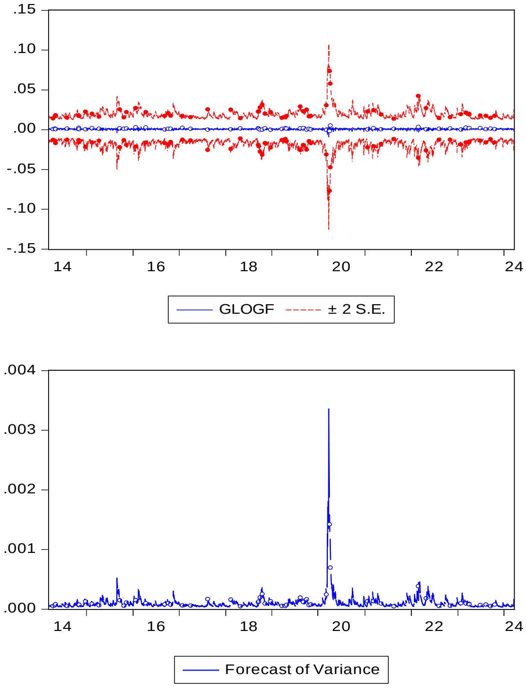
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000671	0.000169	3.977092	0.0001
GLOG(-1)	0.078816	0.020517	3.841434	0.0001
	Variance Equation			
C(3)	8.90E-05	8.09E-05	1.100449	0.2711
C(4)	0.065836	0.009977	6.598898	0.0000
C(5)	0.999853	1.5E-103	6.8E+102	0.0000
C(6)	0.867900	0.017764	48.85790	0.0000
C(7)	1.395735	0.198703	7.024226	0.0000

T-DIST. DOF	7.338239	0.931924	7.874285	0.0000

R-squared	-0.004519	Mean dependent var	0.000534
Adjusted R-squared	-0.004924	S.D. dependent var	0.010525
S.E. of regression	0.010551	Akaike info criterion	-6.579990
Sum squared resid	0.276180	Schwarz criterion	-6.561247
Log likelihood	8177.057	Hannan-Quinn criter.	-6.573183
Durbin-Watson stat	2.132139		

Table 4 APARCH(1,1) student's t distribution
Source: Author's computation using EViews 10.

From the analysis, it can be concluded that there is no baseline effect on the current volatility. The C(4) value suggests that the data is slightly impacted by the previous variances of the past. C(5) value close to 1 suggests that the current volatility is replicated or affected by previous volatility in absolute terms regarding scaling. From the C(6) value, it is also evident that there is a high chance of previous conditional variances and deviations for the current level of volatility. C(7) suggests asymmetry, which provides results that are opposite to the situation. There is a high chance of volatility clustering, long memory volatility, and leverage effect.



Forecast: GLOGF	
Actual: GLOG	
Forecast sample: 2/28/2014 3/15/2024	
Adjusted sample: 3/04/2014 3/15/2024	
Included observations: 2483	
Root Mean Squared Error	0.010546
Mean Absolute Error	0.007350
Mean Abs. Percent Error	142.3423
Theil Inequality Coefficient	0.906829
Bias Proportion	0.000287
Variance Proportion	0.844737
Covariance Proportion	0.154977
Theil U2 Coefficient	1.063075
Symmetric MAPE	164.9741

Figure 4 Graphical presentation of volatility

Source: Author's computation using EViews 10

From the above graphical presentation, it can be observed that it explains the nature the nature of volatility. It can also observed that the residual graph corresponds to the actual volatility.

Conclusions and Recommendations

APARCH(1,1) seems the fittest model to study the volatility of S&P BSE-GREENEX, as it observed that there is asymmetry, volatile clustering, leverage effect, and volatility observed around 2019-20 due to COVID-19, and allied variables such as money supply, inflation, and macroeconomic factors. Although APARCH is a fine model, but it fails to incorporate finer details caused by invisible variables, resulting in the generalization of calculated results. It becomes essential for the academic community to do in-depth research on the finer details of the sustainability indices toinform investors and society. For this, various models are used, such as AI, ML, COPULA, and VAR, which are multivariate in nature and showa larger picture of volatility, and accessingmore information benefits society and investors, promoting transparency, sustainability, and value creation.

Authors' Contributions:

The authors contributed equally to this work.

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