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Article

Volatility Analysis and Persistence in an ESG Mutual Fund: E-GARCH Evidence from the Quantum ESG Best in Class Strategy Fund

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Abstract: This paper examines the return behavior, long-run equilibrium relationships and volatility dynamics of the Quantum ESG Best-in-Class Strategy Fund, an Indian equities mutual fund with an Environmental, Social and Governance (ESG) theme, using daily Net Asset Value (NAV) data from the fund's launch to December 31, 2025. Daily returns are calculated and standard time series diagnostics are used. A unit-root test confirms the stationarity of the returns and the non-stationarity of the level series.Johansen cointegration tests are used to look at long-term connections between: (i) The return on an ESG fund and the general market return (BSE return); (ii) The return on an ESG fund and a competitor peer fund of the same AMC having highest AUM i.e Quantum Value Fund. Finally, conditional volatilities and the performance of ESG funds compared to the BSE ESG index and peer fund are analyzed using EGARCH (calculated in Eviews). The research extends the limited work in India on cointegration and asymmetric volatility modeling of ESG mutual funds, and it provides a useful resource for managers and investors making ESG strategy valuation and investment decisions in emerging nations.
Keywords: ESG mutual funds, Johansen cointegration, EGARCH, Unit-root test and Quantum ESG Best-in-Class Fund

1. Introduction

In India, environmental, social, and governance (ESG) investment has become increasingly popular due to the promotion of ESG-themed products and indexes by regulators, exchanges, and asset managers. Although ESG mutual funds assert that their financial goals are in line with sustainability standards, investors still require proof that these products offer competitive returns and risk profiles in comparison to traditional benchmarks and peer funds.One of the first ESG-themed equity schemes in India, the Quantum ESG Best-in-Class Strategy Fund was introduced in July 2019 and offers a long enough daily NAV series for reliable time-series analysis. Due to its early adoption of research-driven investment strategies and its innovative role in Environmental, Social, and Governance (ESG) investing, Quantum Asset Management Company (AMC) marks a significant milestone in the mutual fund industry in India. Founded with the intention of offering asset management services that are moral, open, and focused on investors, Quantum AMC has become a distinctive force in the cutthroat mutual fund market in India (Quantum AMC,2021)

At first, ESG investing was a relatively new idea in India, with few investors understanding it and doubting its ability to make money (Kumar & Prakash, 2020). However, through intensive investor education programs, Quantum AMC was instrumental in changing perceptions. To raise awareness of sustainable finance, the company held webinars, published whitepapers, and took part in international ESG forums (Quantum AMC, 2021). The Quantum India ESG Equity Fund gained popularity over time, drawing in institutional and retail investors looking for morally sound investment options. The importance of corporate sustainability was further highlighted by the COVID-19 pandemic, which raised interest in ESG funds throughout the mutual fund sector in India (Amel-Zadeh & Serafeim, 2018).

Using Johansen's cointegration methodology, this study looks at (i) return characteristics, (ii) long-term relationships with the market and a conventional peer fund of the same AMC but having highest AUM, and (iii) conditional volatility dynamics using an EGARCH specification using daily NAV data from inception to March 31, 2025.

The comparatively small number of empirical studies, particularly those that provide long-term, comparative, and multidimensional analyses, is a glaring research vacuum in the literature on ESG mutual funds in India.The lack of comprehensive, long-term, and comparative studies highlights the need for more methodical study on ESG mutual funds in India. Firstly, there is a dearth of scholarly research in India that particularly applies sophisticated econometric methodologies (EGARCH and cointegration) to ESG mutual fund NAVs. Secondly, from a practitioner perspective, investors and asset managers need to know if ESG funds show different volatility patterns and long-term relationships from conventional rivals and broad benchmarks.

The research paper is structured as follows: Section 2 examines pertinent literature; The research objectives are described in Section 3,section 4 deals with research methodology,Empirical discussions and hypothesis testing are presented in Section 5; and the conclusion is given in Section 6.

2. Review of Literature

ESG mutual funds in India have grown over the years and are gradually establishing a new paradigm in the Indian mutual fund industry, where the emphasis is now on responsible and sustainable investing rather than purely on returns (Kamalnath, 2025).This has given rise to the launch of ESG driven mutual fund schemes by various AMCs, which give an opportunity to the investors to invest in sustainable wealth creation (Aloysius Edward et al., 2025).There has been a tremendous rise in investor interest in ESG mutual funds, brought about by the growing awareness of sustainability, responsible investing, climate change, social welfare, and corporate governance (Bauer et al., 2021; Tiwari et al., 2024) . Investors are slowly coming to understand that investment decisions should not be made solely based on the return of investment; there are environmental and social effects of companies as well (Heeb et al., 2023). ESG mutual funds offer investors a chance to invest in companies that perform well on environmental, social, and governance (ESG) criteria as well as have the goal of delivering long-term financial returns (Bauer et al., 2021).

The investment philosophy, portfolio construction, stock selection criteria, and investor appeal are the significant differences between ESG mutual funds and traditional mutual funds.Hence, ESG mutual funds are a responsible investment approach and traditional mutual funds are a conventional financial investment approach (Yue et al., 2020).The performance of ESG mutual funds is mostly contrasted with performance of traditional mutual funds to understand whether the incorporation of ESG principles has a positive, negative, or insignificant impact on investors' returns (Gantchev et al., 2024).

It is also important to compare the volatility of ESG funds with traditional mutual funds to understand the investor's outcomes (Plagge & Grim, 2020). Volatility is seen as the extent of fluctuation of fund returns or NAV. Lower volatility could be seen in ESG mutual funds as they are made up of companies that have a stable business model, strong corporate governance, and minimal exposure to controversial sectors. However, if an ESG fund is focused on a particular sector or theme, this can lead to increased volatility. Consequently, comparisons of the volatility of ESG funds and traditional funds can be calculated using the standard deviation, beta, variance and models, such as GARCH or EGARCH (Pavlova & De Boyrie, 2022).

The comparison of ESG funds with other conventional funds of the same AMC is particularly relevant as the vast majority of previous studies have been based on the comparison of ESG funds with broad market indices or with general conventional mutual funds. But within the same AMC, the comparison could give a more in-depth view of the potential impact of the investment strategy on the investor. It can also assist in assessing the performance of ESG funds being assessed as better, worse or equal to ESG funds managed by the same fund house.

Recent Indian studies investigate whether higher ESG scores or ESG-themed funds deliver superior risk-adjusted returns. Soni (2023) finds that mutual funds with higher ESG scores do not generate significant positive alphas after controlling for Fama–French five factors, both in normal and COVID-19 periods, suggesting higher screening and opportunity costs may offset benefits. Other empirical work on Indian ESG funds reports mixed results: some studies find weak short-term correlation but stronger long-term association between ESG ratings and performance, and improvements in risk-adjusted metrics such as the Sharpe ratio for higher-ESG portfolios. Comparative studies of ESG vs. traditional equity funds in India generally conclude that ESG funds can be financially competitive, though outperformance is not uniform across all periods or metrics.

Internationally, cointegration techniques have been used to examine long-run relationships between mutual fund NAVs, market indices, and sector indices, particularly in efficiency and integration studies. In emerging markets, such methods are less commonly applied to ESG-specific funds, creating a gap this paper addresses. Theoretical work on market efficiency and asset pricing supports testing for long-run equilibrium between fund returns and benchmarks, as persistent deviations may indicate mispricing, style drift, or structural differences in portfolio construction.

GARCH-family models are standard for capturing volatility clustering and asymmetry in financial returns. EGARCH, in particular, allows for asymmetric effects (e.g., bad news increasing volatility more than good news), which is relevant for equity funds exposed to market shocks. Indian studies on mutual fund volatility increasingly adopt GARCH/EGARCH frameworks, but ESG-specific applications remain limited. This paper extends that literature by modeling conditional volatility of an ESG fund alongside a dedicated ESG index and a conventional peer.

3. Research Objectives

The present study is guided by the following key objectives:

1. To compare the investor outcomes of Quantum ESG mutual funds with the benchmark of BSE 100 ESG Total Return Index (TRI).
2. To analyse the investor outcomes of Quantum ESG mutual funds relative to peer with Highest AUM in the same asset management companies.
3. To summarize findings and draw conclusions.

4. Research Methodology

4.1 Secondary Data Sources

Secondary data for this research is sourced from the following regulatory and official platforms:

- **AMFI India (Association of Mutual Funds in India):** The primary source for mutual fund regulatory data and daily Net Asset Value (NAV) updates. Website: amfiindia.com
- **Quantum Website:** Official factsheets and NAV data from Quantum AMC websites to ensure data accuracy and completeness.
- **BSE ESG Indices:** BSE 100 ESG Index data for benchmark comparison and cointegration analysis.

4.2 Sample period: Daily NAV from inception 12 July 2019 to 31 December 2025.

4.3 Return Calculation

The return series is generated from the collected time series data of Net Asset Values using the logarithmic return formula:

$$r_t=\ln\left(\frac{NAV_t}{NAV_{t\text{-}1}}\right)\times 100$$

where:

- r_t = logarithmic return on day t
- NAV_t = Net Asset Value on day t
- $NAV_{t\text{-}1}$ = Net Asset Value on day t-1
- $\ln$ = natural logarithm

4.4 Econometric Framework

4.4.1 Unit-Root and Stationarity Tests

To justify time-series modeling, stationarity of the level and return series is tested using standard unit-root test i.e Augmented Dickey–Fuller (ADF). Before applying cointegration analysis, it is essential to test for stationarity in the time series data. A non-stationary series can lead to spurious regression results. The Augmented Dickey-Fuller (ADF) test is employed to test for the presence of unit roots in the return series.

The Dickey-Fuller (DF) test is a unit root test used to determine if a time series is stationary. The basic equation is:

$$\Delta Yt=\alpha+\rho Yt-1+\epsilon t$$

where the null hypothesis (H0) is that $\rho=1$(indicating a unit root and non-stationarity), and the alternative hypothesis (H1) is that $\rho<1$ (indicating stationarity).This is consistent with typical financial time-series behavior and is a prerequisite for cointegration analysis.

4.4.2 Johansen's Cointegration Test

Johansen's multivariate cointegration approach is applied to examine long-run equilibrium relationships between:

- Quantum ESG Best-in-Class Fund and BSE market returns (or BSE ESG Index).
- Quantum ESG Best-in-Class Fund and Quantum Value Fund (peer).

4.4.3 EGARCH Model for Volatility and Performance

For the return series of the ESG fund and independently for the BSE ESG Index and Quantum Value Fund (over the common sample), an EGARCH(1,1) model is estimated in EViews. The model is used :

- Compare conditional volatility levels and persistence across the ESG fund, BSE ESG Index, and peer fund.
- Assess whether the ESG fund exhibits lower, similar, or higher volatility than the ESG index and conventional peer, controlling for asymmetry.
- Model diagnostics include residual tests and stability checks.

5. Data Analysis and Results

The unit root tests were applied to check the stationarity properties of the series before testing the long-run relationship between Quantum ESG and BSE 100 ESG Total Return Index (TRI) and also between Quantum ESG and Quantum Value Fund Return. This first step is important because the cointegration analysis is valid only if the variables are non-stationary in levels but integrated of the same order, often I(1). The variables are integrated of the required order after the unit root tests, and the Johansen cointegration procedure was employed to test for the presence of a stable long-run equilibrium relationship between the two series.

5.1 Co integration analysis between Quantum ESG and BSE 100 ESG Total Return Index (TRI)

The Johansen cointegration test was used to test the null hypothesis of no cointegration between QUANTUM ESG and BSE 100 ESG Total Return Index (TRI) for a stable long-run equilibrium relationship during the sample period 12 July 2019 to 31 March 2025. The test has been estimated in Eviews including a constant in the cointegrating relationship and in the short-run dynamics. The lag interval was set from 1 to 4 in first differences and the model was estimated with 1409 observations.

Hypothesis

Null hypothesis: QUANTUM ESG and BSE 100 ESG Total Return Index (TRI) do not share a long-run equilibrium relationship.

Alternative hypothesis: QUANTUM ESG and BSE 100 ESG Total Return Index (TRI) share a long-run equilibrium relationship.

Table 1. Johansen cointegration test between QUANTUM ESG and BSE 100 ESG Total Return Index (TRI)

Null hypothesis	Test statistic	5% critical value	p-value	Decision
None r=0r = 0r=0	488.5994	15.49471	0.0000	Reject
At most 1 r≤1r \leq 1r≤1	202.8219	3.841465	0.0000	Reject

Table 2. Johansen maximum eigenvalue test between QUANTUM ESG and BSE 100 ESG Total Return Index (TRI)

Null hypothesis	Test statistic	5% critical value	p-value	Decision
None r=0r = 0r=0	285.7776	14.26460	0.0000	Reject
At most 1 r≤1r \leq 1r≤1	202.8219	3.841465	0.0000	Reject

Table 1 and 2 indicates that the trace test strongly rejects the null hypothesis of no cointegration. The trace statistic for r= 0 was 488.5994, which is far above the 5% critical value of 15.49471 with a p-value of 0.0000. The null of one cointegrating equation was also rejected as the trace statistic of 202.8219 is greater than the 5% critical value of 3.841465 and the associated p-value is 0.0000. The maximum eigenvalue test yielded the same inference, with the null of no cointegration being rejected by a max-eigen statistic of 285.7776 against a 5% critical value of 14.26460, again with p-value 0.0000.

Refutation of the null hypothesis no cointegration implies that QUANTUM ESG and the BSE 100 ESG Total Return Index (TRI) are cointegrated in the long run meaning that the relationship between the two series has a long-run equilibrium which implies that deviations in the short-run are not sustainable in the long run. It would seem to suggest that there is commonality between the two ESG return series in the stochastic trends. The outcome confirms that there is a stable relationship in the performance of dynamics of the quantum ESG portfolio and the BSE 100 ESG Total Return Index (TRI)series over the sample period.

5.2 Co integration analysis between Quantum ESG and BSE 100 ESG Total Return Index (TRI)

The Johansen cointegration test was used to test the null hypothesis of no cointegration between Quantum ESG return and Quantum value fund return for a stable long-run equilibrium relationship during the sample period 12 July 2019 to 31 March 2025. The test has been estimated in Eviews including a constant in the cointegrating relationship and in the short-run dynamics. The lag interval was set from 1 to 4 in first differences and the model was estimated with 1409 observations.

Hypothesis

Null hypothesis: Quantum ESG return and Quantum value fund return do not share a long-run equilibrium relationship.

Alternative hypothesis: Quantum ESG return and Quantum value fund return share a long-run equilibrium relationship.

Table 3. Johansen trace test — QUANTUM_ESG_RETURN and QUANTUM_VALUE_FUND_RETURN

Null hypothesis	**Eigenvalue**	**Trace statistic**	**5% critical value**	**Decision**
None (r = 0)	0.164112	435.5230	15.49471	Reject
At most 1 (r ≤ 1)	0.122925	184.0207	3.841465	Reject

Table 4. Johansen max-eigen test — QUANTUM_ESG_RETURN and QUANTUM_VALUE_FUND_RETURN

Null hypothesis	**Eigenvalue**	**Max-eigen statistic**	**5% critical value**	**Decision**
None (r = 0)	0.164112	251.5022	14.26460	Reject
At most 1 (r ≤ 1)	0.122925	184.0207	3.841465	Reject

Table 3 and 4 Indicates that the null hypothesis that there is no cointegration is rejected by the Johansen trace test. The trace statistic is 435.5230 for the null $r = 0$, which is much higher than the 5% critical value of 15.49471, and 184.0207 for the null $r \leq 1$, which is higher than the 5% critical value of 3.841465. The same conclusion is reached using the maximum-eigenvalue test: for $r = 0$, the max-eigen statistic is 251.5022 (5% critical value = 14.26460), and for $r \leq 1$, it is 184.0207 (5% critical value = 3.841465). Both tests point to two cointegrating equations and show that the null hypotheses are rejected at the 5% level.The linkage of Longrun may indicate that Long-term portfolio diversification between the QUANTUM ESG strategy returns and the QUANTUM value fund returns may be limited due to their similar trend.The Long-term portfolio diversification between the QUANTUM ESG strategy returns and the QUANTUM value fund returns may be limited by the same trend (Long-run linkage).

5.3 Volatility Analysis of Quantum ESG Mutual Fund

The E-Garch model is used to estimate volatility of Quantum ESG Mutual Fund. Breusch-Godfrey LM test is used to test whether residual are auto correlated in Quantum ESG Mutual Fund. Then the ARCH test was performed to see if variance of residual of Quantum ESG Mutual Fund has been stable. Next step, E-Garch model is utilized to capture clustering effect as well as asymmetric return behavior. In the last, ARCH test was conducted to check whether variance of residual of Quantum ESG Mutual Fund is changing with time or not**.**

5.3.1 The Breusch-Godfrey LM test

Hypotheses

- **H_0 (Null hypothesis):** There is no serial correlation in the residuals up to 2 lags.
- **H_1 (Alternative hypothesis):** There is serial correlation in the residuals up to 2 lags.

Table 5.The Breusch-Godfrey LM test Results Table

Test Statistic	**Value**	**Probability**	**Decision**
F-statistic	0.477010	0.6207	Fail to reject H_0

Obs*R-squared*	0.955461	0.6202	Fail to reject H_0

Analysis Interpretation

The Breusch-Godfrey LM test was conducted to examine whether the residuals of the Quantum ESG Mutual Fund model were autocorrelated up to 2 lags. The F-statistic is 0.477010 with a probability value of 0.6207, and the Obs*R-squared statistic is 0.955461 with a probability value of 0.6202. Since both probabilities are much higher than the 5% significance level, the null hypothesis of no serial correlation cannot be rejected.

This indicates that the residuals of the Quantum ESG Fund are not statistically significantly autocorrelated. This model has the desired property that there is no serial correlation in the analytical sense. Serial correlation in the error term indicates that the model has failed to capture the dynamic movements in the returns over time for the Quantum ESG Mutual Fund.

This result suggests that the Quantum ESG Mutual Fund regression is reasonably specified with respect to autocorrelation. Since the p-values are very large, there is no sign of residual dependence at the tested lag length, and the model can be treated as statistically stable on this diagnostic check.

5.3.2 ARCH test

Hypotheses

- **H_0 (Null hypothesis):** There is no ARCH effect in the residuals of the Quantum ESG Mutual Fund; the variance is constant over time.
- **H_1 (Alternative hypothesis):** There is an ARCH effect in the residuals of the Quantum ESG Mutual Fund; the variance is not constant over time.

Table 6.ARCH test Results Table

Test Statistic	**Value**	**Probability**	**Decision**
F-statistic	63.56193	0.0000	Reject H_0
Obs*R-squared*	60.79962	0.0000	Reject H_0

Analysis Interpretation

The ARCH test was used to check whether the residual variance of the Quantum ESG Mutual Fund remained constant over time. The F-statistic is 63.56193 with a probability value of 0.0000, and the Obs*R-squared statistic is 60.79962 with a probability value of 0.0000. Since both probabilities are far below 0.05, the null hypothesis of no ARCH effect is rejected.

It indicates that the residual terms of the Quantum ESG Mutual Fund is Heteroskedastic. In other words, the magnitude of volatility is not constant over time. In practice, the volatility clustering can be observed for the fund.

Periods of large returns are more likely to be followed by large returns, which often appears in financial returns series.

This is one of the reasons why ARCH, GARCH, and EGARCH are applied to financial econometrics. From the point of analysis perspective, this result provides a strong indication that the Quantum ESG Mutual Fund can not be modeled effectively using constant-variance model. The significant ARCH effect suggests that there exists forecastable volatility dynamic for this series, thus, the series warrants the use of a volatility model such as GARCH or EGARCH for further analysis and risk management purposes.

5.3.3 E-Garch test

Hypotheses

- **H_0 (Null hypothesis):** There is no asymmetric volatility or leverage effect in the Quantum ESG Mutual Fund returns.
- **H_1 (Alternative hypothesis):** There is asymmetric volatility or leverage effect in the Quantum ESG Mutual Fund returns.

Table 7. EGARCH Test Result Table

Variable	Coefficient	Std. Error	z-Statistic	Probability	Interpretation
Mean equation C	0.059102	0.022404	2.638029	0.0083	Significant positive mean return
C(2)	-0.134435	0.020178	-6.662464	0.0000	Significant ARCH effect
C(3)	0.159917	0.024828	6.441021	0.0000	Significant magnitude effect
C(4)	-0.099183	0.011915	-8.324031	0.0000	Significant leverage effect
C(5)	0.957415	0.006258	153.0393	0.0000	Very strong volatility persistence

Analysis and Interpretation

In order to represent volatility clustering and asymmetry in the return series, the EGARCH model is employed. For Quantum ESG Mutual Fund, the mean return coefficient is positive and significant which demonstrates the fund generated statistically significant average returns over the sampled period. However, even more importantly, all the coefficients of variance equation are significant at the 1% significance level which indicates the volatility process of the fund follows clearly structure and persist.

Most Important, the significant negative coefficient C(4), C(4)<0, confirms existence of leverage effect. In EGARCH model terms, bad news or negative shocks will increase future volatility by a larger extent than good news or positive shocks of the same magnitude. Also, a very significant C(5) value reveals an very high volatility persistence, meaning that shocks will have a lingering effect on volatility over long term on the Quantum ESG Mutual Fund.

From an empirical perspective, it shows that Quantum ESG Mutual Fund does not conform to a constant risk assumption but is subject to conditional heteroskedasticity, asymmetric response to shocks and a very high level of persistence of shocks. Hence, EGARCH seems like a proper model for the study of the volatility of Quantum ESG Mutual Fund**.**

5.3.4 Residual Arch test

Hypotheses

- **H_0 (Null hypothesis):** There is no ARCH effect in the residuals of the Quantum ESG Mutual Fund; the variance is constant over time.
- **H_1 (Alternative hypothesis):** There is an ARCH effect in the residuals of the Quantum ESG Mutual Fund; the variance is not constant over time.

Table 8. Residual Arch test Results Table

Test Statistic	Value	Probability	Decision

F-statistic	0.235909	0.6273	Fail to reject H_0
Obs*R-squared*	0.236217	0.6270	Fail to reject H_0

Analysis Interpretation

The ARCH test was performed to determine whether the residual variance of the Quantum ESG Mutual Fund changes over time. The F-statistic is 0.235909 with a probability value of 0.6273, and the Obs*R-squared statistic is 0.236217 with a probability value of 0.6270. Since both probabilities are far above 0.05, the null hypothesis of no ARCH effect cannot be rejected.

Therefore, there is no statistically significant presence of heteroskedasticity in the residuals and the variance may be assumed to be constant on average throughout the sample period. Formally, Quantum ESG Mutual Fund does not exhibit strong conditional heteroskedasticity in its residuals post estimation. We may suggest that there is insufficient evidence in the residual time series of an ARCH type time-varying conditional variance at the lag considered.

5.4 Volatility Analysis of BSE ESG Index

5.4.1 The Breusch-Godfrey LM test

Hypotheses

- **H_0 (Null hypothesis):** There is no serial correlation in the residuals up to 2 lags.
- **H_1 (Alternative hypothesis):** There is serial correlation in the residuals up to 2 lags.

Table 9.The Breusch-Godfrey LM test Results Table

Statistic	Value	df	p-value
F-statistic	2.005522	(2, 1814)	0.1349
Obs*R-squared (LM)	4.008814	Chi-square (2)	0.1347

Analysis and Interpretation

Interpretation With p-values of 0.1349 (F-form) and 0.1347 (LM Chi-square), both exceed conventional significance levels (0.01, 0.05, 0.10), so we fail to reject H0. There is no statistically significant evidence of serial correlation in the residuals up to two lags.

5.4.2 ARCH test

Hypotheses

- **H_0 (Null hypothesis):** There is no ARCH effect in the residuals of the BSE ESG Index; the variance is constant over time.
- **H_1 (Alternative hypothesis):** There is an ARCH effect in the residuals of the BSE ESG Index; the variance is not constant over time.

Table 10.ARCH test Results Table

Statistic	Value	df	p-value
F-statistic	85.92411	(1, 1814)	0.0000
Obs*R-squared	82.12864	Chi-square(1)	0.0000

Analysis and Interpretation

The ARCH LM test overwhelmingly rejects H0 ($p < 0.001$) in both the F-form and the Obs*R-squared (Chi-square) form, confirming that there are statistically significant ARCH effects in the BSE ESG Index model residuals, which means that we cannot consider a constant variance over time because volatility clusters exist; thus inference based on homoskedastic errors will be incorrect and requires an appropriate conditional heteroskedasticity model to model accurate volatilities along with valid standard errors [e.g., GARCH or robust standard errors consistent with independence].

5.4.3 E-Garch test

Hypotheses

- **H_0 (Null hypothesis):** There is no asymmetric volatility or leverage effect in the BSE ESG Index.
- **H_1 (Alternative hypothesis):** There is asymmetric volatility or leverage effect in the BSE ESG index.

Table 11. EGARCH Test Result Table

Equation	Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean	C	0.043991	0.019570	2.247883	0.0246
Variance	C(2)	-0.147773	0.011564	-12.77827	0.0000
Variance	C(3)	0.184472	0.014202	12.98953	0.0000
Variance	C(4)	-0.101556	0.010505	-9.667493	0.0000
Variance	C(5)	0.957838	0.005440	176.0868	0.0000

Analysis and Interpretation

The E-GARCH results show that all variance-equation coefficients are statistically significant at the 1% level, indicating strong evidence of volatility clustering and asymmetric volatility behavior in BSE_RETURN. The significant negative coefficient on C(2) suggests the presence of a leverage or asymmetry effect, meaning that negative shocks affect volatility differently from positive shocks. The positive and highly significant coefficient on C(5) indicates high volatility persistence, implying that shocks to market volatility decay slowly over time. Since the variance parameters are significant and the model fits the data well, the null hypothesis is rejected and the alternative hypothesis is accepted, confirming that BSE returns exhibit time-varying conditional volatility suitable for E-GARCH modeling.

5.4.4 Residual Arch test

Hypotheses

- **H_0 (Null hypothesis):** There is no ARCH effect in the residuals of the BSE ESG Index; the variance is constant over time.
- **H_1 (Alternative hypothesis):** There is an ARCH effect in the residuals of the BSE ESG Index; the variance is not constant over time.

Table 12. Residual Arch test Results Table

Test statistic	Value	p-value	Decision
F-statistic	1.656596	0.0855	Fail to reject H0
ObsR-squared	16.51509	0.0858	Fail to reject H0

Analysis and Interpretation

The ARCH test results indicate that the null hypothesis cannot be rejected at the 5% significance level because both p-values are greater than 0.05. This means there is no statistically significant evidence of remaining ARCH effects in the residuals after the E-GARCH estimation, suggesting that the model has adequately captured the conditional heteroskedasticity in the data. However, since the p-values are close to 0.10, the result is marginal at the 10% level, so weak residual volatility may still be present in the series.

5.5 Volatility Analysis of Quantum Value Fund Return

5.5.1 The Breusch-Godfrey serial correlation LM test

Hypotheses

H0: No serial correlation up to order 2 (ρ1 = ρ2 = 0).

H1: At least one ρj ≠ 0 for j = 1,2 (serial correlation present up to lag 2)

Table 13. The Breusch-Godfrey serial correlation LM test

Test statistic	Value	p-value	Decision (α = 0.05)
F (2,193)	0.8171	0.4419	Fail to reject H0. No evidence of serial correlation. metricgate
Obs*R-squared (LM)*	1.6358	0.4414	Fail to reject H0. No evidence of serial correlation. real-statistics

Analysis and Interpretation

The Breusch-Godfrey serial correlation LM test was applied to the Quantum Value Fund return model with two lags, using the null hypothesis that there is no serial correlation in the residuals up to lag 2 and the alternative that serial correlation is present. The test results show an F-statistic of 0.8171 with Prob. F(2,193) = 0.4419 and Obs*R-squared = 1.6358 with Prob. Chi-Square(2) = 0.4414, both of which are greater than 0.05. Therefore, the null hypothesis cannot be rejected, indicating that there is no statistical evidence of serial correlation in the residuals up to the second lag, and the regression model appears to satisfy the no-autocorrelation assumption.

5.5.2 Arch Test

Hypotheses

- Null hypothesis (H0): No ARCH effects — the residuals have constant conditional variance (no autoregressive conditional heteroskedasticity).
- Alternative hypothesis (H1): ARCH effects are present — the residuals exhibit time-varying conditional variance (ARCH).

Table 14. Arch test Result Table

Test statistic	Value	p-value	Decision (α = 0.05)
F-statistic	76.46207	0.0000	Reject H0 (evidence of ARCH) econ.uiuc
Obs*R-squared*	72.58750	0.0000	Reject H0 (evidence of ARCH) econ.uiuc

Analysis and Interpretation

The ARCH test results for the Quantum Value Fund indicate highly significant autoregressive conditional heteroskedasticity: the F-statistic (76.46207) and the Obs*R-squared (72.58750) both have p-values equal to 0.0000, so we reject the null hypothesis of homoskedasticity and conclude that volatility clusters are present in the fund's returns — periods of high volatility are followed by high volatility and periods of low volatility follow low volatility, implying that a volatility model such as GARCH (or one of its variants) is appropriate for modelling conditional variance and for improving inference and volatility forecasting in subsequent analysis.

5.5.3 E-GARCH TEST

Hypotheses

- H0 (persistence): The conditional volatility follows a persistence process (no persistence = C(5) = 0).
- H0 (ARCH/size effect): Past standardized shocks (magnitude) do not affect log variance (no size effect = C(3) = 0).
- H0 (leverage/asymmetry): Positive and negative shocks have equal impact on volatility (no asymmetry = C(4) = 0).
- H0 (constant): The intercept of the log-variance is zero (no constant in log-variance = C(2) = 0).

Table 15. E-GARCH Test Results

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C (mean)	0.040086	0.021699	1.847363	0.0647
C(2) (const, ln σ^2)	-0.126143	0.011548	-10.92312	0.0000
C(3) (ARCH /	ε	term)	0.160660	0.014398
C(4) (asymmetry / sign term)	-0.080349	0.011177	-7.188768	0.0000
C(5) (GARCH / persistence)	0.962245	0.005869	163.95313	0.0000

Analysis and Interpretation

The EGARCH(1,1) estimates for the Quantum Value Fund indicate a statistically insignificant mean return but strongly significant volatility dynamics. The negative and highly significant constant in the log-variance (C(2) = -0.126, $p < 0.01$) anchors the unconditional level of volatility in the model. The size (ARCH) coefficient C(3) is positive and highly significant (0.1607, $p < 0.01$), implying that the magnitude of past standardized shocks increases current log-variance — larger shocks, regardless of sign, raise volatility. The asymmetry (sign) coefficient C(4) is negative and highly significant (-0.0803, $p < 0.01$), which implies a **leverage** or asymmetry effect: negative shocks (bad news) raise volatility more than positive shocks of the same magnitude do, consistent with typical equity fund behavior. The persistence term C(5) is close to one and highly significant (0.9622, $p < 0.01$), indicating strong volatility persistence — shocks to volatility decay slowly, and conditional variance is highly persistent over time. Cumulatively, these results show that the Quantum Value Fund exhibits volatility clustering, asymmetric response to shocks (bad news has more impact) and high persistency, thus risk forecasts should not neglect a slow mean reversion and a bigger reaction after negative returns. They all favour rejecting the nulls of no ARCH effect and no asymmetry at traditional significance levels and confirm persistent conditional heteroskedasticity in returns.

5.5.4 Residual Arch test

Hypothesis

H_0 (Null Hypothesis): There is no ARCH effect in the residuals; the residual variance is homoscedastic (constant) up to lag 8, i.e., $\alpha_1 = \alpha_2 = ... = \alpha_8 = 0$.

H_1 (Alternative Hypothesis): ARCH effects are present in the residuals; the residual variance is heteroscedastic (time-varying), i.e., at least one $\alpha_i \neq 0$.

Table 14. Residual Arch test Result Table

Test statistic	Value	p-value	Decision ($\alpha = 0.05$)
F-statistic	1.461117	0.1668	Fail to reject H_0
Obs*R-squared*	11.66634	0.1667	Fail to reject H_0

Analysis and Interpretation

The ARCH-LM test was applied to the residuals of the Quantum Value Fund return series to examine the presence of conditional heteroscedasticity (volatility clustering) up to 8 lags. The results yielded an F-statistic of 1.461117 (p = 0.1668) and an Obs*R-squared (LM) statistic of 11.66634 (p = 0.1667), both of which are statistically insignificant at the 5% level, indicating that the null hypothesis of no ARCH effect cannot be rejected. This indication that the squared residuals are not closely related to past squared residuals indicates that the variance of the residuals from the fund's return series is homoskedastic, and that the residual series is not subject to volatility clustering throughout the sample period. As such, the mean equation has a correct variance structure, and there is no justification for expanding to ARCH/GARCH-family models to consider the case where volatility varies over time for the fund's return series.

5.6 Comparative volatility: Quantum ESG vs BSE ESG Index

Based on the EGARCH result we can see that both Quantum ESG and BSE ESG Index show time-varying volatility, volatility clustering, and asymmetry, that implies the volatility respond differently to positive shocks. With EGARCH for Quantum ESG, we can find there are high leverage effect, extremely persistent (with the persistence 0.957415 that implies the shocks in volatility disappear slowly for both Q ESG and BSE ESG Index that with the persistence of 0.957838). As result of that we conclude that the volatility of Q ESG doesn't seem much higher than the BSE ESG Index, on contrary, the volatility of both stocks move with similar persistences and they have similar risk behavior. In addition, we conclude that the conditional volatilities are approximately the same between ESG Fund and BSE ESG Index, so we do not have evidence that the risk from this ESG Fund is systematically higher.

5.7 Comparative volatility: Quantum ESG vs Quantum Value Fund

The comparison with Quantum Value Fund is relevant in the sense that Quantum Value Fund is the peer with highest AUM in the same AMC and therefore may be a real-life investor choice of comparator for Quantum ESG Fund. The report states that ARCH effects, asymmetric volatility and strong persistence are all observed for the Quantum Value Fund too and the EGARCH persistence coefficient is estimated as 0.962245, a slightly higher value than that for Quantum ESG Fund (0.957415). This could suggest that the Volatility of the Value Fund tends to be more persistent or adjusts back to the expected value more slowly after a shock.

On the other hand, strong conditional volatility and leverage effects is exhibited by both funds, so the divergence is only one of magnitude, not of sign.

To put in plain language, the Volatility of Quantum ESG is not necessarily greater than that of Quantum Value Fund. The volatility process of Quantum Value Fund even seems to be slightly more persistent.

6. Conclusion

This paper investigates the return dynamics, long-run relationships, and volatility behavior of the Quantum ESG Best-in-Class Strategy Fund. EGARCH modeling shows that the ESG fund's conditional volatility and asymmetry are broadly comparable to those of the BSE ESG Index and the conventional peer, with no evidence of systematically higher risk. On a comparative basis, the volatility of Quantum ESG Best-in-Class Strategy Fund is broadly similar to that of the BSE ESG Index and the Quantum Value Fund. All three series appear to exhibit volatility clustering, asymmetry to shocks and greater persistency. That said, the Quantum ESG do not consistently appear more volatile than the BSE ESG Index and the Quantum Value fund appear slightly more persist in its volatility. In this context, it appears ESG screen do not introduce undue risk and the Quantum ESG fund continues to resemble the highest AUM conventional product and it's ESG benchmark in the AMC.

Overall, these results indicate that during the sample period, the ESG fund acts as an integral component of the Indian equity market, whereby the ESG screen impacts short-term mispricing but does not unhinge long-term correlations or lead to overshooting volatility. For fund investors and asset managers, these results provide confidence that ESG mutual funds may be managed and analyzed with conventional quantitative techniques, and that ESG goals may be achieved.

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