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Testing the Market Efficiency of S&P BSE Energy Stocks in India

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Abstract: In India, the energy sector contributes significantly to the country's GDP. It is a key driver of economic growth, and it is essential to determine the market efficiency of energy sector in India. The study investigated the random walk behaviour of energy stocks using ten daily stock prices from January 2015 to December 2022. For this purpose, robustified statistical tests and models were employed, including run test for randomness, automatic portmanteau and automatic variance ratio tests for autocorrelation, and GARCH (1,1) model for volatility clustering. The study results illustrated that changes in the prices of energy stocks listed on the S&P BSE Energy are random, indicating that they have random walk characteristics. This study implies that investors could not obtain abnormal profits through the due diligence of stock prices in this efficient market, indicating that past stock returns were not significantly related to future stock prices and returns.

1. Introduction

In the recent years, the Indian stock market has emerged as a rapidly growing force in the global financial landscape (Bhattacharjee *et al*., 2016; Rohilla and Tripathi, 2022). However, the Indian stock market efficiency is often debated, with some arguing that it is only sometimes efficient due to the influence of various factors such as market speculation and irrational investor behaviour (Panda and Dey, 2022). Within the field of asset price modelling, the Efficient Market Hypothesis (EMH) has garnered significant attention and discussion. The core premise of EMH suggests that stock prices accurately depict publicly accessible information about a company, leading to an efficiently functioning market (Fama, 1965). The EMH exists in three different versions: the weak form, which specifies that past prices and returns have no influence on future prices and returns; the semi-strong form, indicating that publicly available information is reflected in stock prices; and the strong form, implying that both public and private information is reflected in prices. This weak form of efficiency resembles the random walk theory, suggesting that historical stock data cannot reliably predict future prices (Rohilla and Tripathi, 2022). Technical analysis, which relies on past trends, may need to be more effective for investors. In an efficient market, stocks are assumed to be fairly valued, and their prices closely align with actual value (Mallesha and Archana, 2023). Consequently, the behaviour of stock prices in such markets are random, responding only to new information, making them unpredictable (Chavarkar and Nayak, 2022; Hayek, 1945). The unpredictability of security prices is further influenced by PESTLE factors and the regulatory environment (Pathak *et al.*, 2020). Thus, the efficiency of financial markets vary depending on the sector's characteristics, trading volume fluctuations, information availability, financial instability, and central bank actions (Khuntia and Pattanayak, 2020). Studying various industrial sector's efficiency in India is essential, mainly due to the growing integration of Indian financial markets (Chavarkar and Nayak, 2022; Mohanty *et al.*, 2023). While weak-form efficiency has been extensively studied in various sectors, including banking, pharmaceuticals, insurance, chemicals, and information technology, focusing on specific sectors, such as the Indian energy sector, allows us to uncover nuances and unique characteristics that may not be evident in more generalized studies. Additionally, the Indian energy sector may have its dynamics, regulatory environment, and information flow, which can affect the efficiency differently. Moreover, energy stocks are sensitive to macroeconomic and political developments (Bjørnland, 2022), which makes us an interesting subject for studying the efficiency of energy stocks (Pandey and Mohapatra, 2017)). In this context, the researcher attempts to examine the random walk behaviour of energy stock prices, as this directly impacts investment decisions, risk management, and resource allocation for both individual and institutional investors. Also, it can influence policymakers in safeguarding market integrity and investors' protection through transparent information sharing.

The remainder of the article follows a specific structure, beginning with a review of relevant literature in the second segment. The third portion outlines the objective and hypothesis of the study, while the fourth part describes the methodology used to collect and analyse the data. Empirical results and their interpretation are discussed in the fifth section, followed by concluding remarks in the last section.

2. Review of Literature

The weak form of EMH posits that historical stock market prices do not contain valuable information for predicting future stock prices (Fama, 1970). This concept has been widely studied in various stock markets using multiple stocks, indices and sectors around the world. Guermezi and Boussaada (2016) found that weak form of inefficiency by using banking sector stocks in the Tunisian Stock Exchange. Onwukwe and Ali (2018) found inefficiencies in the Nigeria Stock Market's insurance sector. The VR test was used to analyse the stock prices in Taiwan from 1971 to 1996 to determine if they followed a random walk. Charles and Darne (2009) examined the advancements in using VR tests for testing the random walk and martingale hypothesis in the markets. The study focussed on various versions of the VR test for market efficiency. Said and Harper (2015) examined if the stock returns followed a random pattern. Different statistical methods, including autocorrelation and the VR test, were used for the

Table 1: Previous Studies on Weak Form of Market Efficiency (Sector-Wise)

Authors (Year)	*Country/Region*	*Methodology/Tests Used*	*Findings*	*Sectors of the Study*
Chavarkar and Nayak (2022)	India	ADF test, runs test, variance ratio test	Efficient	Pharmaceutical sector
Onwukwe and Ali (2018)	Nigeria	Autocorrelation function, Ljung-Box, runs test	Inefficient	Insurance sector
Dimri (2020)	India	Shapiro-Wilk test, Jarque-Bera test, ADF test, runs test, Autocorrelations test	Efficient	Chemicals sector
Ehsan (2021)	Bangladesh	Normality test, Durbin-Watson test, Breusch Godfrey test, runs test, Portmanteau test, variance ratio test.	Efficient	Pharmaceutical sector
Challa *et al.* (2020)	India	Variance ratio test, unit root tests, ARIMA	Inefficient	Sensex index and IT sector
Guermezi and Boussaada (2016)	Tunisia	GARCH (1, 1) and EGARCH (1, 1)	Inefficient	Banking sector
Kumar *et al.* (2020)	India	Run test, event study and NAV comparison	Efficient	Pharmaceutical sector
Kok and Munir (2015)	Malaysia	Panel nonlinear unit root test, panel stationarity test	Efficient	Finance sector

Source: Compiled by Authors

analysis. The Russian stock market showed no weak form efficiency during the study. Sadat (2019) examined daily return data from the DS30 and DSEX indices of the Dhaka Stock Exchange. Using various statistical tests such as ADF, Autocorrelation, and VR, indicating a departure from a normal pattern, the study found that the DSE does not efficiently follow the weak form of the Efficient Market Hypothesis (EMH). Chavarkar and Nayak (2022) found that the Indian pharmaceutical stocks are weak form efficiency during the pre-pandemic and pandemic. Dimri (2020) examined the market efficiency of Indian stock market. The paper conducted several tests, including the Shapiro-Wilk test, the JB test, the ADF test, the runs test, and the autocorrelations test. The results showed that the stock market is efficient in its weak form for chemical sector stocks. Srivastava (2007) studied the characteristics of the Indian Stock market, specifically focusing on its efficiency and random walk behaviour. This study utilized the run test, autocorrelation function, and unit root test over a specific time frame. The study revealed that stock market demonstrates weak form efficiency. In contrast, another study by Mishra *et al.* (2015) examined to assess the random walk model for that unit root were applied to the Indian stock market, considering two structural breaks. Tests examining breaks alone do not dismiss the null hypothesis of a random walk. Yet, a newer heteroskedasticity-aware test reveals mean reversion in stock indexes. Kushwah *et al.* (2013) found that NSE listed stock are efficient in its weak form of efficirny. Kumar et al. (2020) investigated the pharmaceutical companies and the Indian stock market are only efficient in the weak form of the efficient market hypothesis (EMH), but not in the semi-strong and strong forms of EMH during the study. Kalsie (2012) investigated a study on market efficiency within the Indian stock market. Employed runs test on the 30-day average prices of companies listed in the Nifty from 2001 to 2007. The results indicated that the share prices displayed random movement for most companies. Khuntia and Pattanayak (2020) found that the Indian foreign exchange market's efficiency changes over time due to factors. This dynamic nature of market efficiency offers opportunities for traders to exploit arbitrage in response to evolving conditions.

3. Statement of the Problem

The weak form efficiency of energy stocks in India is a relatively underexplored area in existing research. While weak-form efficiency has been extensively studied in various sectors, examining specific sectors like the Indian energy stock market unveils unique nuances not evident in generalized studies. This gap is significant given the pivotal role the energy sector plays in the Indian economy and it can impact the stock market's overall performance (Nandy, 2022). Moreover, the energy sector in India is currently undergoing substantial transformations, driven by governmental initiatives promoting the adoption of alternative energy sources and the privatization of state-run energy firms (Shukla *et al.*, 2019; Singh, 2006). Against this backdrop, researcher attempt to investigate the random walk behaviour of energy stocks, inferring its market efficiency. A more thorough exploration of this study could yield valuable insights into the performance of the energy sector prices (Mensi *et al.*, 2021).

4. Objective and Hypothesis

4.1. Objective of the Study

To examine the random walk behaviour of energy stocks, indicating that past price movements offer no predictive insight into future prices.

4.2. Hypothesis of the Study

The main hypothesis of the study is expressed as follows:

H_0: *The fluctuations in energy stock prices occur randomly.*

H_1: *The fluctuations in energy stock prices do not occur randomly.*

5. Research Methodology

5.1. Sample and Data

The study used daily closing prices of energy stocks listed on the S&P BSE Energy for the period of January 2015 to December 2022. The sample consists of 10 energy stocks listed on the S&P BSE Energy. These companies are Bharat Petroleum Corporation Ltd, Adani Total Gas Ltd, Coal India Ltd, GAIL (India) Limited, Gujarat Gas Ltd, Hindustan Petroleum Corporation Limited, Indraprastha Gas Limited, Indian Oil Corporation Ltd, Oil & Natural Gas Corporation Limited, Reliance Industries Ltd. They were chosen based on their total turnover. The data for these stocks were obtained from the BSE website. The daily returns of the energy stocks were determined by using a specified formula:

$$R_e = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

R_e signifies returns of energy stocks; ln represents logarithm returns; P_t is the energy stocks closing price at time t, P_{t-1} is the energy stocks closing price at time t-1

5.2. Methodology

In order to assess the market efficiency of energy stocks in its weak form, one must infer their random walk behaviour. Robustified tests and models were used, namely the Jarque Bera test, run test, automatic portmanteau test, automatic variance ratio test, and GARCH (1,1) model.

5.2.1. Jarque Bera Test

The Jarque-Bera normally test is the most common. The normality test is one of the variable diagnostic tests. This test determines if the observed returns are normally distributed (Jarque & Bera, 1980). To check for normality, use the JB test with the following formula:

$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right)$$

S represents skewness, and n signifies sample size.

5.2.2. Run Test

Wald and Wolfowitz introduced the run test as a non-parametric method for determining whether a series of values is randomly distributed or exhibits a certain pattern (Chavarkar & Nayak, 2022). If the calculated Z-value is higher than the critical value (±1.96) at the chosen significance level, then the series is considered non-random and has a pattern (Kalsie, 2012). The null hypothesis is that observed series are independent and move randomly.

$$\mu_r = \left(\frac{2n_1n_2}{n_1+n_2}\right)+1$$

The average number of runs, denoted as mr, is calculated based on the sum of positive returns (n1) and negative returns (n2) in a sequence of counts (r).

$$\sigma_r = \sqrt{\frac{2n_1n_2(n_1n_2-n_1-n_2)}{(n_1+n_2)^2(n_1+n_2-1)}}$$

The expected number of runs can have its standard error determined through the use of above-mentioned formula.

$$Z = \frac{n - \mu_r}{\sigma_r}$$

Where Z denotes the standardized variable.

5.2.3. Automatic Portmanteau Test

The automatic portmanteau test, an enhanced version of the Ljung-Box Q statistics, evaluates serial correlation in time series data without relying on assumptions about independence and identical distribution of returns (Escanciano and Lobato, 2009). It determines the optimal lag length, k, using either the Bayesian information criterion (BIC) or the Akaike information criterion (AIC) (Khuntia and Pattanayak, 2020; Lim et al., 2013). The automatic portmanteau test followed as follows:

$$AQ^*_{\tilde{k}} = T\sum_{j=1}^{\tilde{k}} \rho_j^2$$

where T stands for the total count of observations, ρ_j signifies the autocorrelation of order, and $\tilde{k}$ denotes the optimal lag length. This optimal lag length is determined by examining the first k autocorrelations of a time series, which serve as indicators of unpredictability.

5.2.4. Automatic Variance Ratio Test

The variance ratio test (Lo and MacKinlay, 1989) compares the variance of a time series over intervals of length 'k' with 'k' times the variance of the original series. An enhanced version, the automatic variance ratio test (Choi, 1999), selects the holding period 'k' automatically based on data-driven procedures (Lim *et al.*, 2013). In situations with random temporal data, the AVR test ensures equality between the variance of a single period and the variance of the entire period (Khuntia and Pattanayak, 2020). The AVR test statistics under the null hypothesis of no autocorrelation. The AVR test is expressed as:

$$AV(\tilde{k}) = \sqrt{T/\tilde{k}}[V\hat{R}(\tilde{k}) - 1]/\sqrt{2}$$

With the Variance Ratio (VR) computed is as follows

$$V\tilde{R}(\tilde{k}) = 1 + 2\sum_{i=1}^{T-1} m(i/\tilde{k})_{\hat{\rho}_i}$$

In this context, $\hat{\rho}_i$ represents the sample autocorrelation of order i, and m(.) denotes a weighting function with positive and decreasing weights.

5.2.5. GARCH (1,1) Model

The GARCH (1,1) model is a type of statistical model utilized for the examination of financial time series data with the aim of estimating the volatility of the data (Sharma, 2021). The variance formula for the GARCH (1,1) model is outlined as follows.

$$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

σ_t^2 is the volatility at time *t*, ω is the constant, α is the coefficient of the past residuals, β is the coefficient of the past volatility, and *r*(*t*-1) is the past residual. If the total of α and β is nearly 1, it implies a strong persistence in the volatility clustering, suggesting market inefficiency (Ganguly and Bhunia, 2021).

6. Empirical Analysis and Results

In situations where the data series exhibits non-normality and heteroscedasticity, the employment of automatic portmanteau and automatic variance ratio tests is advisable (Khuntia and Pattanayak, 2020). The data was analysed using RStudio 2023.09.0, a statistical software.

Table 2: Descriptive Statistics of the Energy Stocks

Energy Stocks	*Mean*	*Minimum*	*Maximum*	*Std. Dev.*	*Skewness*	*Ex. kurtosis*	*Jarque Bera*	*P-value*
ATGL	0.0038	-0.1909	0.1823	0.0343	0.5391	4.6695	9920	0.0000*
BPSL	-0.0003	-0.7202	0.1404	0.0291	-9.3479	209.3872	3655	0.0000*
COALINDIA	-0.0003	-0.1567	-0.0003	0.0192	-0.1515	4.0003	1333	0.0000*
GAIL	-0.0008	-0.7183	0.1526	0.0293	-9.6065	206.7636	3566	0.0000*
GUJGASLTD	-0.0002	-1.5367	0.1361	0.0419	-27.2282	996.6314	7505	0.0000*
HPCL	-0.0004	-1.1006	0.1372	0.0364	-14.8742	429.8456	1535	0.0000*
IOC	-0.0007	-0.7209	0.0768	0.0310	-13.0778	283.7710	6716	0.0000*
ONGC	-0.0004	-0.3921	0.1704	0.0237	-2.7903	45.2969	1722	0.0000*
IGL	0.0000	-1.6207	0.1034	0.0414	-30.1684	1178.39	1151	0.0000*
RELIANCE	0.0005	-0.6973	0.1367	0.0241	-12.1667	354.0582	1041	0.0000*

Note: * denotes significant @ 5% level

Source: Authors' estimation

Table 2 contains a summary of the statistical information for energy stocks. The random walk theory assumes that the returns of the series follow a standard normal distribution. However, the data analysis shows that the energy stocks' returns have skewness and kurtosis values that do not align with this assumption. This means that not all stock returns fit a normal distribution. Furthermore, the Jarque-Bera value for the energy stocks' returns is significantly higher than expected under a normal distribution, which confirms that the null hypothesis that all observed returns follow a normal distribution is rejected.

Table 3 presents the outcome of the runs test, which is a statistical approach used to determine the randomness of a data set. The results show that most of the stocks examined have a Z statistic value that falls below the critical value of ± 1.96, except for IGL. The null hypothesis, which indicates that the observed return series is random, cannot be rejected. Therefore, it can be inferred that the

Table 3: Run Test for Energy Stocks

Energy Stocks	*runs*	*n1*	*n2*	*Total Cases*	*Z Statistic*	*P-value*
ATGL	496	515	515	1030	-1.2470	0.2124
BPSL	996	990	990	1980	0.2248	0.8221
COALINDIA	989	990	990	1980	-0.0899	0.9284
GAIL	989	980	985	1965	0.2485	0.8037
GUJGASLTD	898	902	902	1804	-0.2355	0.8138
HPCL	1034	990	990	1980	1.9332	0.0532
IOC	1032	990	990	1980	1.8433	0.0653
ONGC	989	990	990	1980	-0.0899	0.9284
IGL	1039	990	990	1980	2.1580	0.0309*
RELIANCE	978	990	990	1980	-0.5845	0.5589

Note: * denotes significant @ 5 % level

Source: Authors' estimation

price changes of energy stocks are random, indicating that the fluctuation of energy stock prices is unpredictable, demonstrating that they exhibit efficient market behaviour. It suggests that any specific trend or sequence does not control the prices of energy stocks and instead is impacted by market forces.

Table 4: Automatic Portmantua Test for Energy Stocks

Energy Stocks	*Stat*	*P-value*
ATGL	5.9620	0.0146*
BPSL	0.0032	0.9551
COALINDIA	0.1455	0.7028
GAIL	1.2741	0.2590
GUJGASLTD	0.9056	0.3413
HPCL	0.0874	0.7675
IOC	0.2680	0.6047
ONGC	0.1738	0.6767
IGL	2.6613	0.1028
RELIANCE	0.1789	0.6723

Note: * denotes significant @ 5 % level

Source: Authors' Estimation

The outcomes in Table 4 illustrate the results of the automatic portmanteau test conducted on the top ten leading energy stocks. The results showed that most observed returns are not statistically serially correlated except ATGL. Hence, most of the observed returns exceed the significance level, which leads to failure to reject the null hypothesis (i.e., no autocorrelation). In most energy stocks, there is no autocorrelation between past and current daily returns, indicating that changes in energy stocks are random.

Table 5: Automatic Variance Ratio Test for Energy Stocks

Energy Stocks	*Stat*	*P-value*
ATGL	2.7486	0.0440*
BPSL	0.0393	0.8600
COALINDIA	0.2145	0.7320
GAIL	0.6839	0.2580
GUJGASLTD	0.0577	0.5700
HPCL	0.2621	0.6880
IOC	0.3486	0.5740
ONGC	-0.6297	0.9752
IGL	-0.8884	0.2040
RELIANCE	-0.1705	0.6840

Note: * denotes significant @ 5 % level
Source: Authors' Estimation

Table 5 illustrates the outcomes of the automatic variance ratio test. The statistical findings, as presented in the table, indicate that most energy stocks exhibit no autocorrelation, with the exception of ATGL. This leads to the rejection of the null hypothesis, implying that the energy stocks are not autocorrelated. Consequently, the returns of energy stocks are generally not autocorrelated by their lag, indicating that energy stocks operate randomly.

Table 6: GARCH (1,1) Model for Energy Stocks

Energy Stocks	α *(ARCH)*	β *(GARCH)*	$\alpha+\beta$
ATGL	0.2712	0.3519	0.6231
BPSL	0.0507	0.9003	0.9510
COALINDIA	0.0544	0.9232	0.9777
GAIL	0.0638	0.9305	0.9943
GUJGASLTD	0.2095	0.4591	0.6686
HPCL	0.2212	0.3892	0.6105
IOC	0.0730	0.9022	0.9753
ONGC	0.0423	0.4391	0.4814
IGL	0.1133	0.6067	0.7200
RELIANCE	0.1067	0.7627	0.8693

Source: Authors' Estimation

Table 6 displays the outcomes derived from the analysis conducted using the GARCH (1,1) model. This model was employed to assess the presence of volatility clustering within the observed time series. The ARCH (1) and GARCH (1) coefficients for BPSL, COALINDIA, GAIL, and IOC are close to one. This posits that these energy stocks exhibit volatility clustering, meaning that their volatility is not random and is influenced by preceding volatility trends. On the other side, the coefficients of ATGL, GUJGASLTD, HPCL, ONGC, IGL, and RELIANCE are not close to one another. Therefore, these energy stocks do not exhibit volatility clustering, and their volatility is more random. Inclusive results indicate that most of the energy stocks are generally non-volatile and not influenced by previous volatility trends.

7. Conclusion

The study examines the efficiency of energy stocks using daily price data from January 2015 to December 2022. Relatively statistical tests and models were employed, including the Jarque-Bera test, run test, automatic portmanteau, automatic variance ratio, and GARCH (1,1) model. The Jarque-Bera test highlights non-normal distribution of energy stock returns. The run test indicates random movement, suggesting no significant relationship between past and future returns. Both automatic portmanteau test and automatic variance ratio test demonstrate a lack of autocorrelation in return series, implying that no serial correlation in energy stocks. The GARCH (1,1) model posits that most of the energy stocks are non-volatile, states that previous volatility does not influence their prices. In conclusion, the study indicated that the fluctuations in the prices of energy stocks listed on the BSE in India are random, meaning that they have random walk characteristics. The study also suggested that in this weak form of market efficiency, investors cannot grab abnormal profits through arbitrage processes. Investors should primarily rely on passive investment strategies and refrain from wasting resources on technical analysis or trying to make profit from past price data, as such methods are unlikely to outperform the market consistently. On the other side, policymakers must maintain market integrity and protect investors by ensuring transparent information dissemination while remaining attentive to systemic risks, as even in a weak form efficient market, regulatory oversight remains essential to safeguard market functioning. The study is limited to ten energy sector companies. A more comprehensive approach involving a wider range of stock prices would have provided more valuable insights for investors. Future research can explore the various factors influencing energy stock prices to enhance predictability.

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