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Uncovering Price Memory in Indian Oil and Gas Stocks: A Rescaled Range Approach

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Abstract
This study examines the behaviour of the Indian capital market with a particular focus on the Oil and Gas sector, aiming to evaluate the validity of weak-form market efficiency. The analysis centers on the NIFTY Oil & Gas Index and its five leading constituent companies. Employing an empirical methodology, the study utilizes secondary time-series data and applies statistical techniques such as the Unit Root Test, Runs Test, and the Hurst Exponent through Rescaled Range Analysis. These methods are used to assess stationarity, randomness, and the presence of long-term memory in stock price movements. The findings suggest that stock prices do not conform entirely to the assumptions of weak-form efficiency, indicating the potential for historical price data to inform future market predictions. Moreover, the identification of long memory effects implies persistent trends within the price series. These outcomes offer practical implications for investors, financial analysts, and institutional decision-makers in formulating strategic investment and risk management approaches.

Keywords: Efficient Market Hypothesis, Hurst Exponent, Indian Stock Market, Nifty index, Oil and Gas sector.

1. Introduction
The financial markets of the 21st century have undergone substantial evolution, driven primarily by the rapid technological innovations of the past two decades. Global stock exchanges have witnessed a sharp increase in active participants, leading to a considerable rise in trading volumes. This heightened engagement has made stock markets a prominent area of interest for scholars, economists, and financial analysts. A wide range of academic studies has focused on analyzing efficiency and volatility of different stock markets. Understanding how information flows and spreads in these financial systems is crucial for safeguarding the socio-economic interests of investors. Time-series analysis in economic research has a long-standing history, tracing back to the 1950s. A landmark contribution was made by **Fama (1970),** who introduced the Efficient Market Hypothesis (EMH) concept, suggesting that in a truly efficient market, stock prices reflect all available information, making it impossible for traders to consistently earn above-average returns. This theory was later refined by **Fama (1991),** who grouped market efficiency into three distinct forms: weak form (based on historical return predictability), semi-strong form (related to publicly accessible information), and strong form (which includes private or insider data).

In contemporary research, a variety of quantitative and mathematical models are being applied to financial datasets to uncover hidden patterns and structural characteristics.

Financial time-series, including stock price movements and exchange rates, have often been found to display fractal and multifractal traits. In this paper, several analytical tools are employed, with particular attention given to the Hurst Exponent—an established metric utilized across various disciplines. In simple terms, the Hurst Exponent allows us to establish whether a given financial time series behaves randomly or exhibits persistent trend. It also assists in understanding whether certain financial events are temporally correlated, particularly in the context of long-range dependence. Serving as degree of autocorrelation, the Hurst Exponent is critical in assessing market behavior. This research specifically targets the efficiency analysis of the Indian Oil and Gas sector within the stock market, which is examined in detail in the subsequent section.

Oil and Gas Sector in India:

Oil continues to be one of the most essential resources worldwide, with its utilization spanning across continents and sectors. The oil and natural gas industry plays a foundational role in the worldwide energy supply chain, contributing heavily to economic development due to its position as a primary energy source. The production, refining, transportation, and marketing of oil and gas involve a highly complex, capital-intensive infrastructure supported by advanced technologies.

In India, the oil and gas sector is recognized as one of the eight core industries and serves as a vital contributor to overall economic performance. With growing domestic energy requirements, there is an increasing need to ensure sufficient and stable supply. Over the years, the country has made substantial progress in enhancing its crude oil refining capabilities. Despite these advancements, the Indian economy remains exposed to the volatility of international oil markets, which have shown a trend toward rising prices. For instance, during the fiscal year 2021, the growth rate in average value of crude oil dropped by approximately 25% compared to the previous year. India’s energy ecosystem includes traditional resources for instance coal, oil, and natural gas, as well as renewable alternatives like solar, hydro, and biomass. The country is currently the third-largest consumer of primary energy globally, trailing only China and the United States. This robust energy demand is evident from the estimated crude oil imports, which reached nearly 197 million metric tonnes in FY 2021. **Rafiq et al. (2009)** conducted a thorough analysis of existing literature, identifying a strong association between crude oil prices and manufacturing activities. The study also emphasizes the asymmetric impact of oil price fluctuations on major macroeconomic indicators, such as output levels, inflation, employment, capital investment, interest rates, trade balances, and currency exchange rates. In particular, negative oil price shocks tend to have more pronounced economic consequences than positive ones. **Jones and Kaul (1996),** through their evaluation of quarterly data from the United States, Canada, Japan, and the UK, found that actual variations in oil prices negatively affect real stock returns. Their findings indicate that markets in the U.S. and Canada adequately factor in oil price shocks when projecting real cash flows. Likewise, **Kilian and Park (2009)** observed that demand-side uncertainties concerning future oil supply contribute to a decline in stock market returns.

The study has been categorized into seven main sections. Section I presents the theoretical framework and rationale for the research. Section II provides a comprehensive literature review. Section III talks about the research gaps in the present literature, leading to Section IV, which outlines the study’s objectives, formulated based on identified research gaps. Section V elaborates on the methodological approach and tools employed for empirical analysis. Section

VI discusses the key findings and results. Finally, Section VII offers final remarks and recommendations for future study directions.

2. Literature Review

Global Evidence on Weak-Form Efficiency

A substantial body of international research has been dedicated to exploring weak-form efficiency across global stock exchanges. For instance, **Chan et al. (1997)** conducted an extensive study analyzing stock prices from 18 different countries using unit root and cointegration methodologies across the period 1961–1992. Their findings highlighted that several global markets failed to exhibit stationarity in stock returns, and only limited cointegration relationships existed, indicating inefficiencies in the long-run behavior of these markets.

In a comparative analysis of European equity markets, **Worthington and Higgs (2003)** examined both mature and developing markets to determine whether they followed a random walk pattern. Their approach combined various statistical tools such as autocorrelation, run tests, the ADF and KPSS unit root tests, and the multiple variance ratio test. They concluded that Hungary reflected characteristics of weak-form efficiency, while several developed economies—namely Germany, Ireland, Portugal, and the United Kingdom—showed evidence of strict random walk behavior. **Podobnik et al. (2009)** evaluated the long-range dependency of stock returns in selected Central and Eastern European markets. Their study reported that Estonia and Lithuania exhibited significant long-term persistence, pointing to moderate-to-low efficiency, whereas Poland and Slovakia demonstrated weaker long-term dependencies, which suggested relatively higher efficiency. **Alexeev and Tapon (2011)** assessed the Canadian stock market's efficiency over a 30-year span using a bootstrap approach grounded in statistical modeling. Their analysis, covering more than a thousand stocks listed on the Toronto Stock Exchange, generally supported weak-form efficiency, although disparities were observed across different sectors, particularly those influenced by volatility (variance) and peakedness (kurtosis) of returns. **Collins et al. (2011)** explored weak-form efficiency in 32 African equity markets by applying variance-ratio tests that relied on rank and sign metrics. Their results indicated that continent-wide indices showed more regularity in return distribution, while individual national indices displayed significant deviations, implying less efficient market behavior at the country level.

Sectoral Studies: Oil and Energy Markets

Given the critical role of the oil and gas industry in the global economy, several researchers have directed their efforts toward examining efficiency within energy markets. **Ramirez et al. (2002)** utilized multifractal Hurst exponent techniques to study crude oil prices across different time intervals (daily, weekly, monthly, and annual) from 1981 to 2002. Their analysis revealed that short-term data (daily and weekly) aligned with random walk behavior, but deviations were found at broader time scales, indicating that market efficiency varied over time. **Lv and Pan (2009)** assessed the weak-form efficiency of major crude oil benchmarks such as WTI (USA), Brent (Europe), China, and OPEC using the generalized spectral method and daily data from 2001 to 2008. Their findings indicated that while WTI and Brent conformed to weak-form efficiency, the Chinese and OPEC markets did not. Differences in regulatory frameworks, market structures, and trading mechanisms were identified as key explanatory factors. **Zhuang et al. (2015)** investigated the relationship between crude oil price dynamics and the efficiency of Chinese sectoral stock indices using multifractal tools such as MF-DFA and MF-DCC. Their results confirmed the presence of varying degrees of multifractality across different sectors, reflecting heterogeneous efficiency levels. **Qiao et al. (2019)** employed quantile regression analysis to evaluate how oil-related equities respond to different oil price shock types. Their findings suggested that during periods of adverse oil price shocks, oil-related stocks often became overvalued, raising questions about the market's informational efficiency. **Mensi et al. (2021)** used asymmetric multifractal detrended fluctuation analysis (A-MF-DFA) to examine stock markets in leading oil-producing (e.g., USA, Russia, Saudi Arabia, Canada) and oil-consuming (e.g., India, China, Japan, Brazil) countries. The study showed that the stock markets of oil-producing nations demonstrated lower efficiency than those of consumers. Additionally, asymmetry and uncertainty in oil prices were found to be strong predictors of return dynamics, particularly during the COVID-19 pandemic and associated oil price collapse.

Empirical Evidence from the Indian Stock Market

Within the Indian economic landscape, numerous studies have been carried out to assess the applicability of weak-form Efficient Market Hypothesis (EMH), often through use of time-series models that identify long-term dependencies in financial data. Among these, the Hurst exponent and rescaled range (R/S) analysis have become widely adopted methods for examining whether stock prices exhibit random walk behavior or display elements of predictability.

In one such study, **Kumar and Manchanda (2009)** analyzed a four-year dataset from two major Indian indices, i.e. BSE100 and NIFTY 50, applying the R/S technique to compute the Hurst exponent. Their findings pointed towards mean-reverting tendencies in the price movements, suggesting that the markets may not operate under weak-form efficiency. This outcome implies that historical price information could influence future price behavior, contradicting the notion of randomness.

Shaikh et al. (2014) took the analysis to the firm level by investigating the stock price behavior of ACC, HINDALCO, INFOSYS, and SBI. Using R/S analysis, they observed Hurst values above 0.5 for all four companies, implying that the returns were not entirely random. Among the firms studied, ACC exhibited the highest degree of volatility and long memory, making its price trends more persistent over different sub-periods. Their results imply that stock prices in such cases could be somewhat forecastable, especially when using historical data.

Further insights were offered by **Jamwal and Malhotra (2016),** who worked with a 20-year daily dataset from the NIFTY 50 index, one of India's most tracked equity benchmarks. Their application of the Hurst exponent revealed consistently persistent patterns in returns, as the values were found to be greater than 0.5. This directly contests the principle of weak-form efficiency, as it indicates that the time series retains a level of memory that could allow for profitable predictions based on past data.

In another comprehensive analysis, **Bal et al. (2021)** explored stock price behaviors for both active and suspended companies listed on the Bombay Stock Exchange over a period stretching from January 1998 to February 2019. Employing the Hurst exponent, they found that both categories of stocks displayed stationarity and self-similarity, suggesting that their return series preserved structural patterns over time. Such persistence is often associated with long memory processes, signaling that markets may not be completely efficient in the weak form.

Collectively, these empirical findings suggest that both index-level and individual stock returns in the Indian market may deviate from the assumptions of weak-form efficiency. The consistent presence of long memory and autocorrelation in return series underscores the utility of the Hurst exponent in detecting market inefficiencies. These insights are particularly valuable for financial analysts, institutional investors, and regulators, as they point to potential inefficiencies that may be exploited or addressed through improved market practices and policy interventions.

3. Research Gap

While extensive research exists on market efficiency in emerging economies like India, there remains a significant lack of focus on sector-specific evaluations. Much of the existing literature centers around broad indices such as the NIFTY 50 or Sensex, leaving a noticeable gap in studies dedicated to particular sectors like Oil and Gas. Given the sector's pivotal role in the economy and its exposure to global crude oil fluctuations, policy reforms, and geopolitical tensions, a focused investigation is both relevant and necessary. However, empirical examinations of weak-form market efficiency within this specific sector are still relatively limited.

Additionally, earlier research predominantly employs isolated statistical tools like the Unit Root Test or Runs Test without combining methodologies for a more robust and comprehensive analysis. More sophisticated techniques, such as Hurst Exponent derived from Rescaled Range (R/S) Analysis, which help identify long-term dependencies in price behavior, are seldom applied in sectoral studies. This lack of methodological integration weakens the analytical depth and reliability of previous findings.

Another notable shortcoming in the literature is the general absence of intra-sector comparisons. Researchers often treat sector indices as uniform entities, overlooking the possibility that individual firms within the same index may demonstrate different levels of market efficiency or memory traits. Moreover, few studies examine how efficiency may evolve across different time periods or under changing market conditions. Finally, although some works do reveal inefficiencies, they frequently fall short of translating these insights into actionable investment strategies or portfolio management techniques.

To bridge these gaps, the current study adopts a multi-dimensional analytical approach to test weak-form efficiency within the Indian Oil and Gas sector. It investigates both index-wide and firm-specific data to uncover sector dynamics and potential opportunities for strategic investment decisions based on historical pricing behavior.

4. Objective

Insights drawn from existing empirical studies on market behavior, especially those focusing on sectoral characteristics and the statistical dynamics of stock return time series have informed the formulation of the present study's objectives:

i. To observe the statistical nature of return distributions, specifically focusing on the normality and stationarity of the Oil and Gas sector index along with selected key companies within the sector.

ii. To analyze the existence of long-range dependence in the return series of the Oil and Gas index and five major sectoral firms by evaluating their long-memory characteristics.

The hypotheses formulated for the above research goals are:

H_{01}: The return series of the Nifty Oil & Gas Index is non-stationary during the sample period.

H_{02}: The return series of the top five Oil and gas companies is non-stationary during the sample period.

H_{03}: The daily return series of the Nifty Oil & Gas index is efficient.

H_{04}: The daily returns series of the top five Oil and gas companies are efficient.

5. Research Methodology

Sample Selection:

For the purpose of conducting a targeted and analytically robust investigation, the National Stock Exchange (NSE) has been selected as the source for data collection. The NSE is widely recognized as one of India's leading stock exchanges and provides comprehensive market data, making it an appropriate platform for this study.

To align with the stated research objectives, this study uses the Nifty Oil & Gas Index as the key benchmark to represent sector-level performance. This index includes top-performing companies within the Oil and Gas sector that are actively traded on the NSE and serves as a proxy for understanding broader industry trends and market behavior. In addition to evaluating the index itself, we have chosen five companies with the highest weightage in the index at the time of sampling to incorporate firm-level perspectives into our analysis. These firms are among the most prominent in the industry, with respect to market capitalization and trading volume, ensuring the reliability and representativeness of the data used.

By combining data from both the index and selected companies, this research is able to perform a comprehensive assessment of market efficiency and long-memory patterns at multiple levels—sectoral and individual. Moreover, since all sampled entities are listed on the same stock exchange and operate under a unified regulatory framework, consistency in data handling and comparability of results is maintained throughout the study.

The list of selected companies included in our sample is provided below:

Table 1: Sample companies and their respective weightage in the index

Source: NSE Website

Companies	Weightage
Reliance Industries Ltd	33.36
Oil & Natural Gas Corporation Ltd.	17.77
Bharat Petroleum Corporation Ltd	8.16
Indian Oil Corporation Ltd.	8.06
GAIL (India) Ltd.	7.88

This research adopts a quantitative and empirical methodology, utilizing secondary data as its primary input for analysis. The financial data necessary for the study was sourced from two reliable platforms: the official portal of the National Stock Exchange (NSE) and the Yahoo Finance website. These platforms offer up-to-date and comprehensive financial datasets, making them suitable for rigorous time-series examination.

The study centers on daily logarithmic yields of the Nifty Oil & Gas Index and five selected firms that are part of this index. Logarithmic returns, rather than raw price values, are used to perform the analysis, as they help eliminate non-stationary trends and standardize variance across the dataset. This transformation allows for more effective statistical modeling and is widely accepted in financial time-series research **(Kumar & Manchanda, 2009).**

The formula used to compute the logarithmic return is given as:

$$r \cong \log(1+R_t) = \log \frac{P_t}{P_{t-1}} \quad \textbf{(Equation 1)}$$

The dataset spans from 1st January 2017 to 31st December 2022. This range ensures that the study captures recent market trends while maintaining a sufficient sample size for robust statistical inference. All tools used in the study including the Hurst exponent have been applied uniformly to the same data to maintain consistency across the analytical framework.

i. Unit Root Test

The unit root test is essential in determining whether a time series is stationary i.e., if its statistical characteristics such as mean and variance stays unchanged over time. A non-stationary series may suggest that its values are dependent on time, which violates key assumptions of many econometric models. This study applies two prominent unit root tests:

- Augmented Dickey-Fuller (ADF) Test
- Phillips-Perron (PP) Test

Both tests are conducted on level form of data to verify the random walk hypothesis, a cornerstone of weak-form market efficiency. A stationary return series implies a denial of the random walk model, thereby indicating potential inefficiencies in the market (Hassan et al., 2007).

ii. Run Test

The Run Test is a non-parametric tool utilised to evaluate randomness of sequences within a time series. Unlike parametric methods, it does not rely on underlying distributional assumptions, making it particularly effective in identifying patterns or autocorrelations in financial data. This test assesses whether a series of positive and negative price changes occur randomly or exhibit some form of clustering or predictability.

The method involves counting the number of "runs" uninterrupted sequences of similar outcomes (either above or below the mean). A large deviation between the authentic number of runs and the anticipated number under randomness indicates a departure from random walk behavior.

The expected number of runs (ER) is calculated using the following formula:

$$ER = \frac{U(U-1) - \sum_{i=1}^{3} s_i^2}{U} \quad \textbf{(Equation 2)}$$

Where, U= Total runs; S_i= Number of changes in Signs

iii. Hurst Exponent and Rescaled Range (R/S) Analysis

The Hurst exponent serves as a powerful statistical measure to spot the presence of long-range dependence in time-series data. This concept originated in hydrology through the work of **Harold Edwin Hurst** in the early 1950s, where it was initially used to study the flow of the Nile River. Over time, the method gained popularity in the field of finance for its ability to evaluate the memory characteristics of asset returns.

One of the most frequently used techniques for estimating the Hurst exponent is the rescaled range (R/S) analysis. This method distinguishes between series that are random and those that exhibit autocorrelated behavior over extended periods. A major benefit of this technique is that it is robust to non-normality, making it particularly suitable for financial time-series data, which often deviate from normal distributions **(Peters, 1991).**

In this study, the R/S method is employed by segmenting the 2048 daily return values into nine equally sized sub-samples, allowing for a more detailed exploration of memory effects across different time intervals.

The Hurst exponent is estimated using the following equation:

$H=\log(R/S)/\log(n/2)$ **(Equation 3)**

Where:

H = Hurst exponent; R/S = Rescaled range; n = Number of observations

The explanation of the Hurst exponent is as follows:

H=0.5: The series follows a random walk (no memory).

H>0.5: Indicates persistence or trend-following behavior.

H<0.5: Suggests anti-persistence or mean-reverting characteristics.

6. Findings and Analysis

Table 2: Summary Statistics

Source: Based on the Author’s calculation.

Particulars	Nifty Oil & Gas index	Reliance	ONGC	BPCL	IOC	GAIL
Mean	0.000453	0.000792	-0.00034	0.000186	7.85E-05	5.69E-05
Median	0.001008	0.000737	0.000328	0.00011	0	0
Maximum	0.086763	0.137307	0.169822	0.142725	0.079198	0.15209
Minimum	-0.12444	-0.14103	-0.18053	-0.22171	-0.17268	-0.13017
Std. Dev.	0.013675	0.018288	0.022252	0.022433	0.019772	0.020844
Skewness	-1.01101	0.060757	-0.56628	-0.84781	-0.5798	-0.09559
Kurtosis	13.93056	10.94351	13.48342	13.28309	8.188191	7.58598

Jarque-Bera	10544.27	5385.741	9487.776	9268.655	2411.69	1797.782
Probability	0	0	0	0	0	0
Sum	0.927928	1.621851	-0.70478	0.381695	0.160726	0.116462
Sum Sq. Dev.	0.382775	0.684658	1.01359	1.030138	0.800212	0.88936
Observations	2048	2048	2048	2048	2048	2048

Table 2 outlines the summary statistics for the return series of NIFTY Oil and Gas Index, along with data pertaining to five leading companies in the sector: Reliance Industries Ltd., Oil and Natural Gas Corporation (ONGC), Indian Oil Corporation (IOC), Bharat Petroleum Corporation Ltd. (BPCL), and GAIL (India) Ltd. These statistical measures offer important insights into the overall behavior and characteristics of the return distributions over the analyzed period.

The mean return, serving as an indicator of average profitability, is positive across all sampled entities with the exception of ONGC, which reflects a negative return. This outcome suggests that most companies, along with the index itself, generated positive returns during the selected timeframe, while ONGC underperformed in comparison.
In terms of volatility, which is measured by standard deviation, the index exhibited a relatively low value of 0.013675, signifying stable price movements. On the other hand, individual companies displayed greater variability in returns, with BPCL showing the highest standard deviation, indicating elevated risk and unpredictability in its return behavior relative to others in the sample.

Analyzing skewness, which reflects the symmetry of return distributions, reveals that all companies except Reliance reported negative skewness values, implying a left-skewed distribution. This characteristic suggests a greater tendency for small gains and a lesser likelihood of experiencing large losses. In contrast, Reliance Industries demonstrated a positive skew, indicating a slight tilt toward higher returns.

The kurtosis measure, which identifies the peakiness and tail behavior of the distributions, provides further insights. A value of 3 typically represents a normal distribution. However, in this analysis, all stocks and the index recorded kurtosis values above 3, categorizing them as leptokurtic. Such distributions are more peaked with fatter tails, implying an increased chance of extreme outcomes compared to a normal distribution.

To assess normality of the return series, Jarque-Bera (J-B) test was applied. This test estimates whether sample data exhibits skewness and kurtosis consistent with a normal distribution. In this study, all return series yielded p-values close to zero, leading to the rejection of the null hypothesis of normality. Thus, the return series for both the index and individual stocks do not follow a normal distribution.

To explore further, the study employed two additional tests to assess randomness and stationarity in the data: the Runs Test and the Unit Root Test. The Runs Test, a non-parametric technique, was utilized to examine the randomness in the sequence of returns, thereby identifying any underlying patterns. Meanwhile, the Augmented Dickey-Fuller (ADF) Test was conducted to verify whether the return series is stationary which is a prerequisite for robust time-series analysis. Collectively, these tests enhance the understanding of return dynamics and statistical properties within the Indian Oil and Gas sector.

Figure 1: Nifty Oil and Gas Index Returns Bar Chart
Source: Based on the Author's calculation.

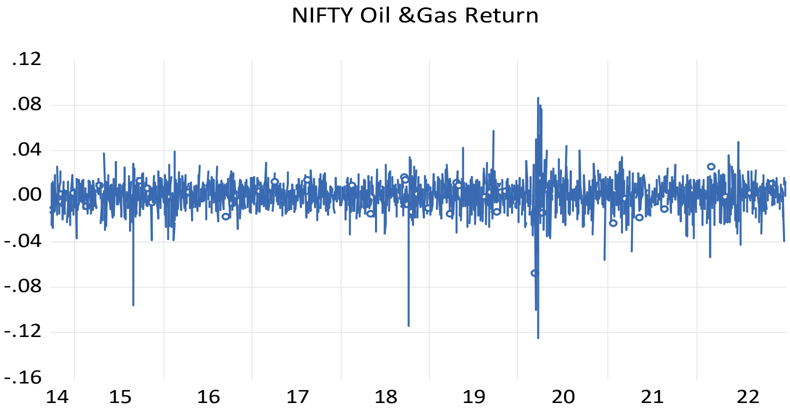

Figure 2: Top Five Oil and Gas Companies Stock Returns Bar Chart
Source: Based on the Author's calculation

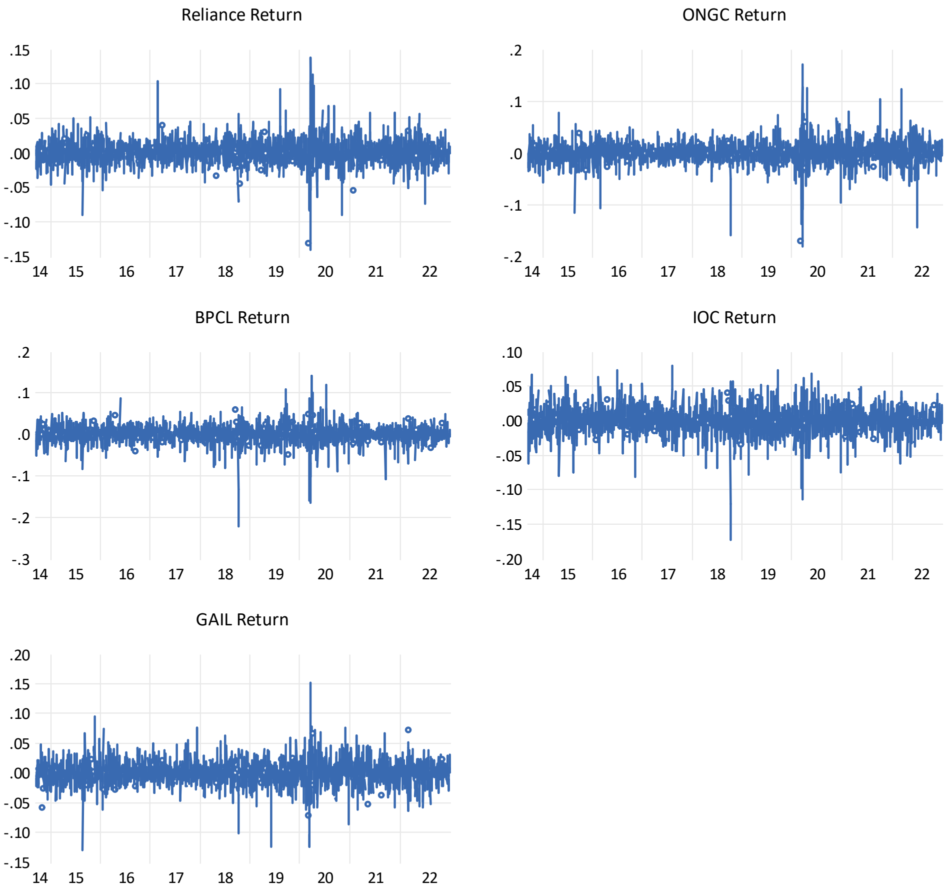

Table 3: Run Test
Source: Based on the Author’s calculation.

Particulars	Nifty Oil & Gas Index	Reliance Ltd.	ONGC	BPCL	IOC	GAIL
Test Value	0.0453%	0.0792%	-0.034%	0.0186%	0.0078%	0.0057%
Cases < Test Value	974	1027	995	1030	1035	1026
Cases >= Test Value	1074	1021	1053	1018	1013	1022
Total Cases	2048	2048	2048	2048	2048	2048
Number of Runs	973	1001	1042	1027	1047	1035
Z	-2.196	-1.061	.788	.090	.978	.442
Asymp. Sig. (2-tailed)	.028	.289	.430	.928	.328	.658

The Runs Test serves as an essential statistical method in evaluating weak-form market efficiency, especially when the data do not meet the assumptions required for parametric testing. As a non-parametric approach, it is particularly well-suited for analyzing return series that do not conform to normal distribution patterns.

The test is grounded in the null hypothesis that return sequences are random, indicating that the market is efficient and historical price changes hold no predictive value for future movements. Should the test outcomes lead to the rejection of the null hypothesis, it would imply non-randomness or serial correlation in returns, thereby challenging the principles of weak-form efficiency as proposed by the Efficient Market Hypothesis (EMH).

To interpret the test outcomes, the computed z-value is assessed against a critical threshold. A z-value beyond ±1.96 suggests statistical significance at the 5% level, justifying rejection of the null hypothesis and indicating a lack of randomness in return series **(Sharma & Kennedy, 1977).**

The findings, shown in Table 3, include the Runs Test results for both the NIFTY Oil and Gas Index and its top five constituent firms: Reliance Industries Ltd., Oil and Natural Gas Corporation (ONGC), Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), and GAIL (India) Ltd. The test was executed using each return series' mean as a benchmark to differentiate between upward and downward runs.

The analysis reveals that the NIFTY Oil and Gas Index alone displays a statistically significant z-value, exceeding the critical threshold, thus leading to the rejection of the randomness assumption. This suggests that the index's return pattern may contain structured trends or dependencies, indicating a potential deviation from market efficiency. In contrast, the return series of all five individual companies fall within the accepted range of z-values, implying no significant departure from randomness. This supports the notion that these individual stocks conform to a random walk model, consistent with weak-form efficient behavior.

The observed divergence between the index and its components might be attributed to aggregation effects, market-wide influences, or composite investor behavior that renders the index more susceptible to structured patterns. These findings carry practical value for market participants, as they imply that while individual stock returns may be unpredictable, the sectoral index may exhibit identifiable trends that could be explored further in technical analysis or trading strategy development.

Table 4: **Unit Root Test (ADF Test)**
Source: Based on the Author's calculation.

S.No.	Particulars	T-Statistics	Probability
1.	Nifty Oil & Gas index	-45.692	0.0000
2.	Reliance Industries Ltd	-45.824	0.0000
3.	Oil & Natural Gas Corporation Ltd.	-20.472	0.0000
4.	Bharat Petroleum Corporation Ltd	-44.869	0.0000
5.	Indian Oil Corporation Ltd.	-45.566	0.0000
6.	GAIL (India) Ltd.	-44.304	0.0000

Table 5: Unit Root Test (PP Test)
Source: Based on the Author's calculation.

S.No.	Particulars	Adj. T-Statistics	Probability
1.	Nifty Oil & Gas index	-45.703	0.0000
2.	Reliance Industries Ltd	-45.824	0.0000
3.	Oil & Natural Gas Corporation Ltd.	-48.001	0.0000
4.	Bharat Petroleum Corporation Ltd	-44.867	0.0000
5.	Indian Oil Corporation Ltd.	-45.592	0.0000

6.	GAIL (India) Ltd.	-44.361	0.0000

Tables 4 and 5 present findings from two commonly utilized stationarity tests: the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. These methods are standard in time series econometrics and are employed to assess whether a given data series is stationary or exhibits unit root characteristics. The core assumption, or null hypothesis (H_0), in both tests is that the series under examination contains a unit root, indicating non-stationarity which is a state where key statistical attributes such as the mean, variance, and autocorrelation changes with time rather than remaining constant.

In financial time series analysis, the existence of a unit root is often linked to a random walk process, which aligns with the notion of weak-form market efficiency, the idea that past prices hold no predictive power for future price movements. On the contrary, if a series is found to be stationary, it implies a consistent statistical structure over time, often associated with mean-reverting behavior and potential predictability, thus challenging the weak-form efficiency assumption.

To evaluate the nature of the return series, the computed T-statistics and adjusted T-values from the ADF and PP tests were compared against critical values at standard significance levels (1%, 5%, and 10%). Across all tested assets, namely the NIFTY Oil & Gas Index and its five leading constituent companies (Reliance Industries, ONGC, IOC, BPCL, and GAIL)—the test statistics were found to be greater (in absolute value) than the respective critical thresholds, leading to the rejection of the null hypothesis for each series.

This outcome indicates that none of the examined return series follow a unit root process, confirming their stationary nature. The implications are significant: first, stationarity suggests that the return behavior of these assets is not purely random and may follow predictable patterns that can be modeled; second, this contradicts the expectations of weak-form efficiency, where price changes should theoretically be random and unpredictable.

As a result of this analysis, we reject both hypotheses H_{01} and H_{02}, which proposed that the return series of the NIFTY Oil & Gas Index and the selected company stocks follow a random walk. Instead, the findings support the existence of mean-reverting tendencies, indicating that price movements in this segment of the market may contain elements of structure or memory, thereby offering potential opportunities for forecasting and strategic decision-making.

Table 6: Hurst Exponent- Nifty Oil & Gas Index
Source: Based on the Author's calculation.

Nifty Oil & Gas Index	Observations(N)								
	1024	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**
R/S Average	47.75	28.48	18.11	13.98	9.91	6.25	4.01	2.55	1.45
Log(N)	6.93	6.24	5.55	4.85	4.16	3.47	2.77	2.08	1.39
Log(R/S)	3.87	3.35	2.90	2.64	2.29	1.83	1.39	0.94	0.37
Standard Error	0.017								
Hurst Exponent	0.602								

T-statistic	5.818
P-value	0.001

Table 7: Hurst Exponent- Reliance Industries Ltd.
Source: Based on the Author's calculation.

Reliance Industries Ltd	**Observations(N)**								
	1024	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**
R/S Average	42.26	24.28	19.29	13.06	9.34	6.08	3.94	2.48	1.44
Log(N)	6.94	6.24	5.55	4.85	4.16	3.47	2.77	2.08	1.39
Log(R/S)	3.74	3.19	2.96	2.57	2.23	1.80	1.37	0.91	0.36
Standard Error	0.018								
Hurst Exponent	0.585								
T-statistic	4.618								
P-value	0.002								

Table 8: Hurst Exponent- Oil & Natural Gas Corporation Ltd.
Source: Based on the Author's calculation.

Oil & Natural Gas Corporation Ltd.	**Observations(N)**								
	1024	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**
R/S Average	44.60	25.43	18.03	13.24	8.63	5.73	3.90	2.46	1.44
Log(N)	6.93	6.23	5.55	4.85	4.16	3.47	2.77	2.08	1.39
Log(R/S)	3.80	3.24	2.89	2.59	2.16	1.75	1.36	0.90	0.36
Standard Error	0.014								
Hurst Exponent	0.593								
T-statistic	6.652								
P-value	0.000								

Table 9: Hurst Exponent- Bharat Petroleum Corporation Ltd.
Source: Based on the Author's calculation.

Bharat Petroleum Corporation Ltd	**Observations(N)**								
	1024	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**
R/S Average	34.81	25.84	17.46	12.18	9.32	6.05	4.01	2.49	1.44
Log(N)	6.93	6.24	5.55	4.85	4.16	3.47	2.77	2.08	1.39
Log(R/S)	3.55	3.25	2.86	2.50	2.23	1.80	1.39	0.91	0.36
Standard Error	0.019								
Hurst Exponent	0.563								
T-statistic	3.279								
P-value	0.013								

Table 10: Hurst Exponent- Indian Oil Corporation Ltd.
Source: Based on the Author's calculation.

Indian Oil Corporation Ltd.	Observations(N)								
	1024	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**
R/S Average	42.30	27.13	18.56	13.32	8.76	5.73	3.89	2.44	1.42
Log(N)	6.93	6.24	5.56	4.85	4.15	3.47	2.77	2.08	1.39
Log(R/S)	3.74	3.30	2.92	2.59	2.17	1.75	1.36	0.89	0.35
Standard Error	0.012								
Hurst Exponent	0.596								
T-statistic	7.830								
P-value	0.000								

Table 11: Hurst Exponent- GAIL (India) Ltd.
Source: Based on the Author's calculation.

GAIL (India) Ltd.	Observations(N)								
	1024	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**
R/S Average	41.85	25.09	16.90	12.72	8.49	5.83	4.00	2.46	1.43
Log(N)	6.93	6.24	5.55	4.85	4.16	3.47	2.77	2.08	1.39
Log(R/S)	3.73	3.22	2.83	2.54	2.14	1.76	1.39	0.90	0.36
Standard Error	0.015								
Hurst Exponent	0.580								
T-statistic	5.253								
P-value	0.001								

An analysis of the long-term dynamics of stock return series in India's Oil and Gas sector was conducted using the Rescaled Range (R/S) Analysis, with the outcomes detailed in Tables 6 through 11. This method serves as a valuable tool in understanding the memory and persistence properties of financial time series, helping to assess whether stock prices evolve randomly or follow identifiable trends that can be used for predictive modelling.

To ensure a more granular evaluation, the dataset was divided into nine separate sub-periods, each reflecting a portion of the complete time series. For each segment, the Hurst Exponent (H) was computed. This exponent is instrumental in detecting long-range dependencies in time series data. In theory, a Hurst value of 0.5 reflects a completely random process, indicating that price changes are independent over time, in line with the assumptions of the Efficient Market Hypothesis (EMH).

When the value of H is less than 0.5, it reflects anti-persistent or mean-reverting behavior, where positive returns are often followed by negative ones and vice versa. Such behavior suggests a tendency for prices to reverse direction over time. Conversely, a Hurst exponent greater than 0.5 denotes persistent behavior, where inclinations are more likely to continue in the same direction. In this case, an upward (or downward) movement is followed by a similar subsequent movement, indicating the potential presence of trend-following patterns and predictability in the data.

The findings show that for all the sample return series—comprising the NIFTY Oil & Gas Index and its five leading constituent stocks, the Hurst values consistently exceed 0.5. This observation strongly suggests that the return distributions are not random, but instead exhibit persistent characteristics over time. As a result, none of the series conform to a pure random walk. Additionally, it is noted that the closer the Hurst exponent is to 0.5, the less defined the trend becomes, whereas higher values indicate a stronger and more stable trend continuity.

These outcomes have meaningful implications for investors and financial analysts. The presence of long-memory and trend persistence in the return series implies that past price information may carry predictive power, casting doubt on the applicability of weak-form market efficiency in this sector. Consequently, data-driven trading strategies based on historical trends could potentially be effective in generating abnormal returns.

Given this statistical evidence, we can reject the third and fourth null hypotheses (H_{03} and H_{04}), which posited that the returns of both the index and its constituent companies follow a random walk. The results confirm that these securities do not align with weak-form EMH assumptions and instead demonstrate structured, predictable patterns, making them suitable for forecasting and strategic financial planning.

7. Conclusion and Scope for Future Studies

Theoretically, financial markets are assumed to operate under the principle of efficiency, where stock prices instantaneously and accurately reflect all relevant information about the issuing companies. This ensures that assets are fairly valued and investors cannot consistently earn excess returns. However, many researchers have pointed out that in practical scenarios, especially within emerging or developing economies, markets frequently fall short of this ideal. Such inefficiencies may introduce opportunities for return predictability and allow for the realization of abnormal gains through informed trading strategies. The results of this study are steady with that viewpoint. An examination of the NIFTY Oil & Gas Index and the returns of its five major constituent firms over an eight-year period reveals that the price series does not follow a random walk, thereby raising questions about the applicability of the weak-form Efficient Market Hypothesis (EMH) in this sector.

Results obtained through the Unit Root Tests confirm the stationarity of the return series, indicating a departure from randomness and suggesting the potential for forecasting based on past values. The result is consistent with **Collin et al. (2021)**. Moreover, the long-term trends assessed using the Hurst Exponent demonstrate that both the index and individual stock returns exhibit persistence, meaning existing trends are likely to continue, aligning with the previous studies done by **Jamwal and Malhotra (2016)** and **Bal et al (2021).** One common interpretation of the Hurst exponent is that a lower value signals greater market volatility, while a higher value implies increased stability. According to the data, Bharat Petroleum Corporation Ltd. displays the highest volatility among the sample, whereas the NIFTY Oil & Gas Index, with the highest Hurst value, emerges as the most stable.

Although the Runs Test suggests that individual stock returns follow a random pattern, the consistent evidence from the Unit Root and Hurst Exponent tests presents a more robust counterargument. Given the alignment of results from these two methods, greater emphasis is placed on their conclusions, reinforcing the view that the Oil and Gas sector does not demonstrate weak-form efficiency.

While the scope of this study is confined to a single sector, the implications are far-reaching. Future studies can broaden this research by conducting cross-sectoral analyses to explore how efficiency varies across different parts of the Indian economy. Furthermore, alternative financial theories such as the Adaptive Market Hypothesis (AMH) and the Fractal Market Hypothesis (FMH) warrant deeper empirical testing within the Indian financial framework. Exploring these models could offer novel insights into investor behavior and the evolution of market dynamics in response to economic and structural changes over time.

8. References

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