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AN EXPERIMENT ON BEHAVIOURAL ASPECTS OF THE INVESTORS WITH NON-LINEAR DATASET

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Abstract

The stock market offers an average rate of return, higher than that of fixed-income securities only because of its maximum risk propensity. However, investors can beat the market return if the market is efficient either in a weak-form sense or semi-strong-form sense. However, Andrew Lo (2004) propounded the Adaptive Market Hypothesis which we have experimented on NSE data mainly with the help of the BDS Test. Our data source is the official website of the National Stock Exchange which we have collected from January 2010 to March 2023. We have attempted Descriptive Statistics and other econometric tests.

Our test results show that the distribution of the daily returns is not normal. From BDS Test we came to know that there is non-linear dependency in the return series and the natural selection. Our experiment proves that a behavioural aspect plays a major role in the decision-making process rather than any other analysis.

Keywords: Adaptive Market Hypothesis, Efficient Market Hypothesis, BDS Test, Behavioral Finance, Variance Ratio Test.

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Introduction

Although the efficiency of the stock market has been extensively researched in the literature, scholars are still unable to agree on the efficiency of markets. The recent bursts of studies establish that markets are not efficient in the strong form sense. Moreover, the overwhelming bulk of research studies on EMH over a predefined sample period ignores the possibility that efficiency levels vary over time and that even a large sample size could not represent the entire period. Financial researchers have continued to pay attention to Fama (1970). According to the Efficient Market Hypothesis (EMH), a market's existing price promptly and accurately reflects new information. As a result, no investor can regularly make returns bigger than the market since prices respond quickly and sensibly to new information. This implies that returns on the stock market must be independent and volatile.

Andrew Lo's Adaptive Market Hypothesis (AMH) is a novel theory that attempts to consider both aspects (2004). Lo (2004) suggests an updated version of the EMH that is based on evolutionary concepts to interpret the magnitude of market efficiency that changes over time. Lo observes in his studies that the biological viewpoint offers insightful conclusions and advocates for an evolutionary substitute for market efficiency. According to Lo's new paradigm, behavioural finance and EMH can coexist in an intellectually coherent way. According to this hypothesis, market efficiency can change over time and coexist with market inefficiencies.

According to Lo (2005), the fundamental presumptions of AMH are as follows:

1. People behave in their self-interest.
2. People make mistakes.
3. People grow and change.
4. Innovation and adaptation are fueled by competition.
5. The market ecosystem is shaped by natural selection.
6. Market dynamics are determined by evolution.

Therefore, there are several real-world financial ramifications to these concepts. First, the stock market's environment and the investors' characteristics inside it affect the risk premium over

time. The second implication that runs counter to the EMH is that there are occasional opportunities for arbitrage in the market. Financial markets that are actively liquid from an evolutionary perspective indicate that there must be chances for profit. Nevertheless, they do vanish as a result of exploitation. However, since some species go extinct, new possibilities arise constantly and the AMH suggests that complex market dynamics, including trends, panics, bubble bursts and crashes, remain a constant in the natural market ecosystem rather than moving towards more efficiency. The conclusion is that the effectiveness of investing methods varies depending on the state of the market. The AMH suggests, in contrast to the EMH, that these methods might experience a temporary downturn before making a profit again when the atmosphere is more favourable for these kinds of transactions. Though theoretically, the EMH does not rule out such cycles, in fact, none of its empirical implementations to date have taken these dynamics into account, presuming instead a world in which markets march to efficiency.
The last conclusion of the AMH is that traits like growth and value may occasionally behave as "risk factors," meaning that companies with these traits may produce greater expected returns when those traits are favourable. Lo (2005) contends that it is not rational to believe that the market is forced towards a perfect level of efficiency and that convergence to equilibrium is neither certain nor probable to occur. Rather, the AMH depends on more intricate market phenomena, including financial market cycles, trends, crashes, and bubbles.

Review of Literature:

Agrawal Gaurav & Srivastav Aniruddh Kumar (2010) analysed the relationship between nifty returns and Indian rupee-US dollar exchange rates. They have used the Unit root test, Correlation Test, and Granger causality in their study. They concluded that nifty returns and exchange rates were non-normally distributed, and the correlation between nifty returns and exchange rates was negative.

Aydemir Oguzhan & Demirhan Erdal (2009) have investigated the causal relationship between stock prices and exchange rates in Turkey. They have used Augmented Dickey-Fuller (ADF) (1979), Phillips-Perron (PP) (1988) and KPSS (1992). Their study has exhibited a causal relationship between exchange rates and all stock market indices in a reciprocal manner. While the negative causality exists between the national 100, services, financials, and industrial index and the exchange rate, a positive relationship exists between technology indices and the exchange rate.

Nieh Chien-Chung & Lee Cheng-Few (2001) tried to determine the dynamic relationship between stock prices and exchange rates for G-7 countries. They have used Unit roots, Co-integration, and Vector Error Correction models. They have concluded that there is no -

- Significant long-run relationship between stock prices and exchange rates in the G-7 countries.
- A significant short-run relationship has only been found for one day in certain G-7 countries.

Imarhiagbe Samuel (2010) has analysed the impact of oil prices on stock prices of selected major oil-producing as the additional determinant. He used VAR, VECM, Granger causality, and variance decompositions. He has concluded that impulse response tests in all countries confirm that oil prices and exchange rates influence stock prices.

Berk Istemi &Aydogan Berna(2012) investigated the effect of crude oil price fluctuations on the Turkish stock market returns. He has used the Vector Auto regression (VAR) model. His study has found that crude oil price shocks have been rationally evaluated in the Turkish stock market.

Jones Charles M. and KaulGautam (1996) have tried to test whether the reaction of international stock markets to oil shocks can be justified by current and future changes in actual cash flows and/or changes in expected returns. They have used Regression Analysis. Their study has concluded with two significant findings:

i) The US and Canadian stock markets are rational: the reaction of stock prices to oil shocks can be wholly accounted for by their impact on current and expected future natural cash flows alone.

ii) Unable to explain the effects of oil price movements on stock returns using changes in future cash flows and/or financial variables often used to proxy for changes in expected returns in the case of Japan and the UK.

Objective

To examine how far the adaptive market hypothesis explains the independent behaviour of NIFTY returns in the Indian stock market.

Data

To examine our objective, we have collected daily futures price data for NIFTY 50 from the official website of the National Stock Exchange (NSE) from January 2010 to March 2023.

Methods

To quantify the objectives, we have converted the price series into a series of returns and applied descriptive tests to see the nature of the series then applied three linear tests the run test, variance Ratio test and unit root test and one nonlinear test like the BDS test on the futures return series for our study. The details of linear and nonlinear tests are hereunder.

Where ρ_j represents the autocorrelation of rt in order j. The Variance Ratio (VR) measures whether the VR is equal to 1 for any k. However, VR values above 1 indicate positive serial correlations and values below 1 indicate negative serial correlations or mean reversions.

Unit root test

The unit root test is the stationarity test that is employed in time series analysis.

$$y_t = \rho y_{t-1} + u_t \qquad (1)$$

Where, $-1 \leq \rho < 1$ and u_t = white noise error term.

We encounter a non-stationarity issue if $\rho = 1$, and come to the conclusion that y_t has a unit root. This suggests that y_t is a random walk series, which means that random shocks, or non-stationary stochastic processes, have an ongoing effect on the series. To determine whether the estimated ρ is statistically comparable to 1, y_t regress on its lagged value y_{t-1}. y_t is non-stationary if this is the case. The model is revised as follows:

$$\Delta y_t = \delta y_{t-1} + u_t \qquad (2)$$

Where, $(\rho - 1) = \delta$ and Δ = 1st difference.

We are now checking the hypothesis that $\delta = 0$. If $\delta = 0$ and $\rho = 1$ are true then y_t is non-stationary and has a unit root.

Now, if $\delta = 0$, then equation (2) becomes $\Delta y_t = (y_t - y_{t-1}) = u_t$ (3) First differences of a time series are stationary because u_t is a stationary white noise error term. Here, we used the Augmented Dickey-Fuller test to check the data series' stationarity. To perform an enhanced Dickey-Fuller test, estimate the following regression. The models are:

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta y_{t-i} + u_t \text{.........................}(1)$$

$$\Delta y_t = \alpha + \delta y_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta y_{t-i} + u_t \text{..................}(2)$$

$$\Delta y_t = \alpha + \beta_t + \delta y_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta y_{t-i} + u_t \text{..........}(3)$$

Where, u_t is a term for white noise error and $\Delta y_{t-1} = (y_{t-1} - y_{t-2}), \Delta y_{t-2} = (y_{t-2} - y_{t-3}), etc.$

The return data may not allow linear testing to detect nonlinear features. To see the nonlinear nature of the series we have applied the BDS test.

BDS test

Brock, et al. introduced the BDS test in 1987, demonstrating nonlinear dependence in stock return series. The null hypothesis assumes that the stock return data generation process is (i.i.d.). The alternative theory states that the model's specifications are incorrect (Brock et al., 1996). The statistics from the BDS are computed as:

$$C_m(n,\varepsilon)=\frac{2}{(n-m)(n-m+1)}\sum_{S=1}^{n-m}\sum_{t=S+1}^{n-m+1} \text{Im}\,(Xs\,,Xt\,,\varepsilon)$$

Where, (ϵ) is the metric bound, which measures the difference between observation pairs that are taken into consideration when computing the correlation integral, n stands for the sample size and m for the embedding dimension. The test statistics are provided by the following equation:

$$W_m(\varepsilon)=\sqrt{\frac{n}{\nabla m}}(C_m\,(n,\varepsilon)-C_1(n,\varepsilon)^m)$$

The BDS considers the random variable $\sqrt{n}(C_m\,(n,\varepsilon)-C_1(n,\varepsilon)^m)$ which, as n rises, converges to the normal distribution for an independent and identically distributed (iid) process. It is capable of withstanding a wide range of potential competing specifications, including nonlinear dependence. The BDS statistic is typically estimated at various levels of m and ε. The choice of ε and m is of utmost significance. Given that, selecting values for ε will capture a relatively tiny number of points. Therefore, is a percentage of the standard deviation of the data in agreement with preceding research? The BDS test is run at multiple embedding dimensions (m) like 2, 3, 4, 5, and 6 at varied distances (ε) like 0.5s, 1.0s, 1.5s, and 2.0s, where 's' stands for the return's standard deviations. The predictability of the BDS test modifications is then determined by computing the mean of the p-values resulting from the values of m.

Hypothesis

For the Run test:

H0: A series of returns is independent.

H1: **A** series of returns is dependent.

For the Variance ratio test:

H0: The series of returns deviates from random walk behaviour.

H1: The series of returns follows a random walk.

For the ADF test:

H0: Return series are nonstationary.

H1: Return series are stationary.

For the BDS test:

H0: Return series are independent and identically distributed.

H1: Presence of nonlinear dependence in the return series.

Results and Discussion

Descriptive statistics of NIFTY futures returns

The descriptive test results are displayed in Exhibit 1.1 below, with a mean return of 0.036487. A standard deviation of 1.087608 denotes a significant degree of variability since the data points are dispersed over a large range. "Lack of symmetry" is skewness. In this case, negative skewness means that the left side of the distribution curve has a longer tail. The kurtosis value indicates the 'flatness or peakedness' of the frequency distribution curve. In this case, the kurtosis value in the return series suggests a leptokurtic distribution. The statistical significance of the Jarque-Bera test results indicates that the NIFTY's daily return distributions are not normal.

Exhibit 1.1: Descriptive Test result of NIFTY 50 returns

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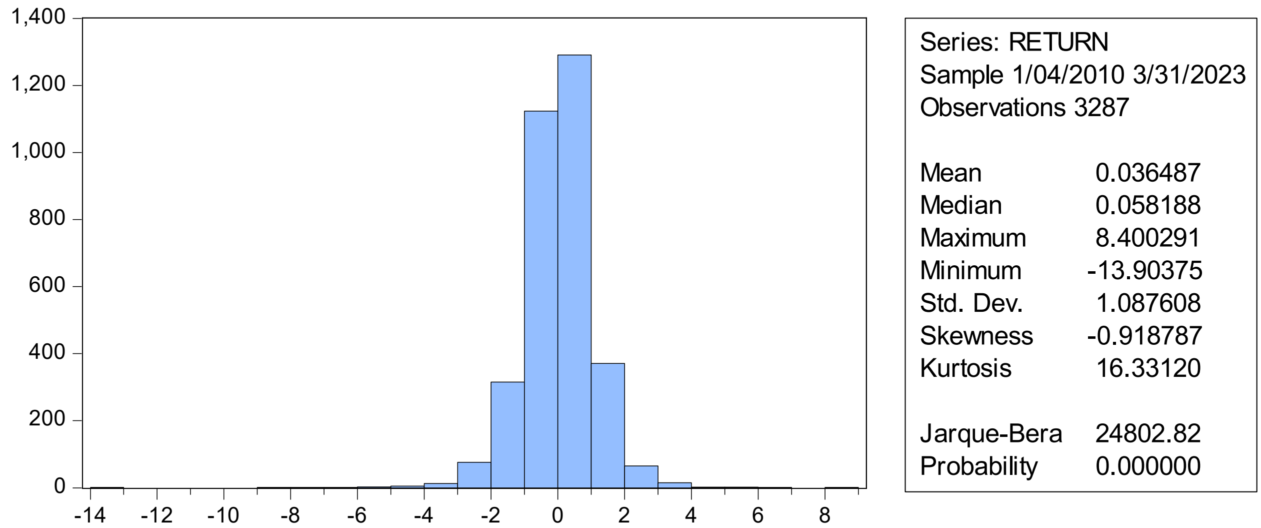

Source: Computed based on data collected from the NSE website

Interpretation of the Run test result

The Z-statistic value in Exhibit 1.2 is -57.101, indicating a positive serial correlation in the return series. However, the fact that the value is significant at 5% suggests that the return series does not exhibit a random walk. Consequently, we concluded that market competition fosters innovation and adaptation for NIFTY returns.

Exhibit 1.2: Run Test result of NIFTY 50 returns

	NIFTY 50
Mean	9533.410143000000000
Cases < Mean	1887
Cases >= Mean	1404
Total Cases	3288
Number of Runs	8
Z	-57.101
p-value	0.000

Source: Computed based on data collected from the NSE website

Interpretation of the Variance ratio test result

Exhibit 1.3 displays the results of the variance ratio test. For periods 2, 4, and 16, a variance ratio less than 1 indicates a negative correlation or mean reverting relationship between the series of returns; however, for period 8, a positive correlation is shown, and the probability values are statistically insignificant for all the periods. Additionally noteworthy is the Chow-Denning (maximum Z statistics) test's p-value. Consequently, we reject the null hypothesis, which states that the series does not follow a random walk, and accept the alternative hypothesis, which states that the return series are independent and vary over time. Thus, we have established that the NIFTY return series obeys the random walk and verifies that people become aware of the state of the market and adjust as necessary.

Exhibit 1.3: Variance ratio Test result of NIFTY 50 returns

	Sample period				
	2	**4**	**8**	**16**	**Joint test statistic**
Variance Ratio	**0.501663**	**0.254866**	**0.127841**	**0.066356**	
Z-Statistic	**-8.236818**	**-7.508542**	**-6.331668**	**-4.793910**	**8.236818**
Probability	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

Source: Computed based on data collected from the NSE website

Interpretation of the Unit root test result

Exhibit 1.4 presents the test results. It reveals that the price level for pure random walks, random walks with drift, and random walks with drift and trend is nonstationary. This suggests that the series is random at the level, but it becomes stationary when the first difference (i.e., the return series) is taken into account. As a result, we have determined that the series under investigation is generally integrated at order one and nonstationary at the level. As a result, the NIFTY futures price return may be predicted with predictability, and market participants act in their own best interests.

Exhibit 1.4: ADF Test result of NIFTY 50 returns

At Level						
Variable	**Test Statistic**	**Critical Value (1%) level**	**Critical Value (5%) level**	**Critical Value (10%) level**	**Prob.**	**Result**
Pure Random Walk						
NIFTY 50	**1.885436**	**-2.565666**	**-1.940920**	**-1.616635**	**0.9862**	**Non-stationary**
Random Walk with drift						
NIFTY 50	**0.118448**	**-3.432151**	**-2.862221**	**-2.567177**	**0.9671**	**Non-stationary**
Random Walk with drift and trend						
NIFTY 50	**-2.316694**	**-3.960833**	**-3.411173**	**-3.127416**	**0.4241**	**Non-stationary**
At First difference						
Pure Random Walk						
NIFTY 50 Return	**-56.03808**	**-2.565666**	**-1.940920**	**-1.616635**	**0.0001**	**Stationary**
Random Walk with drift						
NIFTY 50 Return	**-56.09541**	**-3.432152**	**-2.862222**	**-2.567177**	**0.0001**	**Stationary**
Random Walk with drift and trend						
NIFTY 50 Return	**-56.10413**	**-3.960833**	**-3.411174**	**-3.127416**	**0.0000**	**Stationary**

Source: Computed based on data collected from the NSE website

Interpretation of the BDS test result

The results of the BDS test are shown in Exhibit 1.5. After pre-whitening linear dependences using an AR (5) model, we observe that the test statistic value is significant at 1% for all dimensions, suggesting the presence of nonlinear dependence in the return series. We have therefore inferred that the existence of nonlinear dependency in the series of returns, which implies that market ecology is impacted by natural selection, is indicated by the rejection of the null hypothesis of independent and identically distributed (i.i.d.).

Exhibit 1.5: BDS Test result of NIFTY 50 returns [AR (5)]

Distance(ϵ) → Embedding Dimension (m) ↓	$\epsilon = 0.5s$	$\epsilon = 1s$	$\epsilon = 1.5s$	$\epsilon = 2s$
2	0.004925(0.0000)	0.010773(0.0000)	0.011300(0.0000)	0.008716(0.0000)
3	0.005403(0.0000)	0.021117(0.0000)	0.027036(0.0000)	0.022163(0.0000)
4	0.003732(0.0000)	0.025143(0.0000)	0.040095(0.0000)	0.036304(0.0000)
5	0.002174(0.0000)	0.025380(0.0000)	0.050689(0.0000)	0.050252(0.0000)
6	0.001153(0.0000)	0.022803(0.0000)	0.056702(0.0000)	0.062004(0.0000)

The value of the first row of each cell is a BDS test statistic followed by the corresponding p-value in parentheses."ϵ" Equal to various multiples (0.5, 1, 1.5 and 2) of standard deviation(s) of the data.

Source: Computed based on data collected from the NSE website

Conclusion

When all available information, including insider information, is taken into account or reflected in the asset's price, the market is considered to be efficient. In 2004, Professor Andrew W. Lo made the initial argument that investors are irrational in most cases and non-financial variables affect how they behave. People are always trying to find out more about different situations that could happen to them and trying to adjust as needed. The main objective of this chapter is to evaluate the suitability of the adaptive market hypothesis in explaining the behaviour of the NIFTY returns on the Indian stock market. Descriptive statistics show that the market's standard deviation result indicates that there is still a lot of price volatility. It was found that our shape in the series was leptokurtic. The distributions of the daily returns are not normal, as demonstrated by the results of the Jarque-Bera test. To determine the extent to which the adaptive market hypothesis applies to the Indian stock market, we have conducted three linear tests and one nonlinear test. The outcome of the run test points to the presence of a positive serial correlation, indicating that market rivalry fosters innovation and adaptation. The outcome of the variance ratio test demonstrates how the independence of the return series varies over time, providing evidence in favour of the theory that people are always aware of their surroundings and adjust as necessary. The findings of the ADF test demonstrate that NIFTY futures price returns can be predicted, indicating that market participants act in their own best interests and that prices do not change arbitrarily. Again, an auto-regressive model was employed to eliminate any linear relationship seen in the selected series' returns, indicating a significant degree of stock market dependency. To examine the nonlinear dependence of the returns, we employed the BDS test as a nonlinear test. The results supported the alternative hypothesis, which maintains that there is nonlinear dependency in the returns series and that natural selection has altered the market's ecology, and rejected the null hypothesis, which held that the data were independently and identically distributed (i.i.d.). The stock market is seen to fluctuate between being dependent and independent as a result, suggesting that the adaptive market hypothesis is the most suitable explanation for the NIFTY returns' behaviour.

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