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Evidence Of Structural Breaks in Stock Markets During Pandemic Disruptions-An Empirical Analysis

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Abstract
COVID-19 has demonstrated to be an important event for the globe, making it vital to comprehend its impact on global stock markets. This paper adds to the research on COVID-19 by offering a thorough examination of how COVID-19 has affected the performance of the Indian stock market and in particular critically examines whether there was a structural break that altered the long-standing statistical properties of the Indian Stock Market. The study has been done by applying a widely applied structural break test namely Zivot Andrews Sequential breakpoint test and ARIMA modelling was employed to verify the change in the return behavior of Indian Stock Markets.

Keywords: Structural Breaks, COVID-19, stock returns, ARIMA, unit root testing

INTRODUCTION

The unusual COVID19 pandemic's quick spread has put the globe in peril and suddenly transformed the global landscape. The SARSCoV2 virus, which caused the COVID19 epidemic, first appeared in Wuhan, Hubei Province, China, in December 2019, and quickly spread around the world. This pandemic is not only a global health problem, but it is also a major global economic crisis. As several countries implement sev The financial market has reacted with extreme fluctuation and has been negatively impacted. The economic upheaval caused by COVID19 has had a significant impact on the financial industry, including both the stock and bond markets. The price of oil has dropped significantly as a result of the epidemic, but the price of gold has increased significantly. This epidemic is referred to by Firzli (2020) [i]as "the greater financial crisis." Businesses are heavily leveraged in many nations, weak enterprises are further destabilised, and corporate debt is quite high. In reaction to the pandemic, global financial market risk has grown significantly (Zhang et al., 2020).[ii] Investors have already suffered enough losses as a result of fear and uncertainty. ere quarantine rules to combat the unknown disease, their economic operations are abruptly halted.

A structural break in a time series data is an unanticipated change in the parameters of regression models over time that can lead to substantial forecasting mistakes and model unreliability in general. A structural break in a time series data series may occur as a result of various structural, regulatory, or other macroeconomic changes, and neglecting a structural break may result in a loss of power of a unit root test. Similarly, disregarding a break may result in a loss of test power and render the forecasting as a futile exercise.

However, Nelson and Plosser (1982) [iii]pointed to the fact that the shocks have an indefinite impact on the series, and several other studies have highlighted a major drawback of conventional unit root tests, which completely ignore the structural changes and subsequent structural breaks that have occurred in the economy, resulting in biased results. A slew of novel unit root tests were subsequently devised, each of which takes into consideration any structural breaks that may have occurred in the series and then verifies the existence of a unit root at that time. Mean reversion is a time series attribute in which prices or returns frequently revert to their historical average or mean over time. A stationary stochastic process tends to come back to its mean value and fluctuations about it with similar amplitudes. Furthermore, due of its finite constant variance, a stationary time series will not deviate too far from its mean.

The mean-reverting propensity of stock returns suggests the prospect of forecasting future returns and, as a result, abnormal gains. This contradicts the efficient market hypothesis (EMH), which argues that current prices completely and quickly reflect information, making future returns uncertain. Mean reversion is relevant in financial markets because its presence allows for the forecast of future returns and the creation of mean reversion strategies for anomalous gains, both of which are evident breaches of EMH. Furthermore, speculators may mislead investors about such patterns, inciting them to engage in irrational trading practises.

According to study of previous research, validating the presence of the unit root in the series is critical to evaluating mean reversion because if the unit root is present in the series, the future values are time variant and will never return to their mean value. The majority of previous research employed traditional unit root tests such as the Dickey fuller test, Augmented Dickey fuller test, and PP test, which presume that shocks have a transitory influence on the series and usually fade with time. The purpose of this paper is to verify whether there was any structural break and subsequent mean reversion in Indian Stock Markets caused by Covid-19 outbreak

REVIEW OF LITERATURE

The impact of COVID-19 on global financial markets reveals significant volatility and increased systemic risks. Studies show that the pandemic has led to dramatic market movements, with risks closely tied to the severity of outbreaks in individual countries(Zhang et al., 2021). The analysis of the Hang Seng Index and the Shanghai Stock Exchange Composite Index reveals that the COVID-19 outbreak has adversely affected investor sentiment and market stability. This reinforces existing theories that public health crises lead to heightened uncertainty and risk aversion among investors, resulting in negative stock market outcomes.(Al-Awadhi et al., 2020) Stock market volatility highlights the effectiveness of econometric models like GARCH in predicting market fluctuations, particularly during crisis periods. The study confirms that crises such as COVID-19 increase volatility across global stock indices, while also demonstrating mean-reversion processes. (Chaudhary et al., 2020). Stock markets exhibit a strong negative response to rising COVID-19 confirmed cases, particularly during the early days of the outbreak and between 40 to 60 days after initial confirmations. The decline in stock returns is more pronounced for confirmed cases than for fatalities, suggesting that investor sentiment is primarily influenced by the perceived threat of the virus.(Ashraf, 2020). The COVID-19 pandemic led to unprecedented volatility due to government restrictions and voluntary social distancing in a service-oriented economy. Explanations such as rapid information diffusion or supply chain disruptions are less supported.(Baker et al., 2020). COVID-19 significantly increased volatility in the Indian stock market, with negative returns and higher risks during the pandemic compared to the pre-COVID period. Government interventions, such as RBI's liquidity measures and policy rate cuts, helped stabilize markets. The pharmaceutical sector emerged as a promising area for investment during the crisis.(Bora & Basistha, 2021). The COVID-19 pandemic had an immediate and significant negative impact on global stock markets, particularly in Asia, where abnormal returns were more pronounced. Event studies highlight how investor pessimism and fear contributed to market declines, with COVID-19 confirmed cases serving as a major factor influencing stock indices. The findings emphasize the need for policymakers and investors to consider both financial and psychological effects during such crises.(Liu et al., 2020)

RESEARCH METHODOLOGY

The main aim of this research article is to substantiate and quantify the persistence of security prices and specifically assess the influence of COVID-19, if any, in India.

To fulfill the current research objective, the three significant and inclusive variables chosen were – the Nifty Fifty Index of NSE as the representative of the Indian Stock market, the S & P 500 as a proxy of US stock markets, and the USD Reference Rate as announced by Reserve Bank of India as a representative of Foreign exchange market. The daily closing prices of these indices were taken into account for all variables from June 3rd, 2013, to May 31st, 2023.

STATISTICAL TOOL APPLIED

As part of the empirical research, the statistical approaches utilized in achieving the objectives are **Zivot-Andrews Sequential Break Test Result** and **ARIMA Modelling.**

OBJECTIVES OF THE STUDY

The fundamental objective of the paper is to verify the impact of COVID-19 on the performance of the stock market in India and in particular to analyze whether there was any structural break in the stock series of Indian stock markets. For this purpose, the following objectives were framed

1. To verify whether the COVID-19 pandemic induced structural breaks in Indian stock markets
2. To identify and quantify the structural break window caused by the COVID-19 pandemic in the Indian stock market
3. To analyze the pre and post-Covid characteristics of the return behavior of components of Indian stock markets
4. To develop a suitable statistical model to explain the changes in the return behavior of the components of the Indian stock market

UNIT ROOT TEST

Broadly speaking a data series is said to be stationary if its mean and variance are constant (non-changing) over time and the value of covariance between two time periods depends only on the distance or lag between the two time periods and not on the actual time at which the covariance is computed [Gujarati (2003)]. In order to test for the existence of unit roots, and to determine the degree of differencing necessary to induce stationarity, we have applied the *Augmented Dickey –Fuller test* (ADF Test).Given an observed time series $Y_1, Y_2, \ldots, Y_N$ Dickey and Fuller consider three differential-form autoregressive equations to detect the presence of a unit root:

$$(1) \qquad \Delta Y_t = \gamma Y_{t-1} + \sum_{j=1}^{p} \left(\delta_j \Delta Y_{t-j} \right) + e_t$$

$$(2) \qquad \Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{j=1}^{p} \left(\delta_j \Delta Y_{t-j} \right) + e_t$$

$$(3) \qquad \Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{j=1}^{p} \left(\delta_j \Delta Y_{t-j} \right) + e_t$$

where:

- t is the time index,
- α is an intercept constant called a drift,
- β is the coefficient on a time trend,
- γ (gamma) is the coefficient presenting process root, i.e. the focus of testing,
- p is the lag order of the first-differences autoregressive process,
- e_t is an independent identically distributed error/ residual term.

The difference between the three equations concerns the presence of the deterministic elements α (a drift term) and βt (a linear time trend). The focus of testing is whether the coefficient γ equals to zero, what means that the original $Y_1, Y_2, \ldots, Y_N$ process has a unit root; hence, the null hypothesis of $\gamma = 0$ or $\rho=1$ (random walk process) is tested against the alternative hypothesis $\gamma < 0$ which signifies the given series is stationary.

ZIVOT AND ANDREWS SEQUENTIAL BREAK TEST

When a series has a broken trend, Zivot and Andrews proposed a test that successively looks for a break point and then tests for the presence of a unit root. The test automatically determines the break date using T test statistics that provide the most negative or minimal value at a certain break point, and then investigates the test's null hypothesis, which is the presence of unit root.

Furthermore, this test adheres to the methods suggested by Perron (1989), who offered three models. Model A allows for a mean break, Model B investigates a slope break, and Model C validates a mean and slope break. As a result, Zivot and Andrews created their own three models: Model A, which allows for a break in the intercept, which is the mean value, Model B, which allows for a break in the trend only, and Model C, which allows for a single break in both the intercept and the trend. Model C is used in research since it confirms both the intercept and the trend.

Zivot-Andrews Model-C is defined as follows,[1]

$$\Delta IR_t = \mu + \theta IRDU_t(\lambda) + \beta t + IRDT_t(\lambda) + \propto p_{t-1} + \sum_{j=1}^{k} \Phi \Delta p_{t-j} + \varepsilon_t \quad (10.1)$$

Where ΔIR_t is the first difference of the index or currency series $IRDU_t$ is a dummy variable that capture the significance break in the intercept and λ represents the location of the break date and $IRTD_t$, another variable that represents the shift in trend that occurring at a time T_B $\mu, \lambda, \propto, \Phi$ are constants. The dummy variables IRDU and IRDT are defined as

$$IRDU_t(\lambda) = \{1 \text{ if } t > T_B, 0 \text{ otherwise}\} \quad (10.2)$$

$$IRDT_t(\lambda) = \{1 \text{ if } t > T_B, 0 \text{ otherwise}\} \quad (10.3)$$

Zivot Andrews verify the null hypothesis that the trend of the return series contains a unit root along with drift that ignores structural break along with the alternative hypothesis that the return variable is a trend stationary process including one break in both intercept and trend.

The test further examines the presence of unit root at a structural break with an alternative of stationarity at same unknown point. To identify the break point and to calculate the test statistics for unit root, an ordinary least square regression is employed with the break T_B , where T_B ranges from 1 to T2. For each value of T_B the number of extra regressor's k is chosen following a sequential downward T test on all the lags (Zivot & Andrews 1992). The test selects the break point where the T statistics testing the null hypothesis is reporting the most negative that is the minimum value

ARIMA MODELLING OF CHOSEN VARIABLES

The next focus of the study is to analyze the auto regressive nature of the chosen currency series by applying ARIMA models The acronym ARIMA stands for **Auto-Regressive Integrated Moving Average**. Lags of the stationarized series in the forecasting equation are called "autoregressive" terms, lags of the forecast errors are called "moving average" terms, and a time series which needs to be differenced to be made stationary is said to be an "integrated" version of a stationary series. Random-walk and random-trend models, autoregressive models, and exponential smoothing models are all special cases of ARIMA models.

A nonseasonal ARIMA model is classified as an "ARIMA(p,d,q)" model, where:

- **p** is the number of autoregressive terms,
- **d** is the number of nonseasonal differences needed for stationarity, and
- **q** is the number of lagged forecast errors in the prediction equation.

The forecasting equation is constructed as follows. First, let y denote the d^{th} difference of Y, which means:

If d=0: $y_t = Y_t$

If d=1: $y_t = Y_t - Y_{t-1}$

[1] Zivot, E., and Andrews, D.W.K. (1992) Further evidence on the great crash, the oil price shock, and the unit root hypothesis, Journal of Business and Economic Statistics, Vol.10, No.3, pp.251-70

If d=2: $y_t = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2}$

In terms of y, the general forecasting equation is:

$\hat{y}_t = \mu + \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} - \theta_1 e_{t-1} - \ldots - \theta_q e_{t-q}$

To identify the appropriate ARIMA model for Y, i…e AR(1), AR(2), …, and MA(1), MA(2), … etc..we begin by determining the order of differencing (d) needing to stationarize the series by examining ACF and PACF functions of each currency series with the help of correlogram .

After identifying the probable models the Akaike Information Criteria (AIC)and Schwartz Bayesian Criteria (SBC/BIC) are used to select that ARIMA(p,d,q) model for which the AIC and BIC are minimum

RESULTS

PRESENTATION AND INTERPRETATION OF EMPIRICAL RESULTS

As discussed in the above section, as a first step Unit Root Test was done on the three variables and the results are as follows

Table 1.1: Augmented Dickey Fuller Test Results of chosen Variables

S N	Variables	At Level		At First Differences	
		τ statistic	***p-value***	***τ statistic***	***p-value***
1	Nifty Fifty Index	-0.124970	0.9449	-48.75058	0.0001
2	S & P 500 Index	-0.816735	0.8138	-15.74272	0.0000
3	U S Reference Rate	-0.886466	0.7930	-12.02304	0.0000

As it can be seen from Table 1.1, the Null Hypothesis for all the variables at their level cannot be rejected as the test statistic value of-0.124970 for Nifty Fifty Index, -0.816735 for S & P 500 Index and -0.886466 for US Reference Rate are lesser than the ADF test critical value -2.872545 at 5% level of significance along with insignificant p-values. Therefore we can conclude that Nifty Fifty Index, S & P 500 Index and U S Reference Rates are Non-Stationary in their level form.

Further, these variables were subjected to First Differences as shown in Table and the Null Hypothesis for both the variables is rejected as ADF test statistic value -48.75058 for Nifty Fifty Index, -15.74272 for S & P 500 Index and -12.02304 for US Reference Rate are greater than the ADF test critical value -2.872545 at 5% level of significance. Hence we conclude that the variables are stationary in their First Differences

ZIVOT-ANDREWS SEQUENTIAL BREAK TEST RESULT FOR CHOSEN VARIABLES

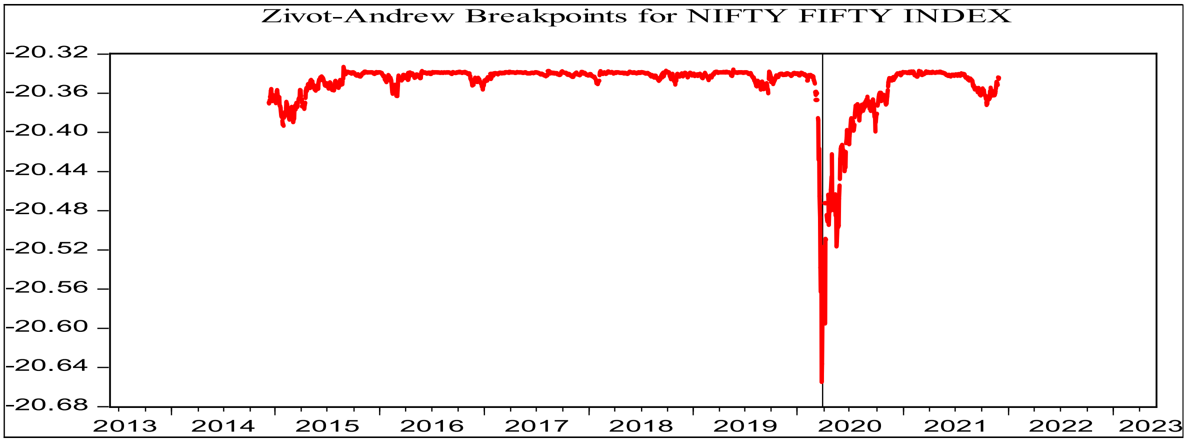
The authors of the study examined the presence of mean reversion using Zivot Andrews sequential break test, which examines mean reversion by verifying possible structural break and then examining whether the series has unit root against the alternative of trend stationarity, which if proved, shall be strong evidence of mean reversion.

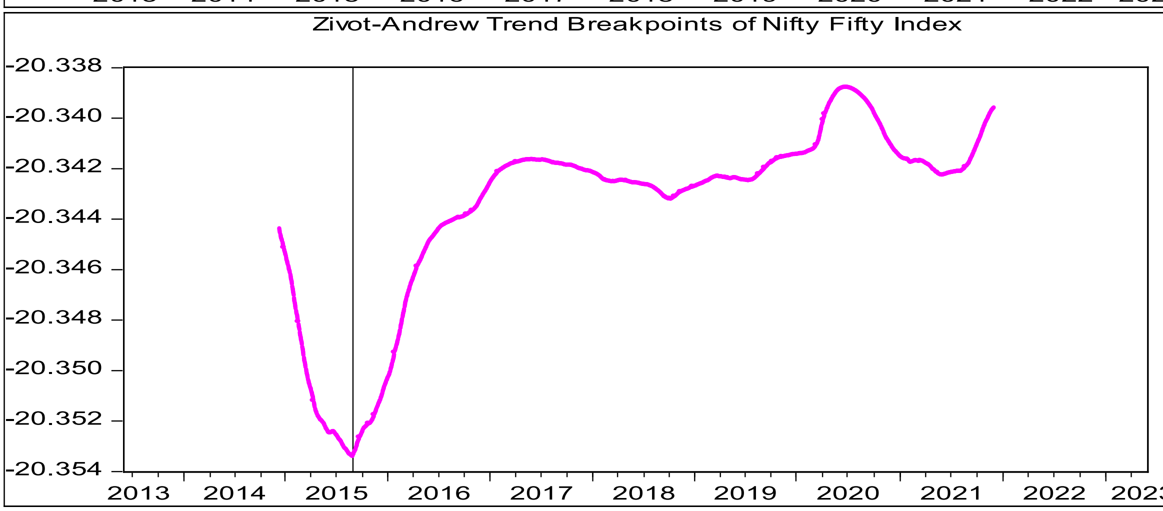
Table 1.2 : Zivot-Andrews Sequential Break Test Result for Nifty Fifty Index

Varaible	***Zivot-Andrews t-Statistic***	***p-value***	***Chosen break point***
Nifty Fifty Index	**-20.65466**	**0.000802****	**24-03-2020**
1% critical value:	**-5.34**		
5% critical value:	**-4.93**		
10% critical value:	**-4.58**		

Note: The test adhered to Model "C," which allows for a break in both intercept and trend and compares the null hypothesis that the series has a unit root at a structural change against the alternative of stationarity at the structural break at an unknown moment. Column two displays the trend break date as determined by the test, followed by the lag order, and finally the test statistic result. At a 5% level of significance, the critical value of the test is -5.08. Asterisks indicate rejection of the null hypothesis at the 5% level of significance.

Table1.2 presents the Zivot Andrews structural break test results of NSE NIFTY50 Index. It can be observed that the Index strongly **reject the null hypothesis** of presence of unit root at the structural break point as the Zivot-Andrews test statistic values of **-20.65466** are found to be greater than the test critical value of -5.08 and highly significant at 5% level of significance.





The test results are in par with the graphs provided by the test and the corresponding identification of structural break point by sequential test procedure. The analysis reveals that the structural break date pointed out by the sequential test is associated with multiple crashes during march 2020 that are associated with the fall of Indian stock market. If we look at the **Bombay Stock Exchange there is a drop in the Sensex index to 13.2% on March 23, 2020**. It was the highest single they fall after the news of the Harshad Mehta Scam, April 28, 1991 Similarly, Nifty has also declined to almost 29% during this period.

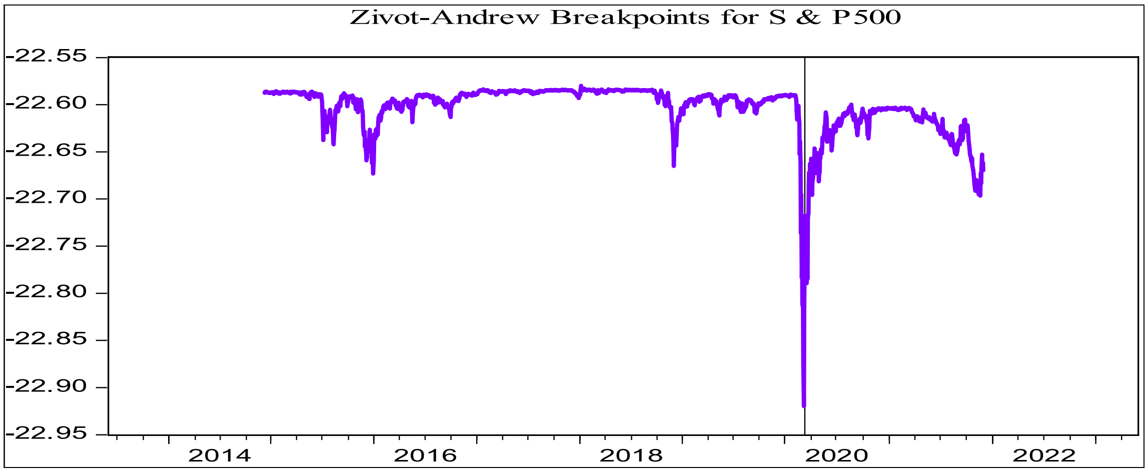
Table 1.3 : Zivot-Andrews Sequential Break Test Result for S&P 500 Index

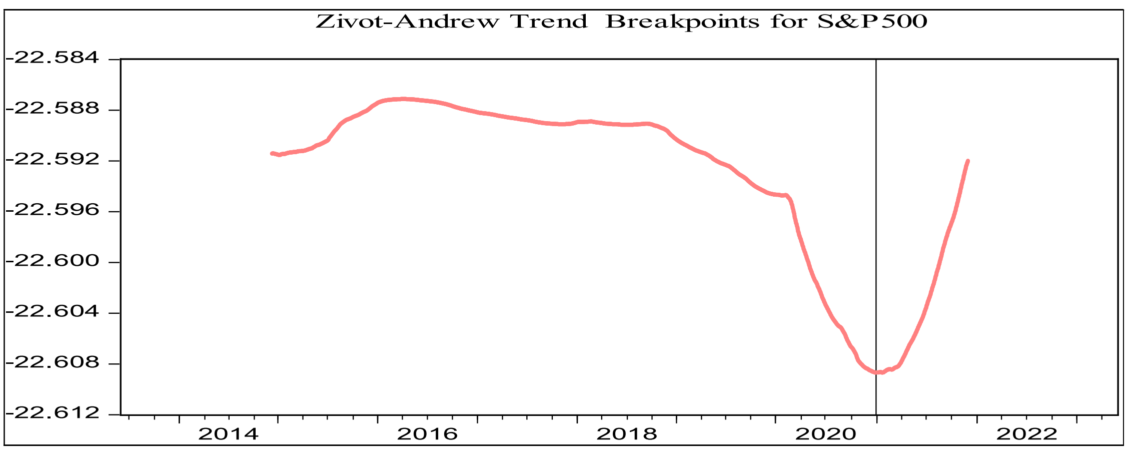
Varaible	***Zivot-Andrews t-Statistic***	***p-value***	***Chosen break point***
S&P 500 Index	**22.91956**	**0.000802****	**05-03-2020**
1% critical value:	**-5.57**		
5% critical value:	**-5.08**		

10% critical value:	**-4.82**

Note: The test adhered to Model "C," which allows for a break in both intercept and trend and compares the null hypothesis that the series has a unit root at a structural change against the alternative of stationarity at the structural break at an unknown moment. Column two displays the trend break date as determined by the test, followed by the lag order, and finally the test statistic result. At a 5% level of significance, the critical value of the test is -5.08. Asterisks indicate rejection of the null hypothesis at the 5% level of significance.

Table 1.3 presents the Zivot Andrews structural break test results of S&P 500 Index Index. It can be observed that the Index strongly **reject the null hypothesis** of presence of unit root at the structural break point as the Zivot-Andrews test statistic values of **-22.91956** are found to be greater than the test critical value of -5.08 and highly significant at 5% level of significance.





The test results are in par with the graphs provided by the test and the corresponding identification of structural break point by sequential test procedure. The analysis reveals that the structural break date pointed out by the sequential test is associated with multiple crashes during march 2020 that are associated with the fall of the S&P 500 index that fell 19.4%, and the Down Jones Industrial Average fell 8.9%. Tech stocks were some of the worst performers, down between 22% and 66%

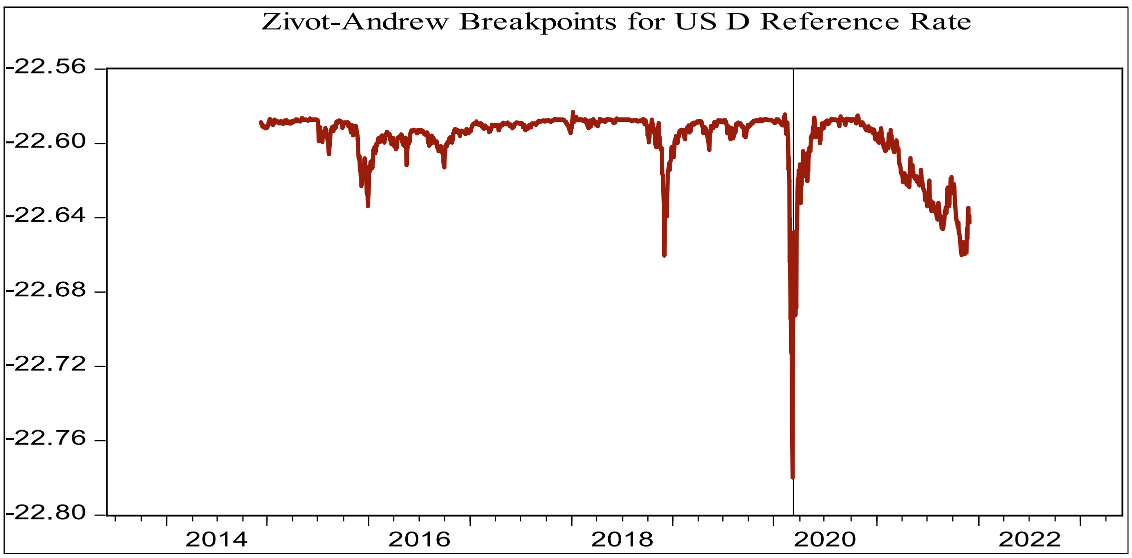
Table 1.4 : Zivot-Andrews Sequential Break Test Result for USD Reference Rate

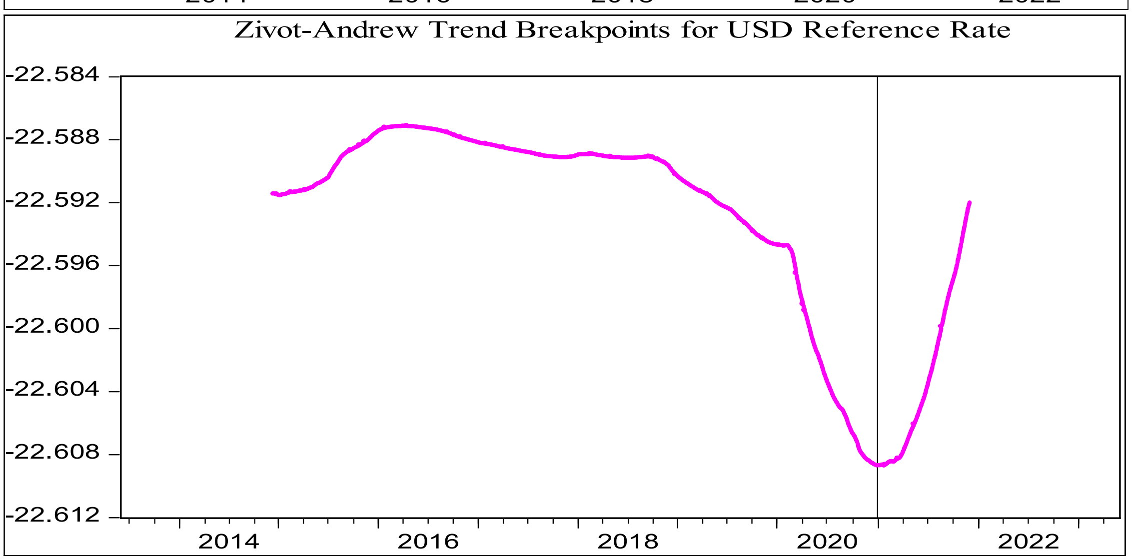
Varaible	***Zivot-Andrews t-Statistic***	***p-value***	***Chosen break point***
USD Reference Rate	**-22.779**	**0.0052****	**05-03-2020**

1% critical value:	**-5.37**
5% critical value:	**-4.93**
10% critical value:	**-4.58**

Note: The test adhered to Model "C," which allows for a break in both intercept and trend and compares the null hypothesis that the series has a unit root at a structural change against the alternative of stationarity at the structural break at an unknown moment. Column two displays the trend break date as determined by the test, followed by the lag order, and finally the test statistic result. At a 5% level of significance, the critical value of the test is -5.08. Asterisks indicate rejection of the null hypothesis at the 5% level of significance.

Table 1.4 presents the Zivot Andrews structural break test results of USD Reference Rate. It can be observed that the Index strongly **reject the null hypothesis** of presence of unit root at the structural break point as the Zivot-Andrews test statistic values of **-22.779**are found to be greater than the test critical value of -5.08 and highly significant at 5% level of significance.





The test findings are consistent with the graphs generated by the test and the related identification of structural break points using the sequential test technique. The study demonstrates that the sequential test-identified structural break date is connected with many incidents in March 2020. The RBI cut interest rates on

March 27 by 75 basis points - its biggest cut since 2009 - to 4.40 per cent, following 135 basis points of cuts in 2020. The RBI also announced targeted long-term refinancing operations to ensure market liquidity and the rupee declined to its all-time low of Rs 78 against US Dollars.

ARIMA MODELLING OF NIFTY FIFTY INDEX

With a view to understand whether the identified structural break has caused any changes in the mean reverting behaviour of Indian Stock Markets, the authors have fitted ARIMA Model by splitting the Nifty Fifty data in to two sample data files. The first part is taken from 03-062013 till 23-03-2020 as the test pointed out 24-03 2020 as structural break point and the second part is taken from 25-03-2020 to 31-03-2023

Table 1.5 : ARIMA(2,1,2) model fitting for pre structural break period

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000158	0.000268	0.590747	0.5548
AR(1)	-1.645580	0.026211	-62.78199	0.0000
AR(2)	-0.964628	0.025063	-38.48851	0.0000
MA(1)	1.583575	0.031296	50.59930	0.0000
MA(2)	0.914573	0.029311	31.20234	0.0000
SIGMASQ	0.000106	1.97E-06	53.73943	0.0000
R-squared	0.022625	Mean dependent var		0.000164
Adjusted R-squared	0.019706	S.D. dependent var		0.010414
S.E. of regression	0.010311	Akaike info criterion		-6.307295
Sum squared resid	0.177978	Schwarz criterion		-6.287915
Log likelihood	5304.128	Hannan-Quinn criter.		-6.300116
F-statistic	7.750199	Durbin-Watson stat		1.843913
Prob(F-statistic)	0.000000			

The ARIMA modelling for pre structural break period revealed that an ARIMA with an order 2,1,2 was best fitted for the said data. This model is fitted with AR(1) and AR(2) terms that are found to be highly significant along with MA(1) and MA(2) terms which were also found to be significant. Further the model diagnostic showed that the model is free from auto correlation as the Durbin-Watson test statistic was at 1.84 followed by a highly significant F statistic of 7.75 this reveals that the model is statistically adequete.

Table 1.6 : ARIMA(5,1,5) model fitting for Post-structural break period

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001003	0.000419	2.397364	0.0167
AR(5)	-0.897637	0.036458	-24.62118	0.0000
MA(5)	0.962424	0.024446	39.37014	0.0000
SIGMASQ	0.000127	3.37E-06	37.70554	0.0000
R-squared	0.019207	Mean dependent var		0.001015
Adjusted R-squared	0.015458	S.D. dependent var		0.011391
S.E. of regression	0.011303	Akaike info criterion		-6.120858
Sum squared resid	0.100285	Schwarz criterion		-6.097179
Log likelihood	2418.679	Hannan-Quinn criter.		-6.111756
F-statistic	5.124151	Durbin-Watson stat		2.030841
Prob(F-statistic)	0.001628			

ARIMA model for the post structural break data recommended an ARIMA (5,1,5) model which revealed that AR (5) term and MA(5) term were found to be highly significant and the model adequacy reported a Durbin-Watson test statistic of 2 which underlined that the model is free from auto correlation and a highly significant F statistic suggest that the model is statistically adequate .

CONCLUSION

The primary objective of research paper was to verify whether pandemic disruptions cause structural breaks in time series data and alter this statistical properties of the said data. For this purpose a widely accepted and sophisticated econometric test called as Zivot Andrews sequential break point test was employed based on the test results and other finding the following conclusions are drawn.

1. The results signify that covid 19 pandemic caused quantifiable structural break in all the choosen series.
2. It was also noted that series remained stationery even after such structural breaks and exhibited mean reverting behavior.
3. Even though all the variable showcased mean reverting tendencies after the structural break evidences of long memory were noted that can be a potential area to be researched upon in future.
4. The mean reverting tendencies also indicate that these series are not reformed efficient and are proven to market predictions and beat the market strategies.

The analysis of these two models reveals that the ARIMA model fitting was done to the same date file that was split into two time frames and generally a same model has to be fitted for both the files as the source data is same. But there was a structural break that was noted which also was a point of split of the data and there was an identifiable change that has accounted for in the post structural break period and was reflected in a different ARIMA order. The pre structural break period reported an ARIMA(2,1,2) model but the post-structural break revealed that ARIMA of the higher order of (5,1,5) is required. so this quite surprising to not that the source data though was same but two different models were required to be fitted. This also prove that the Nifty 50 Index, after the structural break has underwent significant statistical transformation and mean reversion.

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