Fundamental, technical and external factors induced positive and negative extreme events in stock market

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Sporadic large fluctuations in stock price are seen in the stock market. Such large fluctuations occur due to three important factors: (a) the significant change in the fundamental parameters like excellent or bad result; (b) the formation of special technical setup in the stock price like double-bottom and (c) external factors like war. These factors may lead to occasional and rare upsurge or crash of significant height in the stock price, and such upsurge or crash is termed as positive or negative extreme event (EE), respectively. In this work, we have identified EE in the stock price of selected companies from global stock markets due to the above factors in minute, daily, weekly time-scales. Augmented Dickey-Fuller and degree of nonstationarity tests show that the stock price time-series is nonstationary. Subsequently, we applied Hilbert-Huang transformation to identify EE. The analysis shows that the instantaneous energy (IE) concentration in the stock price is very high during an EE with $IE > E_\mu + 4\sigma$, where $E_\mu$ and $\sigma$ are the mean energy and standard deviation of energy, respectively. The analysis shows that investor can gain or lose a significant amount of their capital due to these events. Hence, identification of the EEs in stock market are important as it helps the investor and trader to take rational decisions during such crisis. The investors should carefully monitor the factors that lead to EEs for entry or exit strategy in the market.

I. INTRODUCTION

Extreme Event (EE) can impact a system and its surrounding in a severe way and hence, its study is very important [1–3]. A sudden emergence of an extraordinary event from an ordinary state, such as floods, earthquakes, stock market crashes, power blackouts, heart attack, global war, pandemic can be termed as an EE [4–6]. An event can be quantified as an EE when it crosses a certain threshold observable value [2,7]. There are various factors that lead to an EE in a system. The analysis of different factors induced EE is of utmost importance as such events have very strong impact [3,7]. Though the study of EEs have been carried out in various disciplines, very limited work has been done in finance, especially in stock market [6,8]. Therefore, rigorous study of EEs in stock market to further expand the previous studies is extremely important to understand its impact.

In the stock market, sudden crash or upsurge in the stock price above a significant height may be considered as an EE. The stock market crash of 1987, the dot-com crash of 2000, the financial crash of 2008 and the recent COVID-19 crash in stock market can be considered as negative EEs [4,13]. These crashes happened due to fundamental factors like overvaluation, debt, low earning and external factors like pandemic, etc. On the contrary, the stock market also often witnesses rapid upsurge in the stock price. For example, the rapid upsurge in BSE SENSEX in 1991, the rise in S&P Index in 1982 happened due to the various fundamental and external factors like adoption of liberal policies, excellent corporate results, good monsoon, reduction in the corporate and income tax [14–16]. These upsurges can be considered as positive EEs. Limited studies have been carried out on such crash and upsurge in the stock price in terms of EE. Especially, study of company-specific EE in stock price due to various factors are very necessary for an investor to make entry or exit strategy in the market. The factors leading to EEs can be broadly categorized into fundamental, technical and external factors.

Investors examine the fundamental factors like the financial parameters of a company before investing [17], and these parameters are published quarterly through financial result. Results indicating significant change in net profit, sales, earning and growth i.e., significant change in overall performance has a very strong impact on the stock price movement [18,19]. Studies also reveal that stock price reacts strongly on the announcements of major corporate decisions, significant change in stake holdings, regulatory policy, macroeconomic conditions, buy or sell recommendations by the brokerage firms and many other factors that affect the fundamentals of a company [20,21]. These fundamental factors may lead to EE in the stock price and hence, it’s study is important to make investing decisions.

Sometimes impact of the technical factors on the stock price are also very significant. The formation of different types of technical chart patterns lead to an abrupt change in the stock price [22,23]. Such change in the stock price is due to the synchronized buy or sell trades by the uniformed traders [24,25]. Different chart patterns indicate different stock price trends. Technical chart patterns like

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formation of ascending or descending triangles, double-bottom, support-resistance may lead to EE in the form of upsurge or crash in the stock price \(^{26, 27}\). As these occasional EE has great impact on the profitability, study of such events may also be useful for an investor.

Apart from the fundamental and technical factors, there are several external factors which cause EE in stock price. Such as the interest rate change by the U.S. Federal Reserve led to a stock market crash \(^{28}\). Political events like general election, change of government impact the stock price return \(^{22, 34}\). Global events like war, nuclear test have also severely impacted the stock market \(^{31-33}\). Natural hazards like earthquake, cyclones have major impact on the stock price movement \(^{34, 35}\). Hence, analysis of the stock price movement due to external factors are necessary for the identification of EE.

The earlier studies as mentioned above show that EE can be of two types: positive EE (sudden upsurge in stock price) and negative EE (sudden crash in stock price). Usually, EEs are characterized based on the magnitude of the event or by quantifying its impact \(^{8}\). Events with amplitude greater than four to ten times of the standard deviation of normal events are generally considered as EEs \(^{6, 36, 37}\). In ref \(^{8}\), the stock price crash during COVID-19 pandemic is identified as an EE by using Empirical mode decomposition (EMD) based Hilbert-Huang transformation (HHT) method. As the stock price is nonstationary, nonlinear and EEs are sharp fall or rise, this method is very suitable to detect EE by estimating the instantaneous energy (IE) \(^{6}\). For an EE, IE > \(E_\mu + 4\sigma\), where \(E_\mu\) and \(\sigma\) are the mean energy and standard deviation of energy, respectively.

The present work identifies EE in the stock market due to various factors in different time-scales. We have identified positive and negative EE due to fundamental, technical and external factors. We have applied EMD based HHT to identify the EE. Rest of the paper is organized as: Methods used for the analysis are discussed in Section II. The data analysed is represented in Section III. The results are discussed in Section IV. Section V consist of conclusion of the work.

II. METHOD OF ANALYSIS

In order to check the stationarity of a time-series data, we have used Augmented Dickey-Fuller (ADF) and degree of nonstationarity (DNS) test. Empirical Mode Decomposition (EMD) technique is used to identify EEs in the stock market. The details of the above techniques are given below.

A. Augmented Dickey-Fuller (ADF) Test

Augmented Dickey-Fuller (ADF) test is a commonly used unit root statistical test for checking the stationarity of a time-series \(^{38}\). This test is an extended version of Dickey-Fuller (DF) test. In DF test, the time-series is characterised by Auto Regressive (1) model. Said and Dickey extended DF test by including extra lagged terms of the dependent variables to get rid of the problem of autocorrelation and their test is called Augmented Dickey-Fuller test \(^{39, 40}\). The ADF test involves the following regression:

\[
\Delta y_t = \beta + \gamma t + \alpha y_{t-1} + \sum_{j=1}^{n} \psi_j \Delta y_{t-j} + \epsilon_t \tag{1}
\]

\(\Delta\) is the difference operator, \(\epsilon_t\) is the white noise error, \(\beta\) is the contant, \(\gamma\) is the trend of the regression.

ADF test is based on testing of a statistical hypothesis to determine the presence of unit root in a time-series. The null hypothesis for the test is that the given time-series has a unit root, which means that the time-series is nonstationary. The alternative hypothesis is that the time-series is stationary and has no unit root \(^{38, 41}\). In particular,

\[
H_0 : \alpha = 1 \Rightarrow y_t \sim I(1) \tag{2}
\]

\[
H_1 : |\alpha| < 1 \Rightarrow y_t \sim I(0) \tag{3}
\]

The null hypothesis is tested using the t-statistics which are based on the least squares estimates of equation (1). It is given by

\[
t_{\alpha=1} = \frac{\hat{\alpha} - 1}{SE(\alpha)} \tag{4}
\]

\(\hat{\alpha}\) is the least square estimate and \(SE(\alpha)\) is the standard error estimate.

The ADF test gives the following results: t-statistic, p-value and critical value at different significance levels. For a nonstationary time-series, t-statistics and p-value are greater than the critical value and level of significance, respectively \(^{38, 42}\).

B. Empirical Mode Decomposition (EMD)

Empirical mode decomposition (EMD) technique is applied to decompose a nonlinear and nonstationary time-series data \(^{43, 44}\). The EMD technique decomposes a time-series into unique intrinsic mode function (IMF) with definite timescales. For a time-series to be an IMF, it needs to satisfy two criteria:

1. The number of zero crossings and the number of extremas (i.e., maxima and minima) must be equal or at most differ by one.

2. The mean value of the envelope which is defined by the local maxima and the envelope defined by the local minima must be equal to zero.

A detailed procedure to decompose a signal into IMFs are given below:
1. The upper envelope \((UE_t)\) and lower envelope \((LE_t)\) of a data set \((D_t)\) are drawn by connecting maxima and minima, respectively, with the help of spline fitting.

2. A new dataset \((ND_t)\) is obtained by subtracting the old dataset \((D_t)\) with the mean value of the envelope, where mean = \((UE_t + LE_t)/2\). \(ND_t = D_t - \text{mean}\).

3. Until the IMF criteria are satisfied, the above steps (1) & (2) are repeated taking \(ND_t\) as the new dataset. After the conditions of IMF are satisfied, the dataset \(ND_t\) is considered as the first IMF i.e., IMF1.

4. The same process is followed to calculate IMF2 with the dataset as \(N_t = D_t - \text{IMF1}\). The whole process is stopped after the final dataset is monotonic in nature. The monotonic dataset is called the residue that represents the overall trend of the dataset \(D_t\). The dataset \(D_t\) can be reproduced by the combination of all the IMFs including the monotonic dataset, \(D_t = \sum_{j=1}^{n} \text{IMF}_j + \text{residue}\), where \(\text{IMF}_j\) represents the \(j^{th}\) IMF and \(n\) is the total number of IMF.

Hilbert transform is used to calculate the instantaneous frequency \((\omega)\) of a IMF. Hilbert transform is defined as \(A_t = \frac{C}{\pi} \int_{-\infty}^{\infty} \frac{\text{IMF}}{t - t'} dt\). Here, \(C\) is the value of Cauchy principle. \(\omega\) is defined as \(\omega = \frac{d\theta_t}{dt}\), where \(\theta_t = \tan^{-1} \frac{A_t}{\text{IMF}}\).

Hilbert spectrum \([H(t, \omega)]\) is a time-frequency distribution of a time-series and is defined as

\[
H(t, \omega) = \text{Re} \sum_i M_i(t) e^{i \int \omega_i(t) dt}
\]  

(5)

Here, \(M_i(t)\) is the amplitude and \(\omega_i(t)\) is the frequency of the \(i^{th}\) IMF. We have considered all the IMFs excluding the residue to estimate the \(H(t, \omega)\) as residue is a monotonic function.

Instantaneous energy \(IE(t)\), which is useful to identify EE, can be estimated from \(H(t, \omega)\) and it is defined as

\[
IE(t) = \int_\omega H^2(t, \omega) d\omega
\]

(6)

In our work, we estimate the \(H(t, \omega)\) of a combination of IMFs using Eqn. [4]. We can easily identify the occurrence time of an EE by identifying the maximum energy concentration in the \(H(t, \omega)\) spectrum.

However in order to quantify an EE we need to estimate the \(IE\) of the combined IMF from Eqn. [9]. We have used the normalized \(IE_N(t)\) for the analysis, where \(IE_N(t) = IE(t)/\max[IE(t)]\). Events whose \(IE_N\) are greater than the threshold value will be identified as an EE. The threshold energy is calculated as \(E_{th} = E_h + B \sigma\), where \(B\) is a constant, \(E_h\) is the average energy and \(\sigma\) is standard deviation of the energy. We have chosen \(B=4\) for our analysis.

Degree of nonstationarity \([DNS(\omega)]\) test is applied to check the stationarity of a time-series. DNS is defined as

\[
DNS(\omega) = \frac{1}{T} \int_0^T [1 - \frac{H(t, \omega)}{h(\omega)}] dt
\]

(7)

Here, \([0, T]\) is the time window and \(h(\omega)\) is the marginal spectrum and it is defined as, \(h(\omega) = \frac{1}{T} \int_0^T H(t, \omega) dt\). In the case of stationary time-series, the \(DNS(\omega)\) plot is a horizontal line and for nonstationary time-series data, the \(DNS(\omega)\) plot is not a horizontal line [43].

III. DATA ANALYZED

We have selected and analyzed stock price of companies from different countries such as USA, Germany, Russia, India and UK. The list of the companies analyzed in this paper are shown in table I. The data length of the stock price has been chosen based on the occurrence and duration of the event as given in table III. All the data are downloaded from Yahoo Finance website [46]. The results of the analysis are shown in subsequent sections.

IV. RESULTS AND DISCUSSION

The results are presented in two parts. Subsec. \([1VA]\) presents the result of the nonstationarity tests of all the stock price time-series. Subsec. \([1VB]\) presents the analysis and identification of positive and negative EEs induced by different factors.

A. Nonstationarity Tests

We have carried out the stationarity test for all the stock price time-series using Augmented Dickey-Fuller (ADF) test as described in Sec. \([IIA]\). The result of the test is given in Table I. The result shows that t-statistic values are greater than the critical values for all the time-series. The p-values are also greater than 0.01 (0.01 is the significance level of critical value) [42]. The above results indicate that the stock price time-series are nonstationary i.e., the null hypothesis is not rejected and the time-series have unit root as discussed in \([IIA]\). As the stock price time-series is nonstationary, we use the EMD based HHT technique as discussed in Sec. \([IIB]\) for subsequent analyses.
### Table I

| Company Name              | t-statistic | critical Value | p-value |
|---------------------------|-------------|----------------|---------|
| Avast plc.                | 0.8703      | -2.5756        | 0.8963  |
| NINE                      | -0.7878     | -2.5754        | 0.3648  |
| Jocil Ltd.                | 0.4367      | -2.5839        | 0.8065  |
| JUBLINGREA                | -0.1589     | -2.5961        | 0.5904  |
| GODREJCP                  | 0.1447      | -2.5700        | 0.7046  |
| PNBHOSING                 | -0.9479     | -2.5804        | 0.3034  |
| GameStop Corp.            | -1.1703     | -2.5900        | 0.2221  |
| IRCTC Ltd.                | 0.3702      | -2.5753        | 0.7864  |
| PHIA                      | -1.1233     | -2.5753        | 0.2396  |
| Shopify Inc.              | 0.9929      | -2.5753        | 0.9182  |
| BioNTech SE               | 0.6324      | -2.5874        | 0.8512  |
| 9939.HK                   | -0.6831     | -2.5749        | 0.4011  |
| ZEEL                      | 1.2775      | -2.5788        | 0.9487  |
| SELAN                     | 1.0176      | -2.5754        | 0.9187  |
| Netflix Inc.              | -1.1157     | -2.5755        | 0.2424  |
| NK Rosneft’ PAO           | -0.3620     | -2.5756        | 0.5186  |
| Chevron Corp.             | 1.9830      | -2.5890        | 0.9953  |
| HDFCLIFE                  | -0.8743     | -2.5753        | 0.3307  |
| Ishanch                   | 0.0894      | -2.5700        | 0.6843  |
| HITECHCORP                | 1.9396      | -2.5774        | 0.9873  |
| TEXMOPIPES                | 0.4454      | -2.5796        | 0.8000  |
| HAPPSTMNDS                | 1.8528      | -2.5811        | 0.9845  |
| GLENMARK                  | 0.6507      | -2.5753        | 0.8557  |
| Pindusdoo Inc.            | -0.8401     | -2.5702        | 0.3417  |
| ALKYLAMINE                | 2.2430      | -2.5758        | 0.9940  |
| Coal India Ltd.           | 0.0963      | -2.5854        | 0.6854  |
| ADANIPORTS                | -0.3625     | -2.5700        | 0.5187  |
| OXY                       | 2.3747      | -2.5753        | 0.9953  |
| Bajaj Finance Ltd.        | 1.2868      | -2.5898        | 0.9960  |
| NVIDIA Corp.              | 1.4612      | -2.5754        | 0.9643  |
| Macy’s Inc.               | 0.3787      | -2.5928        | 0.7875  |
| AT&T Inc.                 | 0.0211      | -2.5810        | 0.6584  |
| Boeing Co.                | 0.7192      | -2.5803        | 0.8681  |

In order to validate the result of the ADF test, we further use degree of nonstationarity (DNS) test as described in Sec. [113](#). Fig. 1 represents the DNS(ω) plots of Nine Energy Service Inc., Kintor Pharmaceutical Ltd,(9939.HK), Avast Plc., NK Rosneft’ PAO, Selan Exploration Technology Ltd., Netﬂix Inc., respectively. As the DNS(ω) plot is not a horizontal line, it is clear that the time-series are nonstationary. The DNS test is carried out for all the stock price time-series and it shows that the time-series are nonstationary. Hence, the use of EMD technique is appropriate for the analysis of EE in the stock price.

### FIG. 1

The figure represents the DNS plot of Nine Energy Service Inc., Kintor Pharmaceutical Ltd.(9939.HK), Avast Plc., NK Rosneft’ PAO, Selan Exploration Technology Ltd. and Netlix Inc., respectively.

#### B. EE induced by Different Factors

The emergence of EE in stock market depends mainly on three factors: (1) fundamental; (2) technical; (3) external.

##### 1. Fundamental factors

The result of a company is one of the important fundamental factors based on which the investors take their investment decisions. On 12 May 2021, we have seen a drastic price surge of 28% within minutes due to the unexpected good result. We have taken 10 min. data from 28 Apr. 2021 to 20 May 2021 for the analysis. Fig. [2](#) represents the Hilbert spectrum [H(t, ω)] of the stock price of all the intrinsic mode functions (IMFs). The stock price surge is clearly captured by H(t, ω) as shown by the red patch in Fig. [2](#). The red patch represents the maximum energy concentration. Further, normalized instantaneous energy [IE_N(t)] of the stock price time-series is shown in fig. [2](#). It shows a clear spike in IE_N(t) during the event. The IE_N(t), the average energy (E_a) and threshold energy (E_th) are represented by blue solid, black solid and dotted lines, respectively, in Fig. [2](#). As discussed in Sec. [113](#) the events with IE_N greater than E_th are considered as an EE, where
FIG. 2. Plot (a) and (b) represent the \( H(t, \omega) \) and \( IE_N(t) \) plot of Godrej Consumer Products Ltd. and plot (c) and (d) represent the \( H(t, \omega) \) and \( IE_N(t) \) plot of Ishan Dyes And Chemicals Ltd., respectively.

FIG. 3. Plot (a) and (b) represent the \( H(t, \omega) \) and \( IE_N(t) \) plot of Nine Energy Service Inc. and plot (c) and (d) represent the \( H(t, \omega) \) and \( IE_N(t) \) plot of PNB Housing Finance Ltd., respectively.

\[ E_{th} = E_\mu + 4\sigma. \] \( \sigma \) is the standard deviation of the energy. Since, \( IE_N \) during this event is greater than the \( E_{th} \), the price surge of Godrej Consumer Products Ltd. due to excellent result is considered as a positive EE. We have found similar kind of positive EE for many stocks which has given unexpectedly good result.

On the other hand, the result of Ishan dyes and chemicals Ltd. was announced on 31 May 2021 and the result was below expectation \( 17 \). As a result, the stock price crashed around 20% almost instantaneously. Fig. 2(c) shows the \( H(t, \omega) \) of the stock price. For this analysis, we have taken 10 min data from 17 May 2021 to 04 June 2021. The crash in the stock price is captured by the red patch in the \( H(t, \omega) \). The \( IE_N(t) \) of the above stock price time-series is also obtained from \( H(t, \omega) \) and is shown in Fig. 2(d). A clear spike is visible in the \( IE_N(t) \) during the event. As discussed above, \( IE > E_{th} + 4\sigma \) for Ishan dyes and chemicals Ltd. due to unexpected bad result. Hence, the price crash can be considered as negative EE. Similar negative EE due to unexpectedly bad result have been found.

The appearance of positive and negative EEs due to unexpectedly good or bad result is almost instantaneous as obtained from the above analysis of minute data. It is almost impossible for an investor to enter or exit during positive or negative EE. However, a continuous monitoring of the financial position of a company may help an investor to anticipate a positive EE and make an early entry. If unexpected negative EE happens, the investor may make an entry into the stock at lower level considering its future outlook. For such entry during positive and negative EEs, the investor should stay with some cash.

Nine Energy Service Inc. had reported that their business activity is continuously improving from the start of the year and are expecting better future results. Based on their continuous growth and positive outlook, the stock price of Nine Energy Service rose sharply. The daily stock price data from May 2021 to Apr. 2022 is used for the analysis. Fig. 3(a) shows the \( H(t, \omega) \) of the stock price of all the IMFs. The maximum energy concentration, shown by a red patch, is clearly visible during the stock price upsurge due to the positive outlook. Fig. 3(b) shows the \( IE_N(t) \) plot and a sudden spike is seen in \( IE_N \) during the time of event. As the spike is greater than the \( E_{th} \), the upsurge of the stock price in Nine Energy Service Inc. due to positive growth and outlook is considered as a positive EE.

On 31 May 2021, the stock price of PNB Housing Finance Ltd. upsurged rapidly after the news on the acquisition of stake over 50% by a private equity firm Carlyle Group. The stock price rallied more than 70% after the announcement. We have taken weekly data from Oct. 2018 to Sept. 2021 for the analysis. Fig. 3(c) shows the \( H(t, \omega) \) of the stock price and it clearly shows the maximum energy concentration during the rapid upsurge of stock price. Fig. 3(d) represents the \( IE_N(t) \) obtained from the \( H(t, \omega) \). A significant spike in \( IE_N \) is seen during the event and it is greater than \( E_{th} \). Hence, the stock price upsurge in PNB Housing Finance Ltd. due to the acquisition of stake can be considered as a positive EE.

Identification of the fundamental factors that lead to an EE are important as the investors can make entry or exit positions when similar situation arises in the future. From the above results, we can conclude that a regular monitoring on fundamentals and any new updates on the company are necessary to anticipate EEs. By continuous
monitoring, the investors may be able to make a right entry or exit positions during EEs. In order to take benefit from EEs, investors should keep some cash in hand. Positive and negative EEs due to other fundamental parameters are shown in Table I.

2. Technical factors

![Graphs](#)

FIG. 4. Plot (a), (b) and (c) represent the 5 min closing price, $H(t, \omega)$ and $IE_N(t)$ plot of of Boeing Co. Plot (e), (f) and (g) represent the daily closing price, $H(t, \omega)$ and $IE_N(t)$ plot of Jubilant Ingrevia Ltd., respectively.

Technical analysis is one of the most widely used technique in the stock market for profitable trades. Fig. 4 (a) shows the closing price of Boeing Co. from 14 Apr. 2022 to 19 Apr. 2022. The data was taken in an interval of 5 min. During this period, a double-bottom (DB) technical chart pattern was formed which is shown by the dashed lines in Fig. 4 (a). A positive breakout is seen in the stock price after the formation of DB. A clear maximum energy concentration is visible from the $H(t, \omega)$ in Fig. 4 during the breakout. The maximum energy concentration is represented by the red patch. Fig. 4 (c) represents the $IE_N(t)$ obtained from the $H(t, \omega)$. The figure shows a significant spike in the $IE_N(t)$ during the positive breakout and it is greater than $E_{th}$. Hence, the breakout due to DB chart pattern may be considered as a positive EE. Such kind of positive breakouts are seen for different chart patterns.

There are also negative breakouts due to technical chart patterns. Fig. 4 (d) shows a daily closing price of Jubilant Ingrevia Ltd. from Jul. 2021 to Nov. 2021. A channel chart pattern was formed during this period and it is shown by dashed lines in Fig. 4 (d). A negative breakout is seen after the stock price broke the lower support line. Fig. 4(e) shows that during a negative breakout the energy concentration is maximum. The breakout energy concentration is represented by red color. $IE_N(t)$ plot in Fig. 4 (f) also shows a sudden spike during the breakout. As the magnitude of the sudden spike is greater than the $E_{th}$, the negative breakout due to channel formation may be considered as a negative EE.

The above results clearly show that the positive and negative EE may arise due to different breakout patterns. A trader with a sound knowledge on technical setups can take benefit of such EEs within a short period of time, as is evident from our analysis. Trader can make an entry during the formation of a bullish chart setup and wait for the breakout. They must keep some unallocated funds so that they can enter before a breakout. They can also exit their positions during the formation of a bearish chart setup and may enter after the negative EE. A strict target and stoploss should be followed by a trader to book their profits or minimize their loss. EEs due to different chart patterns are shown in Table II. Apart from the fundamental and technical factors, positive and negative EEs also happen due to external factors that are discussed in the next subsection.

3. External factors

![Graphs](#)

FIG. 5. Plot (a) and (b) represent the $H(t, \omega)$ and $IE_N(t)$ plot of NK Rosneft’ PAO and plot (c) and (d) represent the $H(t, \omega)$ and $IE_N(t)$ plot of Chevron Corp., respectively.

On 24 Feb. 2022, Russia invaded Ukraine, and due to
this invasion, the Russian stock market crashed severely on the same day [48, 49]. For example, the stock price of NK Rosneft’ PAO crashed nearly 60% on the day of invasion. Fig. 5 (a) represents the $H(t, \omega)$ of the stock price of all the IMFs and the figure captures the crash due to Russia-Ukraine war by a red patch (maximum energy concentration). Fig. 5 (b) represents the $IE_N(t)$ obtained from the $H(t, \omega)$. Fig. 5 (b) shows a significant upsurge in $IE_N$ during the war which is greater than the $E_{th}$. Hence, the crash in the stock price of NK Rosneft’ PAO due to Russia-Ukraine war is termed as a negative EE. We have taken daily closing data from Jan. 2021 to Apr. 2022 for the analysis.

On the other hand, there are few companies which benefited from the Russia-Ukraine war. After the invasion, the oil prices soared high as some countries banned oil imports from Russia. As Russia is the second largest oil exporter, this led to the increase in demand of oil worldwide. The stock prices of oil companies like Chevron Corp. and Occidental Petroleum Corp. sky rocketed. The weekly stock price data of Chevron Corp. is taken from May 2020 to Apr. 2022 for the analysis. The stock price upsurge is clearly captured by $H(t, \omega)$ as shown by the red patch (maximum energy concentration) in Fig. 5 (c). Fig. 5 (d) shows the $IE_N(t)$ of the stock price time-series that is obtained from the $H(t, \omega)$. The figure clearly shows an abrupt spike in the $IE_N$ during the war. This spike in $IE_N$ is greater than the $E_{th}$ and hence, the stock price upsurge in Chevron Corp. due to Russia-Ukraine war is considered as a positive EE.

The above results show that the external factor like war leads to both positive and negative EEs. In case of Russia-Ukraine war, stocks like NK Rosneft’ PAO crashed heavily but stocks like Chevron Corp. upsurged rapidly. Such EEs provide opportunity to the investors to restructure their portfolio and invest in stocks with better future outlook. Therefore, investors should stay updated with the external factors like geopolitical news so that they can use such factors in their favor. EEs due to other external factors are shown in Table III.

The formation of breakout patterns excite the traders who are carefully inspecting the chart patterns. When there is a breakout in the setup, there is an uninformed synchronization between the traders which lead to huge buy or sell of the stock. This uninformed synchronization leading to huge buy or sell is evident from the rise in the volume. Fig. 6 (a) represents the daily closing price (line plot) and volume (bar plot) of Jocil Ltd. Plot (b) represents the $H(t, \omega)$ and plot (c) represents the $IE_N(t)$. The results show that the stock price shows a positive EE due to fundamental factors like excellent financial result, future growth and acquisition of stakes. $H(t, \omega)$ shows maximum energy and $IE_N > E_\mu + 4\sigma$ during a positive EE. Similarly, we have obtained negative EE trades as there were no fundamental or external factors. The emergence of EE is also evident from the significant upsurge in the volume, hence analysis of EE in terms of volume analysis could be interesting and may be done in future.

V. CONCLUSION

In this paper, we have discussed three important factors that trigger a sudden positive or negative extreme event (EE) in the stock price from a normal state in different time-scales. We have found that EEs mainly occur due to fundamental, technical and external factors. Firstly, augmented Dickey-Fuller and degree of nonstationarity tests are carried out on the stock price time-series and the tests show that the time-series are nonstationary. Hence, we employ empirical mode decomposition (EMD) based Hilbert-Huang transformation to identify positive and negative EEs. EMD decomposes the time-series into different intrinsic mode functions (IMFs). Hilbert Spectrum $|H(t, \omega)|$ and instantaneous energy $|IE_N|$ are applied to identify the EE. $IE_N > E_\mu + 4\sigma$ during an EE.

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TABLE II. Col-2 represents the companies analysed, Col-3 represents the time-scale of the stock price data of each company, Col-4 shows the event that had occurred, Col-5 shows the impact of the event on the stock price of the company and Col-6 shows the ratio of the difference between maximum energy and mean energy to the standard deviation of energy. Abbreviation of technical setup: SR=Support-Resistance, AC=Ascending-Channel, AT=Ascending Triangle, VCP=Volatility Contraction Pattern, AC=Ascending Channel, DB=Double Bottom

| Sl. no | COMPANY NAME | Time-scale | Event | Impact on stock price | Ratio |
|-------|--------------|------------|-------|-----------------------|-------|
| 1     | GODREJCP     | 10 min     | Result| Positive              | 9.3   |
| 2     | Ishanch      | 10 min     | Result| Negative              | 11.9  |
| 3     | MINE         | Daily      | Increase in earning | Positive | 9.2   |
| 4     | PNBHOUSING   | Weekly     | Carlyle Group to acquire controlling stake | Positive | 7.9   |
| 5     | JUBLINGREA   | Daily      | Technical setup(AC) | Negative | 4.3   |
| 6     | Boeing Co.   | 5 min      | Technical setup (DB) | Positive | 4.9   |
| 7     | NK Rosneft PAO | Daily | Russia-Ukraine War | Negative | 10.6  |
| 8     | Chevron Corp. | Weekly | Russia-Ukraine War | Positive | 5.0   |
| 9     | Jocil Ltd.   | Daily      | Technical setup(SR) | Positive | 6.7   |
| 10    | Avast plc    | Daily      | Merger | Positive              | 8.5   |
| 11    | 9939.HK      | Daily      | COVID-19 drug fails clinical trial | Negative | 6.5   |
| 12    | BioNTech SE  | Weekly     | Strong sale of COVID vaccine | Positive | 4.3   |
| 13    | Shopify Inc  | 15 min     | Growth in Performance | Positive | 4.5   |
| 14    | PHIA         | 15 min     | Inspection in its facilities | Negative | 8.6   |
| 15    | GameStop Corp. | Weekly | Manipulation | Positive | 7.8   |
| 16    | Netflix Inc  | Daily      | Lost 2 lakh subscribers in Q1 | Negative | 7.7   |
| 17    | NVIDIA Corp. | Weekly     | Technical setup (AC) | Positive | 5.8   |
| 18    | Macy’s Inc.  | 15 min     | Technical setup (AT) | Positive | 4.1   |
| 19    | AT&T Inc.    | Daily      | Technical setup (AT) | Positive | 4.9   |
| 20    | Pinduoduo Inc. | Daily | Positive statement from China State Council | Positive | 5.7   |
| 21    | SELAN        | Daily      | Antelopus Energy to buy stake | Positive | 7.8   |
| 22    | ZEEL         | Daily      | Removal of MD  | Positive | 6.0   |
| 23    | ZEEL         | Daily      | Merger with Sony | Positive | 5.7   |
| 24    | IRCTC Ltd.   | 30 min     | Overvaluation | Negative | 6.7   |
| 25    | OXY          | Weekly     | Russia-Ukraine War | Positive | 4.7   |
| 26    | GLENMARK     | Daily      | Enters 3rd clinical trial for COVID drug | Positive | 10.7  |
| 27    | HDFCLIFE     | 10 min     | Standard Life to sell stake | Negative | 6.1   |
| 28    | HAPPSTMNDS   | Daily      | Buy recommendation | Positive | 5.3   |
| 29    | TEMMOPIPES   | Weekly     | Technical Setup (AC) | Positive | 8.3   |
| 30    | HITECHCORP   | Daily      | Technical Setup (AT) | Positive | 7.6   |
| 31    | ADANIPORTS   | 10 min     | NSDL freezes 3 FPI accounts | Negative | 9.5   |
| 32    | Coal India Ltd. | Daily | Russia-Ukraine War | Positive | 4.9   |
| 33    | ALKYLAMINE   | Daily      | Technical setup(AT) | Positive | 8.3   |
| 34    | Bajaj Finance Ltd. | 15 min | Technical setup (VCP) | Positive | 4.9   |

for negative fundamental factors like bad financial result. We found both positive and negative EE for technical factors. We obtained positive EE for bullish chart patterns like double bottom and negative EE for bearish chart patterns like channel formation. We also found both positive and negative EE for external factors like war. For example, in case of Russia-Ukraine war we obtained positive EE for a few companies which had positive business outlook. On the contrary, we also obtained negative EEs for companies whose business outlook changed to negative due to the war.

Identification of the EE due to different factors is important as it may be beneficial for the investors and traders to take appropriate investment decisions. While it is very difficult to make profit from positive EE, one can take the opportunity to enter at lower level of a fundamentally strong stock when the stock price crashes due to technical and external factors induced negative EE. This analysis shows that there should be always a cash position in a portfolio to grab such an opportunity. We noticed sudden surge in volume during the occurrence of an EE. In future, working on the analysis of EE in terms of volume may be very interesting.

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