“Performance Analysis of Global Stock Market Indices during Ukraine-Russia War using Python”

Introduction

The Russian invasion of Ukraine on February 24 kicked off series of historic policy actions and moves across global markets. The Russia-Ukraine dispute – the most significant conflict in Europe since the second world war comes at a sensitive time when World Health Organization (WHO) declared COVID–19 outbreak as a public health emergency of international concern, the global economy is still straining under a range of burdens: surging inflation and unemployment rates, tangled global supply chains, and tumbling financial markets.

The Russia-Ukraine war has magnified each threat and complicated the potential solutions. The repercussions of this conflict are threatening the global economy, sparing uncertainty in financial markets, and making life more perilous for everyone worldwide. These implications of the Russia-Ukraine war for the global economy and financial markets mainly come from three channels: economic sanctions, commodities prices, and supply-chain disruptions.

The response of stock markets to the war is more complex, given that different markets have more or less exposure to different commodities than others. They also have different levels of exposure to the Russian stock market. The Russian ruble continues to reach all-time lows and the Russian equity market (Moscow Stock Exchanges) remained closed for considerable amount of time. This paper attempts to study the effect of Ukraine Russia war on four global stock indices namely NIFTY50, NASDAQ Composite, EURO STOXX50 and FTSE100 for period between 1 October,2021 to 14th April,2022.

Due to an escalation of war by Russia, benchmark indices were on a massive selling, which not only affected gold and crude, but the overall commodities prices worldwide. While global equity markets rebounded back on February 25, they fell again the next session, suggesting investors and traders are on edge due to the uncertainty surrounding the rapidly evolving conflict in eastern Europe.

As the European Union is not at the centre of the dispute, its direct losses are minimal. Due to geopolitical impact of the war, the financial markets in Europe are in the state of uncertainty, which will not only affect European financial markets but also drive down the Euro.

Financial markets are one of the most globalized areas, as the geopolitical conflicts escalates, this change will have long-term implications on the global financial capital markets. Europe and the United States, in particular, have imposed financial sanctions on Russia, exposing the global financial market to geopolitical risk. These policy and market changes arising from the Russia-Ukraine conflict will cause an increase in global capital risk.

Literature Review

Several studies were done in the past to understand effect of negative shock i.e., war on the global economy and stock markets. War has several adverse economic and financial effects such as a reduction in the physical capital, increased costs of financial and other counter-War regulations, damage of critical infrastructure (power plants, nuclear facilities, chemical factories, bridges, pipelines and water supply), increased economic instability, destruction of market infrastructure and operations and a decrease in investor confidence.

Carter and Simkins (2004) examined the effect of the September 11th attacks on New York in 2001 and find large significant negative abnormal returns for airfreight firms and international airlines. Further Chen and Siems (2004) examine the US capital markets response to various terrorism attacks dating back to 1915 and up to the September 11th attacks in 2001. They show that these attacks had a significant negative impact on the US capital markets but that they are more resilient than in the past and recover sooner from terrorist attacks than other global markets.

Magner and Roa (2019) did a study that investigated the effect of 13 different terrorist attacks that happened in countries like France, India, United States of America, Indonesia, Spain, England and Norway (areas with strong relations with Latin America) between period 2001 to 2018 on six main Latin American stock markets. To research this they calculated CAAR (Cumulative Average abnormal return) of 115 companies on the day of terrorist attack and next 2 days. To expand their results, they repeated process for 13 international terrorist attacks and applied eight parametric and non-parametric tests to determine stock market reactions. They estimated overall results using GARCH (1,1) model to generate non-normal returns to evaluate dependence of non-normal generating model. They found out terrorist attacks outside of US have weak and non-significant effect on Latin-America and terrorist attacks from US have strong and significant impact on Latin America stock market. The effect varied through different countries and different sectors. The most sensible countries

were Brazil, Peru and Chile and the most sensitive sectors were energy and communications. They attribute the adverse effect of terrorist attacks in US on Latin American stock market to strong correlation between them and to the adjustment in expectations of investors when an attack occurs anticipating a drop in cash flows of Latin American companies traded in local markets with strong economic connection with United States.

Schneider and Troeger (2022) examined the influence of political developments within three war regions on global financial markets - CAC (Paris), Dow Jones (New York), FTSE (London) from 1990 to 2000. Their study attempted to account for the divergent reactions of the most important financial markets to militarized conflict. They used modifications of the GARCH (1,1) model to examine the degree to which the day-to-day trading in these stock markets reflects cooperative and conflictive events within three prominent conflict regions: the confrontation between Iraq and the United Nations and some of its member states following the invasion in Kuwait, the conflict between Israel and the Palestinians, and the civil wars in Ex-Yugoslavia. They found out that for all three stock markets positive and negative shocks have an asymmetric effect. Specifically, in all three cases, negative shocks have a greater impact on volatility than positive event. They concluded that international traders only welcome conflictive events whose anticipated costs lift the uncertainty over the future course of action and promise a less costly resolution of the conflict than originally anticipated. The stock market rallies that often accompany the beginning of anticipated wars are a typical illustration of this trend. The stock market reactions to international crises largely depend on the severity of an anticipated or real international event and the collective expectation that an event will materialize. They found out that even though financial markets are highly integrated same political affects each one differently depending upon the sensitivity of each market to the event.

Boungou and Yatié (2022) studied the responses of world stock market indices to the ongoing war between Ukraine and Russia. Using daily stock market returns in a sample of 94 countries and for period between 22 January 2022 and 24 March 2022. Using panel data econometrics, they found out a negative and a stronger impact at the beginning of the war (especially two weeks after the invasion), this impact becomes weaker three to four weeks after, thus highlighting a recovery in global stock markets. They found out that the stock market indices of countries geographically close to the conflict have been the most impacted by the war and they observed a negative stock market reaction for both the countries that

condemned the invasion and those that remained neutral. However, the impact was significantly greater for the countries that condemned the invasion.

Methodology

The methodology employed for the purpose of research is quantitative in nature. The aim is to conduct the analysis and to draw the conclusion from the model formed using quantitative data.

The study aims to recognize how the global stock market indices impacted during the Russia-Ukraine war. Data of daily closing prices of NIFTY 50, NASDAQ Composite, EURO STOXX 50 and FTSE 100 have been collected from the secondary sources and then this data was further segregated as

- **Pre-war period:** from 1st October,2021 to 18th February,2022 and
- **War period:** from 21st February,2022 to 14th April,2022.

Though the war between Russia and Ukraine started on 24th February,2022, Russia had already been planning to invade Ukraine from very long. As the tensions among various countries increased and the sentiments of major investors were hurt, global stock market saw a major fluctuation in the prices of indices. The aim of the research paper is therefore to determine the amount of volatility each indices experienced.

Data on daily closing prices of indices was collected from the https://finance.yahoo.com/.

The study has deployed the closing price of these four stock market indices for analyzing the volatility in the stock market. Total 102 data points are used in the Pre-war period and 39 data points during the war period excluding the weekends.

After collecting the data from a credible source, it has been analyzed by using the programming language “Python”. Before analysis, the data is gathered in Excel and then imported into Python for the purpose of modeling.

Compound Returns Calculation:

The Compound Returns of closing price data of each index has been calculated to find how the stock price returns changed during the Pre-war period and the war period. To calculate the return, the following formula is applied:

$$R_t = ln(P_t) - ln(P_{t-1})$$

Here,

R_t=day-wise log returns;

P_t= the closing price of the stock at time t;

P_{t-1}= the previous day's closing price of the stock at time t-1;

ln= symbolizes the natural log.

After calculation of returns, in order to check whether a time series of a particular index is stationary or non-stationary, Augmented Dickey-Fuller (ADF) test and Phillips and Perron (PP) test have been used.

Augmented Dickey-Fuller Test:

ADF test adds a lagged difference term to remove autocorrelation from the series and then test the results to find out the stationarity of the data. The ADF test is based on the estimation of following model equation:

$$\Delta Y_t = \propto_0 + \gamma_1 Y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_t$$

Here,

Δ represents first difference operator;

p symbolizes lag;

$\propto_0$ represents intercept or constant term;

γ_1 and β_i are parameters;

ε_t denotes a stochastic error term.

The hypotheses for the test:

Null Hypothesis (H_0): That the time series is non-stationary.

Alternative Hypothesis (H_a): That the time series is stationary.

Phillips and Perron Test:

PP test uses nonparametric serial correlation method to take care of autocorrelation in the error term without adding lagged difference term. It is based on the estimate of the following regression:

$$\Delta Y_t = \propto + \rho y_{t-1} + \varepsilon_t$$

Here,

Δ represents first difference operator;

$\propto$ symbolizes constant;

ρ represents parameter;

ε_t denotes residual.

The hypotheses for the test:

Null Hypothesis (H_0): That the time series is non-stationary.

Alternative Hypothesis (H_a): That the time series is stationary.

Ljung-Box Test:

The Ljung-Box test checks if there is a presence of autocorrelation in a time series.

It uses the following hypotheses:

Null Hypothesis (H_0): The residuals are independently distributed.

Alternative Hypothesis (H_a): That residuals are not independently distributed, they exhibit serial correlation.

ARCH-LM Test:

An uncorrelated time series can still be serially dependent due to a dynamic conditional variance process. A time series exhibiting conditional heteroscedasticity or autocorrelation in the squared series is said to have autoregressive conditional heteroscedastic (ARCH) effects. Engle's ARCH test is a Lagrange multiplier test to assess the significance of ARCH effects.

Null Hypothesis (H_0): That the lagged regression coefficients are zero, there is no ARCH effect.

Alternative Hypothesis (H_a): That the squared residuals are autocorrelated, there is presence of ARCH effect.

These tests of stationarity will generate test statistics which is not sufficient to analyze whether a series is stationary or not, therefore, P-value is to be taken into consideration for taking an appropriate decision.

P-value:

In statistics, P-value is the probability of obtaining results by chance. It is evidence against the null hypothesis. The general rule is to compare the p-value of the test statistics to the alpha level. Alpha level is a significant value which is taken to be as 5%. If p-value >0.05, then we fail to reject the null hypothesis and therefore p-value is called as insignificant. A p-value <0.05 is considered to be highly significant and is evidence to reject the null hypothesis (H_0).

GARCH Modeling:

Modeling the financial time series of the global market indices faces a challenge due to the presence of heteroskedastic effects, meaning that the volatility of the process is not constant.

To analyze the effect of the Ukraine- Russia war on the stock market volatility, the GARCH model is used. Tim Bollerslev (1986) proposed a useful extension of the ARCH model known as the generalized ARCH (GARCH) model. In the GARCH process, the conditional mean is constant but the conditional variance is nonconstant.

A GARCH (generalised autoregressive conditionally heteroscedastic) model uses values of the past squared observations and past variances, to model the variance (σ_t^2) at time t.

A time series $\{Y_t\}$ is a GARCH model of order p, q, denoted by GARCH(p,q) can be written as follows:

$$\boldsymbol{Y_t = \sigma_t \varepsilon_t}$$

with $\{\varepsilon_t\}$ is discrete white noise with zero mean 0 and unit variance, and σ_t^2 is given by:

$$\boldsymbol{\sigma_t^2 = \omega + \propto_1 Y_{t-1}^2 + \cdots + \propto_p Y_{t-p}^2 + \beta_1 \sigma_{t-1}^2 + \cdots \beta_q \sigma_{t-q}^2}$$

In the study, the GARCH (1,1) model is used. This model is widely used in financial time series modeling.

A GARCH (1,1) process is given by:

$$Y_t = \sigma_t \varepsilon_t$$

$$\sigma_t^2 = \omega + \propto_1 Y_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

This process takes into account one past value of squared observations and one past value of volatility to model the volatility at time t.

The conditions for nonnegativity are to ensure σ_t^2 remains positive are:

$$\propto_1 \geq 0$$

$$\beta_1 \leq 1$$

$$(\propto_1 + \beta_1) < 1$$

Here,

ω is intercept term;

$\propto_1$ is coefficient of past squared observations;

β_1 is coefficient of the past volatility;

Y_{t-1}^2 is past squared observation;

σ_{t-1}^2 is past volatility.

The purpose of using the GARCH model is to find out the β_1 coefficient of the volatility for each index during both the time frames. After finding out the value of β_1 coefficient for each index, the β_1 value during Pre-war period and the War period would be compared to find out the significant change in the volatility.

Omega (ω) is the value of volatility when both past values alpha and beta are zero. That means no information of the past volatility is passed in to the model and today's volatility is zero. Omega is the intercept term of the GARCH model. It is the baseline variance for the model. Value of omega is taken to be as the amount of variance in the model if the information about the past variance was not passed to the model.

Alpha ($\propto_1$) catches the ARCH effect. Alpha [1] measures the extent to which the previous period's volatility add to today's volatility.

Beta ($\boldsymbol{\beta_1}$) coefficient catches GARCH effect. Beta coefficient represents the persistence of the volatility. Volatility is said to be persistence if today's returns have a large impact on the unconditional variance of many periods in the future. The large values of the $\boldsymbol{\beta_1}$coefficient means that large changes in the volatility today will affect future volatility for a long period of time since the decay is slower.

Value at Risk:

Value at Risk helps in quantifying the extent of probable financial losses for some confidence level within some time frame. VaR is measured by assessing the amount of potential loss, the probability of occurrence for the amount of loss and the timeframe.

The computation produces a confidence interval about the likelihood of extending a certain loss threshold when the measurement is applied to an investment portfolio. The VaR is a probability-based assessment of the minimum loss in dollar terms over a period. Investors utilize this information to make strategic investment decisions.

In the study, VaR is calculated for each index in the Pre-war period and during the War period. Below steps shows the calculation of VaR:

- Firstly, mean returns of each index would be computed.
- Secondly, standard deviation of log returns of each index would be computed.
- By taking into account the mean of log returns, standard deviation of log returns and 5% confidence level, Value at Risk of all the global stock market indices would be computed.

Portfolio Volatility:

It is a measure of portfolio risk, which refers to a portfolio's tendency to deviate from its mean return. A portfolio is made up of individual positions, each position has its own volatility measure. When all these individual variations are combined, the outcome that is generated is a single measure called Portfolio Volatility.

In this paper, the volatility of a portfolio which is made up of four stock market indices would be calculated. Following are the steps to measure portfolio volatility:

- Calculation of each index's log returns for the Pre-war period and the war periods.
- Each of the four indexes is equally weighted, with weights of 0.25 each.
- Then a Covariance matrix for each index is formed to compute how two indices change together.
- After finding out the Covariance Matrix, portfolio mean and portfolio standard deviation is calculated with the help of weights.
- Portfolio volatility is calculated by using the weights, individual volatility of the indices and covariance between the pair.

In order to calculate the portfolio volatility consisting of the four indices, following portfolio volatility formula is used:

$$\sigma_p = \sqrt{w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + w_3^2\sigma_3^2 + w_4^2\sigma_4^2 + 2w_1w_2Cov_{1,2} + 2w_2w_3Cov_{2,3} + 2w_3w_4Cov_{3,4} + 2w_1w_4Cov_{4,1}}$$

Formation of Covariance Matrix of four indices:

A covariance matrix is a square matrix that shows the covariance between each pair of elements of a given random vector. Any covariance matrix is symmetric and positive semi-definite, with variances in the major diagonal.

The covariance matrix is referred to as the variance covariance matrix, because the variance of each element is represented along the main diagonal of the matrix.

The covariance between two indices is defined as

$$Cov(X,Y) = \sum \frac{(X_i - \bar{X})(Y_i - \bar{Y})}{N} = \sum \frac{x_i y_i}{N}$$

Where,

N=Number of observations in each index;

$\bar{X}$ **and** $\bar{Y}$ **= Mean of N no. of observations in X and Y data set;**

X_i **and** Y_i **= Values in each X and Y index.**

Covariance is calculated between two variables and it measures how the two variables vary together. The covariance between two variables can be positive, negative, and zero. A

positive covariance indicates a positive relationship between the two variables whereas a negative covariance shows that they have a negative relationship. A zero covariance indicates that two elements do not vary together.

Portfolio VaR:

In order to quantify the amount of loss on portfolio, a portfolio worth of $100,000 is formed which would be then multiplied by the Value at Risk value to get the total amount of losses or volatility that would be incurred before and during the war period.

Analysis and Interpretations

This section of the paper provides a holistic representation of the obtained data in the form of graph and tables. A proper analysis of how the sentiments of the people trading in the stock market was impacted before and during the war.

The descriptive statistics of the closing price and the return of the indices, graph of each index pre and during the war, analysis of GARCH model, calculation of VaR for each index and Portfolio Volatility have been displayed below in the graphs and tables.

Table 1 presents the descriptive statistics of closing prices of each index during both the Pre-war period and the War period. Comparative analysis of how each index price was impacted during the two phases is done below. Total number of observations in Pre-war era and War era are 101 and 39 respectively.

Price analysis

It is observed that mean prices of all the indices reduced during the war period as compared to Pre-war period indicating the downfall in the closing price and adverse impact on stock prices, except FTSE100 which means it was not largely impacted during the war unlike other indices.

Median also declined during the war period except FTSE100. Maximum price of all indices in Pre-war period shown a fall during the war period. Table shows that minimum price of each index decreased during the war.

Standard deviation of the NIFTY50, EURO STOXX50 and FTSE100 increased during the War period while standard deviation of NASDAQ Composite decreased during the war

period. This implies that volatility of the all three indices except NASDAQ Composite increased during the Ukraine – Russia war.

Table 1 – Descriptive statistics of Closing Prices

	NIFTY50 (in Rs)		NASDAQ Composite (in USD)		EURO STOXX50 (in €)		FTSE100 (in £)	
	Pre-War era	During War era	Pre-War era	During War era	Pre-War era	During War era	Pre-War era	During War era
Observations	101	39	101	39	101	39	101	39
Mean	17623.36	17086.43	15037.30	13653.73	4226.67	3888.74	7340.19	7404.73
Median	17617.15	17206.65	15180.43	13643.59	4220.88	3913.72	7310.37	7473.14
Maximum	18477.10	18053.40	16057.44	14619.64	4401.49	4104.63	7672.40	7669.56
Minimum	16614.20	15863.15	13352.78	12581.22	3996.41	3599.93	6995.87	6959.48
SD	433.23	538.17	727.91	511.63	99.98	106.61	166.87	193.99
Skewness	-0.04681	-0.38559	-0.54307	-0.09220	-0.13260	-0.79538	0.08313	-0.94899
Kurtosis	-0.92615	-0.44133	-0.82861	-0.58626	-0.84217	1.16566	-0.82208	-0.06997

Table 2 represents the descriptive statistics of returns of each index during both the Pre-war period and the War period. Comparative analysis of how each index returns were impacted during the two phases is done below. Total number of observations in Pre-war era and War era are 100 and 38 respectively.

Return analysis

Below table shows that the mean returns of NIFTY50 and NASDAQ Composite increased during the war period as compared to Pre-war period. This shows that both the index was not largely impacted due to war. On the other hand, mean returns of EURO STOXX50 and FTSE100 decreased significantly, causing low and negative returns to stock market participants.

Median returns of all indices declined during the war period except FTSE100. Minimum returns of NIFTY50 and FTSE100 decreased during the as compared to Pre-war period.

However, minimum returns of NASDAQ Composite and EURO STOXX50 increased during the war period.

Standard deviation of all the indices increased during the War period, this implies that volatility of the all the indices increased during the Ukraine – Russia war.

Table 2 – Descriptive statistics of Returns

	NIFTY50 (in Rs)		NASDAQ Composite (in USD)		EURO STOXX50 (in €)		FTSE100 (in £)	
	Pre-War era	During War era	Pre-War era	During War era	Pre-War era	During War era	Pre-War era	During War era
Observations	100	38	100	38	100	38	100	38
Mean	-0.000147	0.000408	-0.000725	-0.000385	0.000229	-0.001694	0.000669	0.000460
Median	0	-0.000664	0.000336	-0.00289	0.000831	-0.002457	0	0.001112
Maximum	0.0298	0.024948	0.033513	0.036989	0.033067	0.046004	0.016201	0.038391
Minimum	-0.0311	-0.04896	-0.038082	-0.036913	-0.048599	-0.033876	-0.037113	-0.039555
SD	0.0106	0.014014	0.014502	0.019732	0.010696	0.015837	0.008276	0.014576
Skewness	-0.50098	-0.95007	-0.26434	0.259637	-0.577514	0.803767	-1.139986	-0.36238
Kurtosis	0.75244	2.92473	-0.00743	-1.052648	4.35067	2.691341	4.198611	2.43428

Time Plot

- **NIFTY50**

Figure 1 and 2 represent the time plot of NIFTY50 closing prices before and during the Russia-Ukraine war era. Before the Russia-Ukraine war, the prices of the index were smooth from 1st October,2021 till mid-November but after that it decline to some extent. But after a sharp decline NIFTY50 index showed improvement. As Russia was already planning to invade Ukraine, index started showing a dip in its closing prices. During the war, NIFTY50 showed major fluctuations in its prices. Closing prices start to fall from 23rd February the day before the war. It plummeted below Rs16000 at the start of March,2022. From April, 2022, it

showed a positive trend and went above Rs18000 as stock market sentiments improved slowly and steadily.

Figure 1: Closing Price of NIFTY50 before war

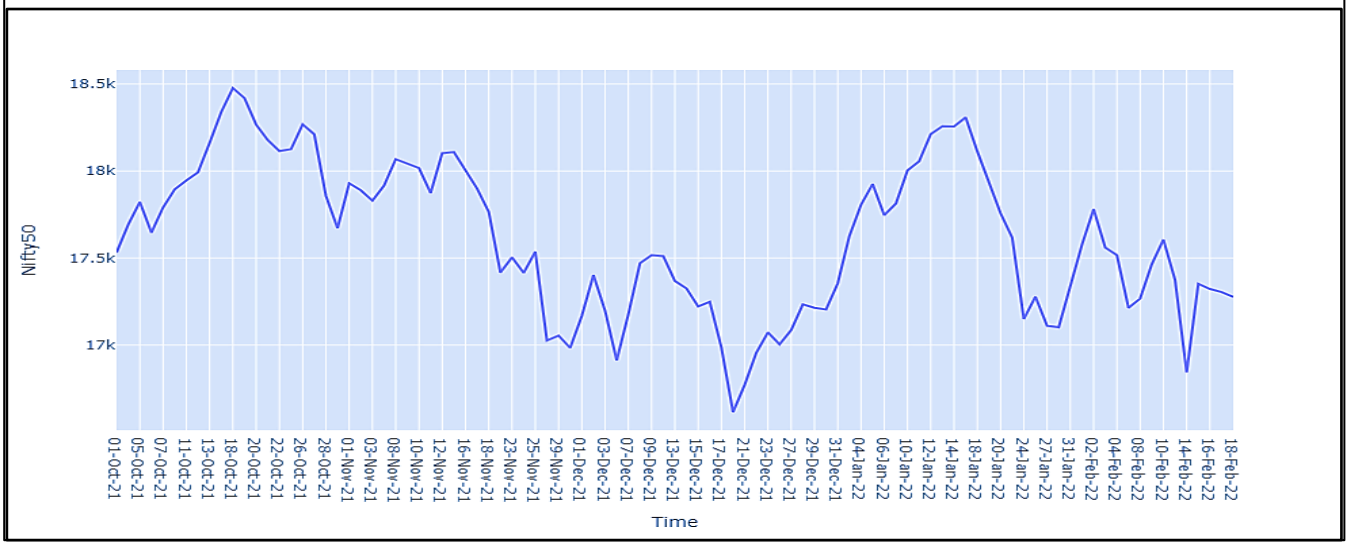


Figure 2: Closing Price of NIFTY50 during war

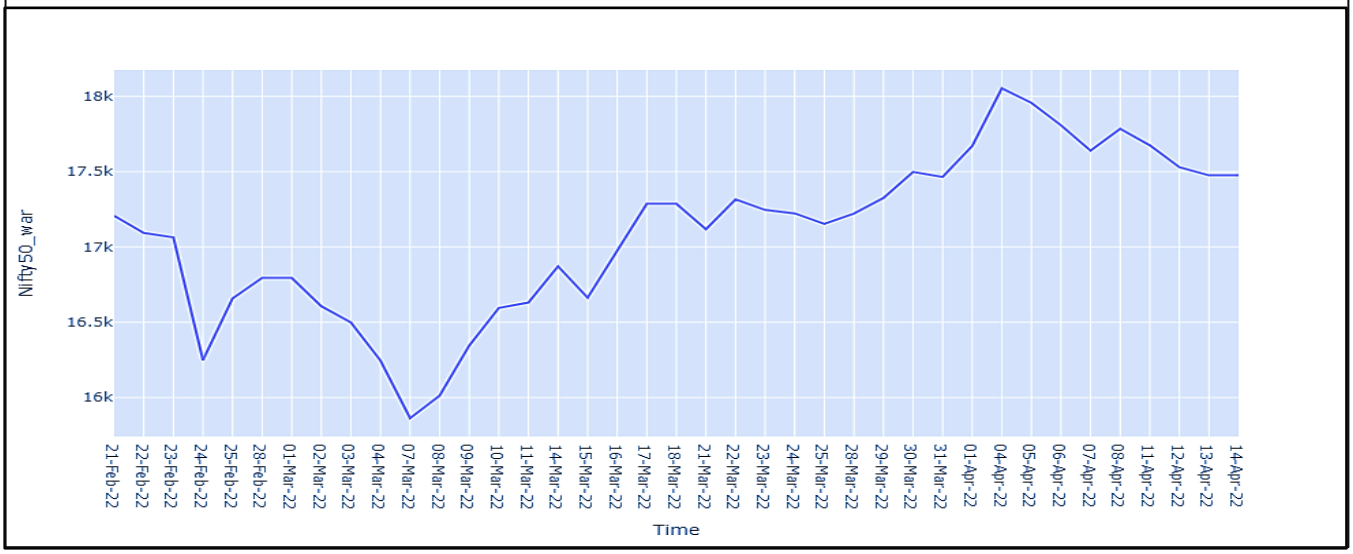


Figure 3 and 4 shows the log return of NIFTY50, during the Pre-war period and the war period. The result depicts that the log returns during the war period was more volatile as compared to pre-war era. On most of the dates, returns fluctuates between -0.01 and 0.01 before war. But as the news of war spread globally, it showed negative returns close to -0.05 on 24th February (the day on which war started) and then it showed a upward trend. Though returns showed major improvement after 25th February, but were highly volatile during the war period as compared to pre-war period. The range of

fluctuations increased from -0.01 and 0.01 to -0.02 and 0.02. Therefore, the graph illustrates that the negative returns of NIFTY50 increased during the war.

Figure 3: Log Returns of NIFTY50 before war

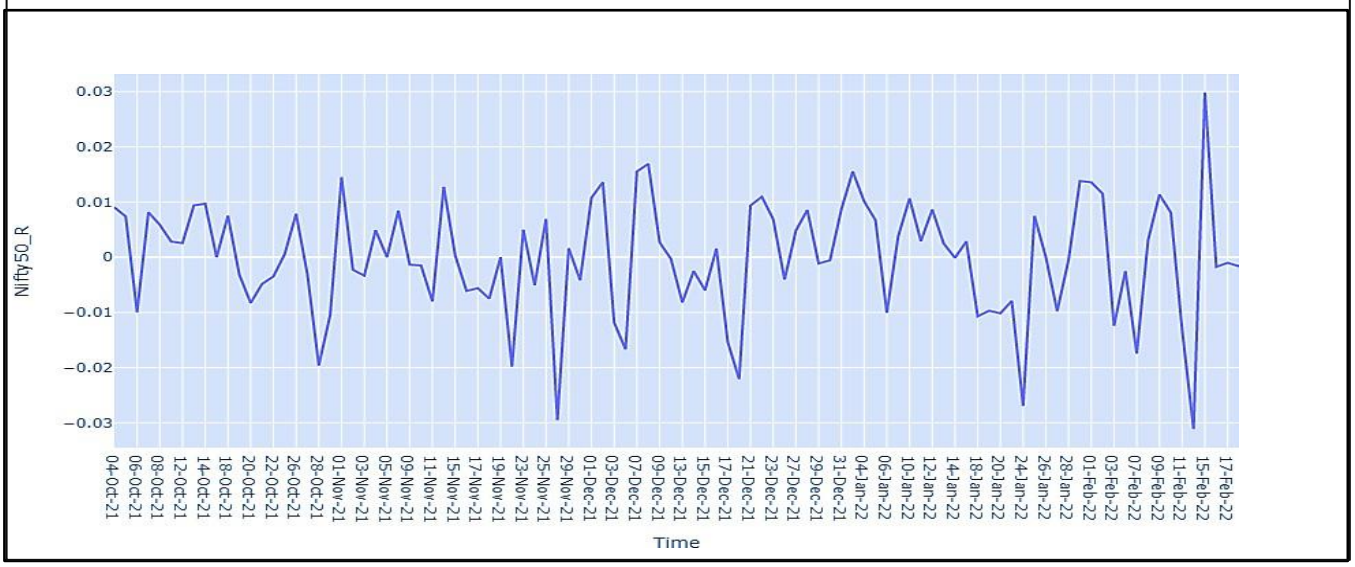
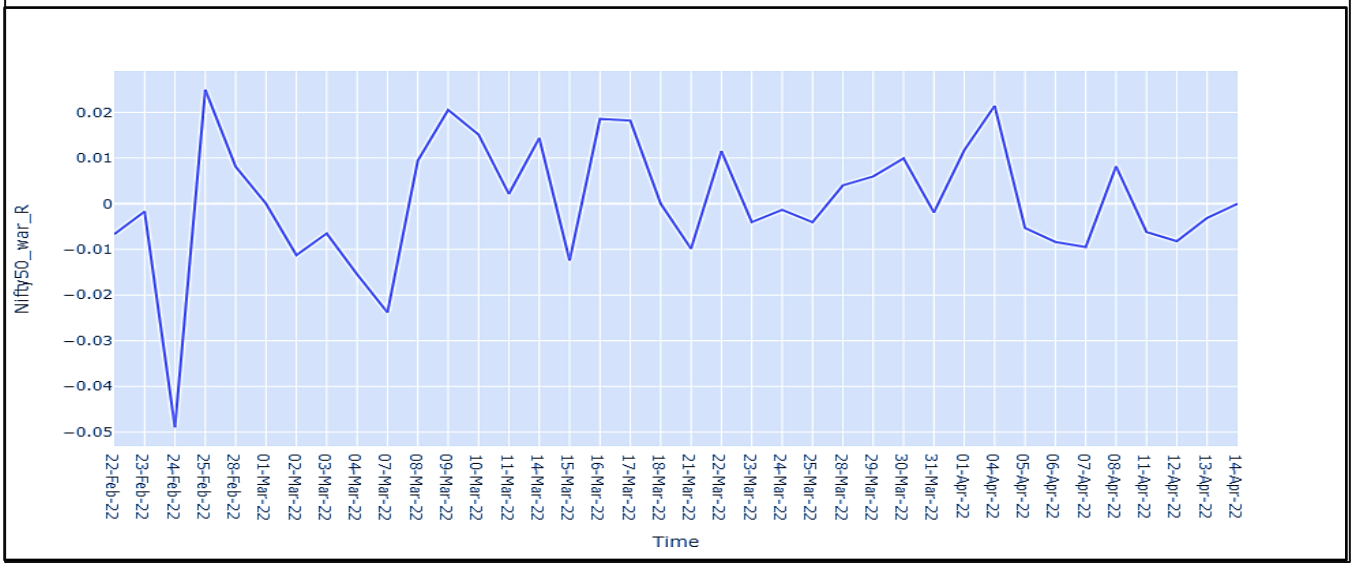


Figure 4: Log Returns of NIFTY50 during war



- **NASDAQ Composite**

Figure 5 and 6 shows the time plot of NASDAQ Composite closing prices before and during the war period. Before the war, the price of the index show less volatility in the closing prices. From 1st October, prices showed upward trend and from 4th November it showed a smooth and consistent move in the closing prices. But from 12th January,2022 prices start to

decline and were volatile. On 27th January, 2022 prices dwindled below US$ 13500 and then started increasing. As war started, closing price declined to US$13000 which then further decreased to US$12600 on 14th March, 2022. After a sharp decline in the prices, Nasdaq Composite showed an increasing trend and reached to level of US$14500. But then it again showed a decreasing trend. This analysis shows that NASDAQ Composite was highly volatile during the war period as compared to pre-war period.

Figure 5: Closing prices of NASDAQ Composite before war

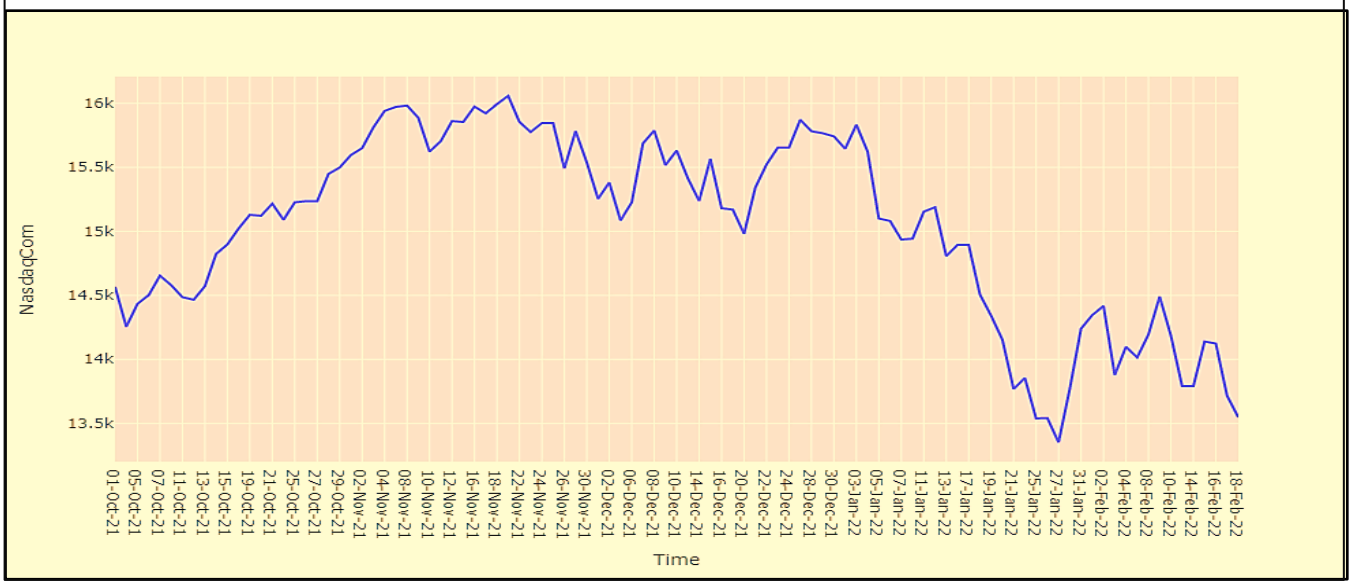


Figure 6: Closing prices of NASDAQ Composite during war

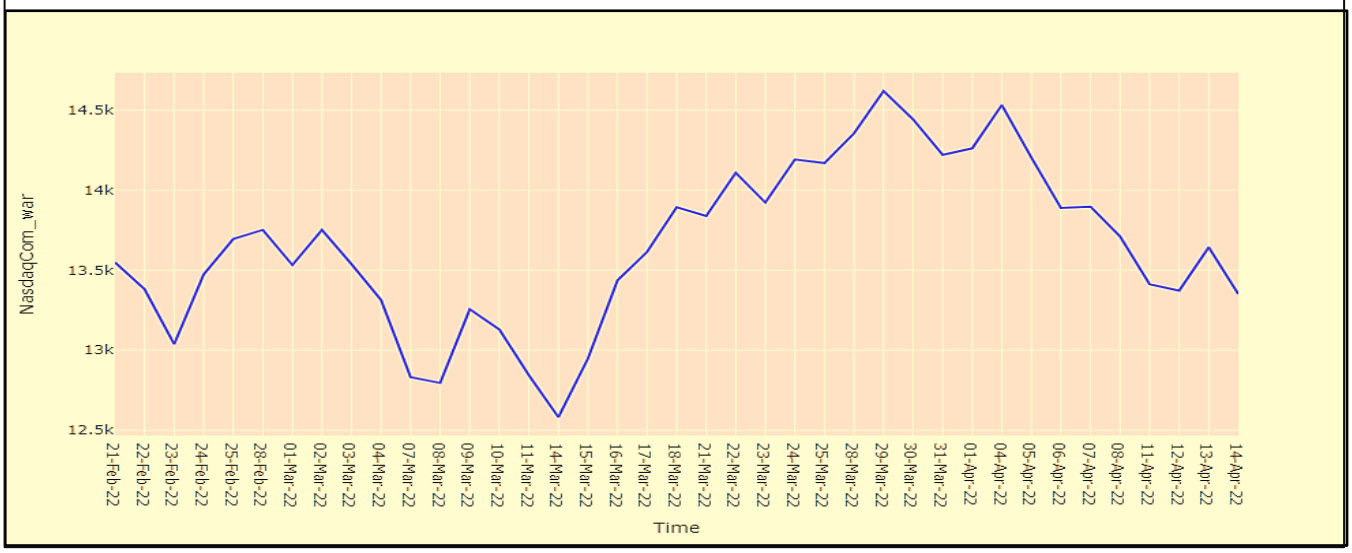


Figure 7 and 8 shows the log return of NASDAQ Composite during the Pre-war period and the war period. The result depicts that the log returns during the war period was more volatile as compared to pre-war era. Mostly log returns fluctuates between -0.02 and 0.02 before war. But as the news of war spread globally, it showed negative returns close to -0.03 on 23th February.Then it saw a sharp increase in the returns on 24th Feruary.But then it declined till 1st March. This shows that it was impacted after Russia attacked Ukraine. After that returns showed huge fluctuations. NASDAQ Composite retrusn fell more then -0.03 on 7th March.The range of fluctuations increased from -0.02 and 0.02 to -0.03 and 0.03. This shows that returns earned from NASDAQ Composite were highly volatile during the war period as compared to pre-war period.

Figure 7: Log Returns of NASDAQ Composite before war

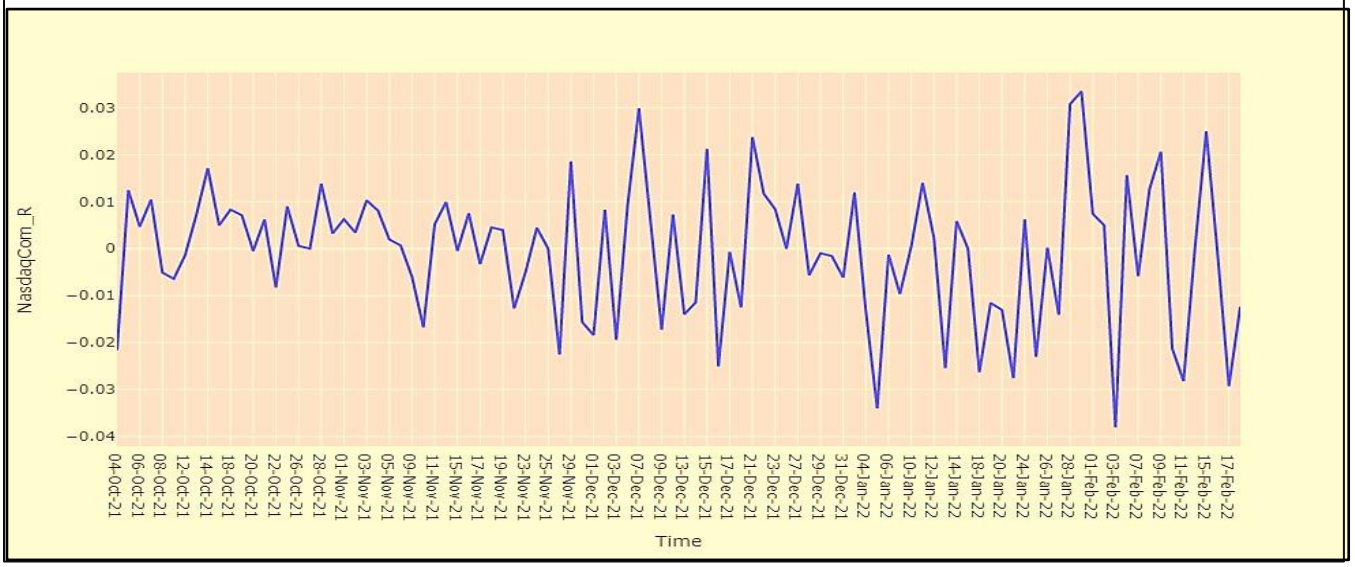
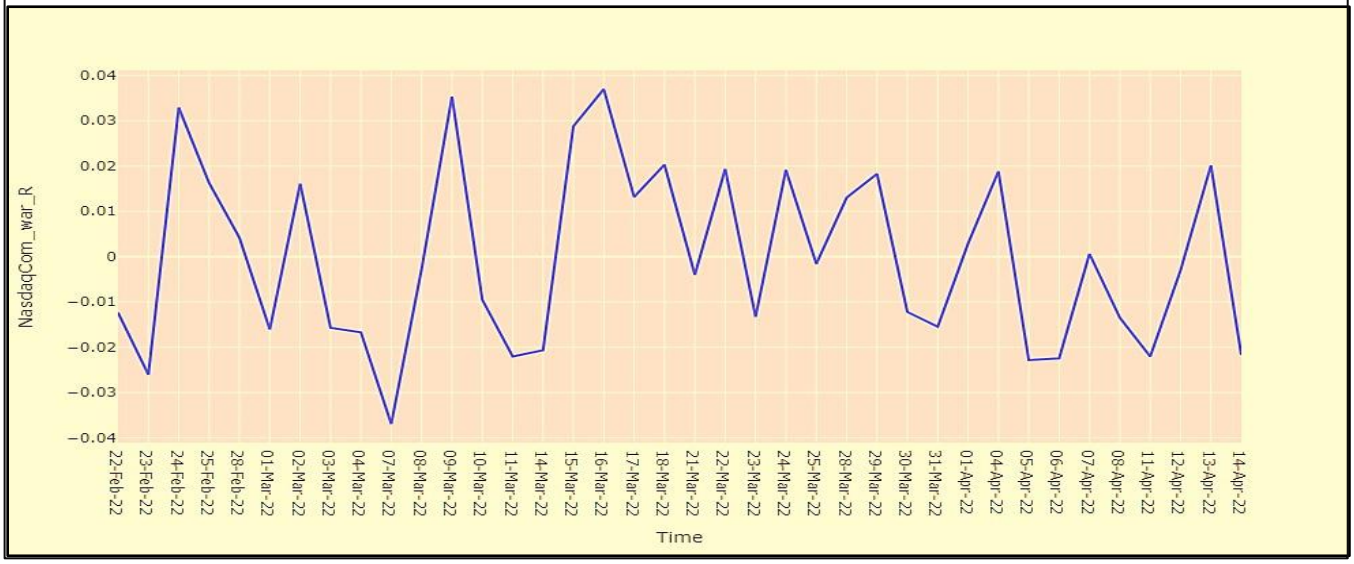


Figure 8: Log Returns of NASDAQ Composite during war



- **EURO STOXX 50**

Figure 9 and 10 shows the time plot of EURO STOXX50 closing prices before and during the war period. Before the war, the price of the index show less volatility in the closing prices. From 1st October, prices showed upward trend and reached to €4400 on 16th November. Then it declines and again showed an upward trend from 20th December to 5th January. It then plummeted to €3600 on 7th March,2022. Though, EURO STOXX50 showed recovery in its closing prices after 7th March it was highly volatile as and when the war between the two countries took place.

Figure 9: Closing prices of EURO STOXX50 before war

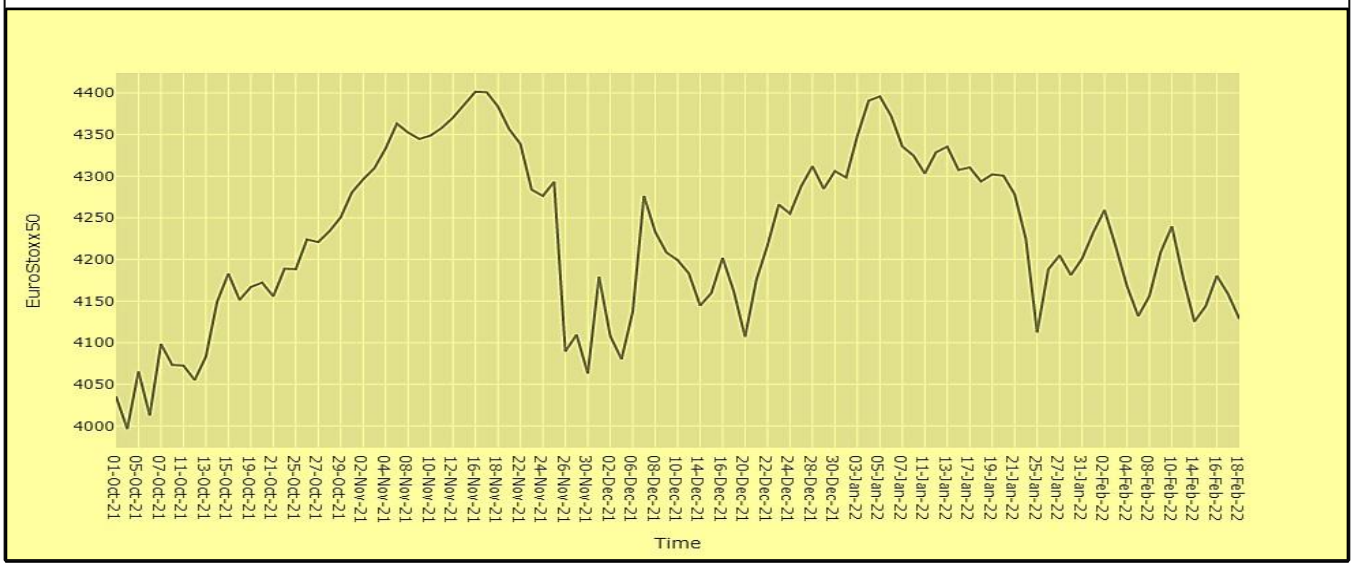


Figure 10: Closing prices of EURO STOXX50 during war

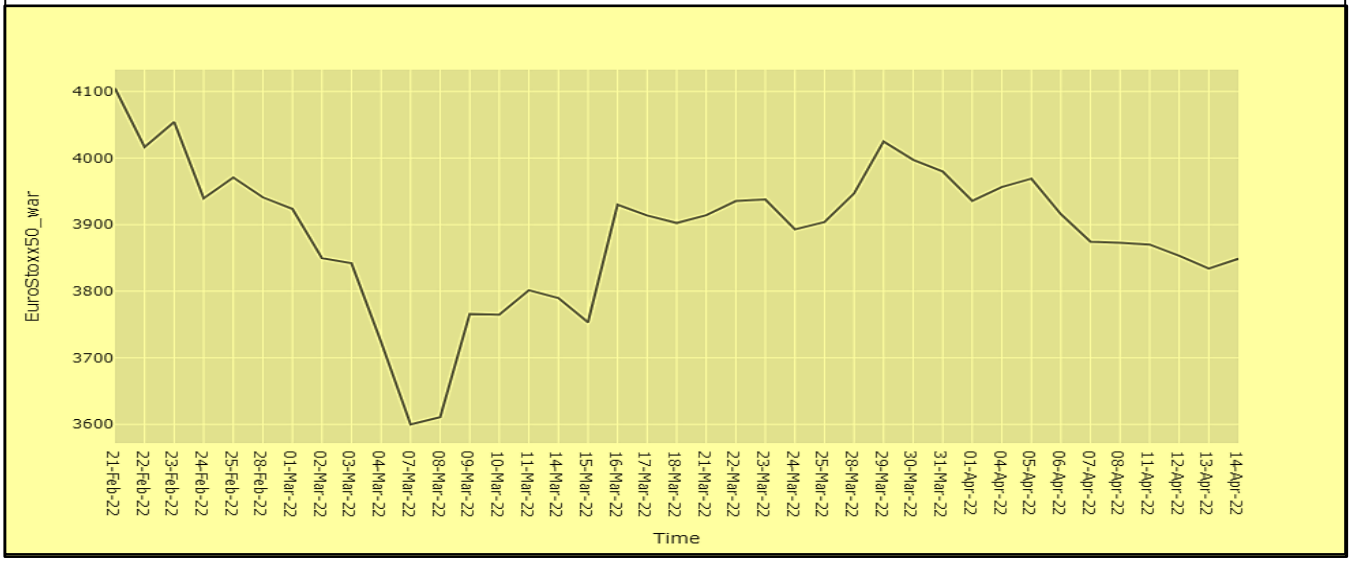


Figure 11 and 12 shows the log return of EURO STOXX50 during the Pre-war period and the war period. The result depicts that the log returns during the war period was more volatile as compared to pre-war era. Mostly log returns fluctuates between €-0.01 and €0.01 before war. But as the news of war spread globally, it showed negative returns of €-0.03 on 24th February.Then it increase to €0.01 on 25th February. It again illustrated a downward trend and reached to a lowest level on 7th February. Returns sharply incresed to €0.04 on 9th February. But after this increment, returns were highly volatality during the war period as compared to pre-war period.

Figure 11: Log Returns of EURO STOXX50 before war

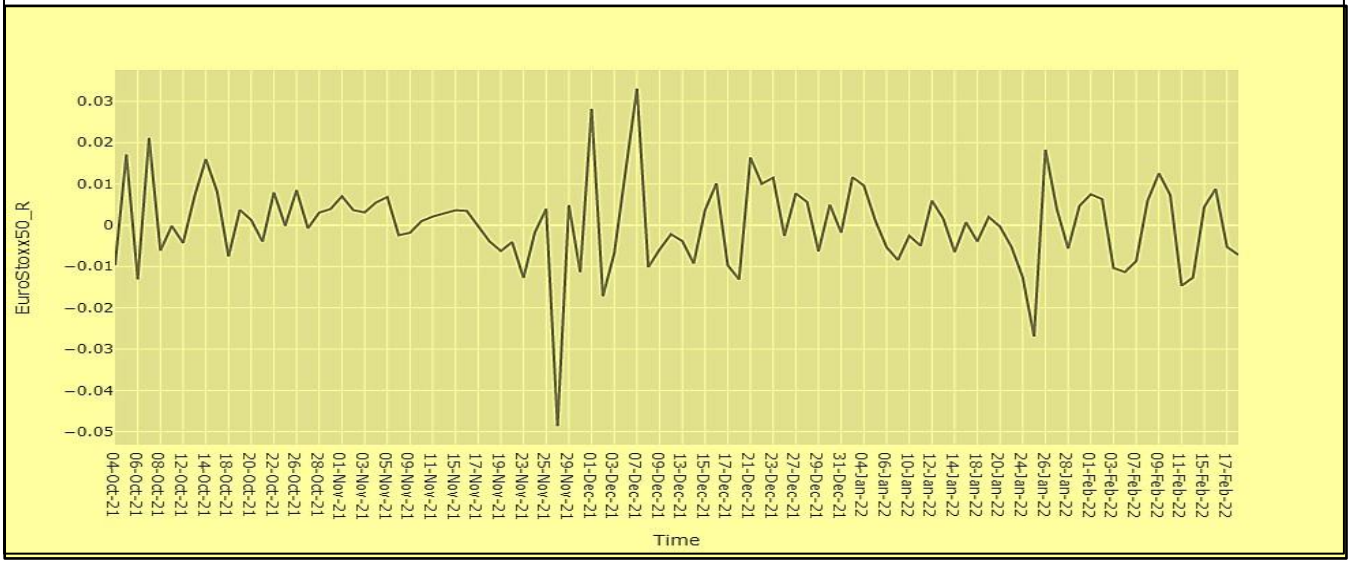
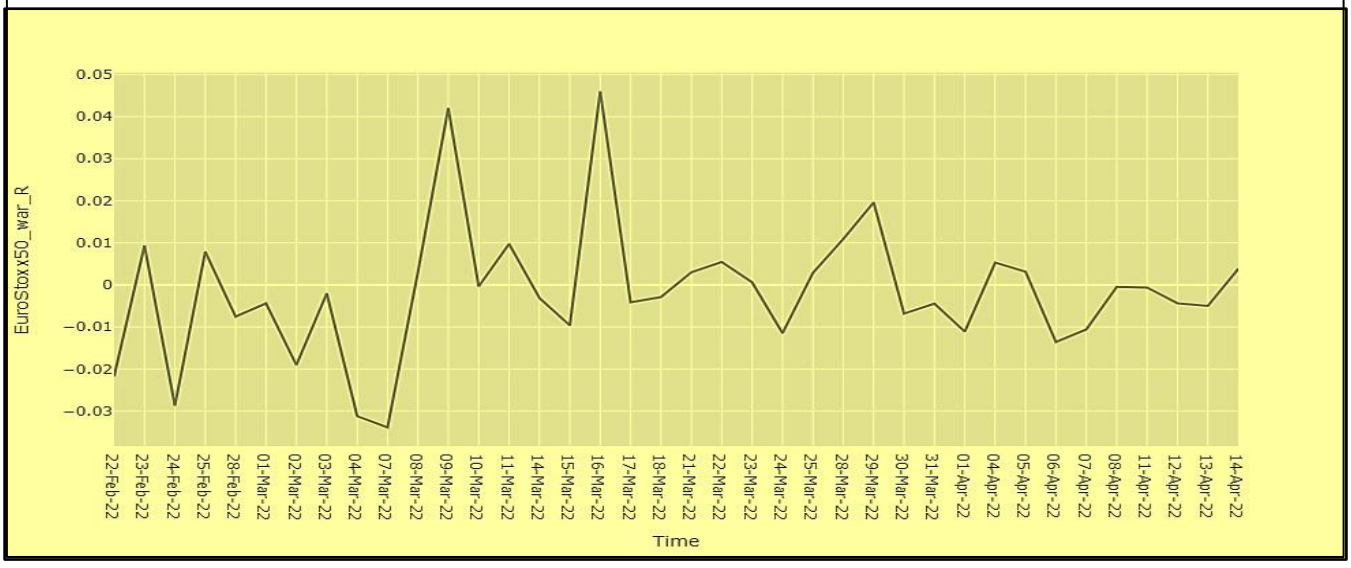


Figure 12: Log Returns of EURO STOXX50 during war



- **FTSE100**

Figure 13 and 14 shows the time plot of FTSE100 closing prices before and during the war period. Before the war, the price of the index show less volatility in the closing prices. From 1st October, prices showed upward trend and reached close to £7400 on 11the November. Then it declines and again showed an upward trend from 20th December to 19th January. It then plummeted to £7300 on 23rd January ,2022. However, it again showed a upward trend but as Russia was already planning to attack Ukraine, hurt sentiments of investors caused a decline in closing prices of FTSE100. It fell down to £7200 on 24th February and then it became highly volatile. From 4th March to 8th March, it was at its lowest at £7000. Despite strong improvements in its closing prices from 8th March, FTSE100 was highly volatile during the war period.

Figure 13: Closing prices of FTSE100 before war

Figure 14: Closing prices of FTSE100 during war

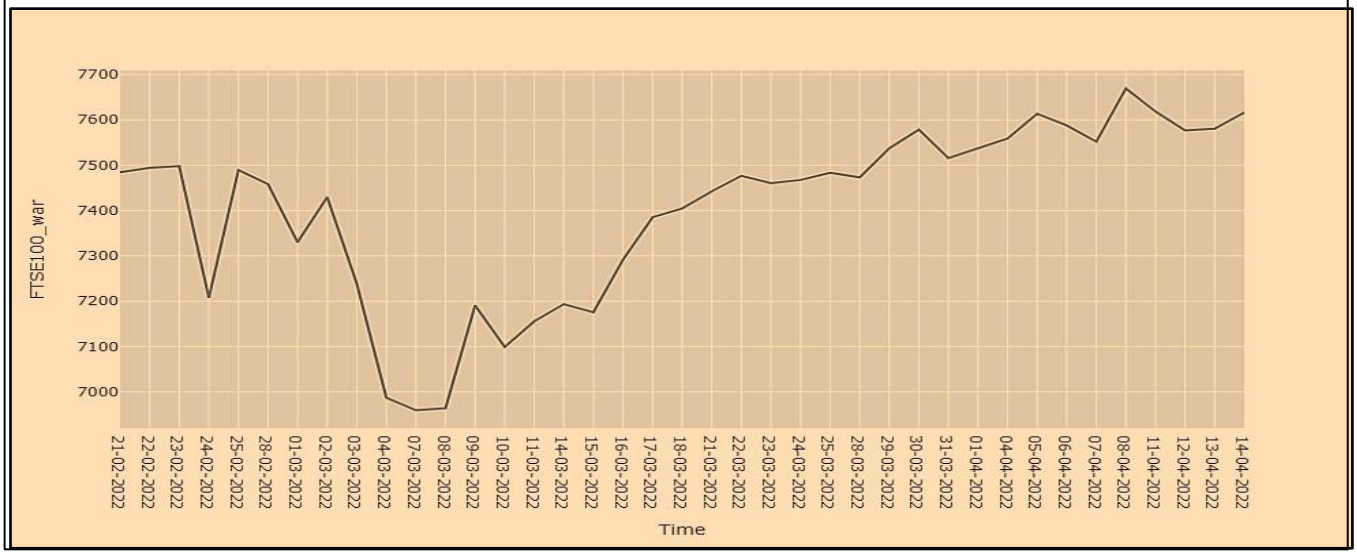


Figure 15 and 16 shows the log return of FTSE100 during the Pre-war period and the war period. The result depicts that the log returns during the war period was more volatile as compared to pre-war era. Mostly log returns fluctuates between £-0.01 and £0.01 before war. But as the news of war spread globally, it showed negative returns of £-0.04 on 24th February.Then it increase to £0.04 on 25th February. It again illustrated a downward trend till 4th Marh. Returns sharply incresed to £0.03 on 9th February. But after this increment, returns were highly volatality during the war period and were between the range of £-0.01 and £0.01 after 10th March,2022.

Figure 15: Log Returns of FTSE100 before war

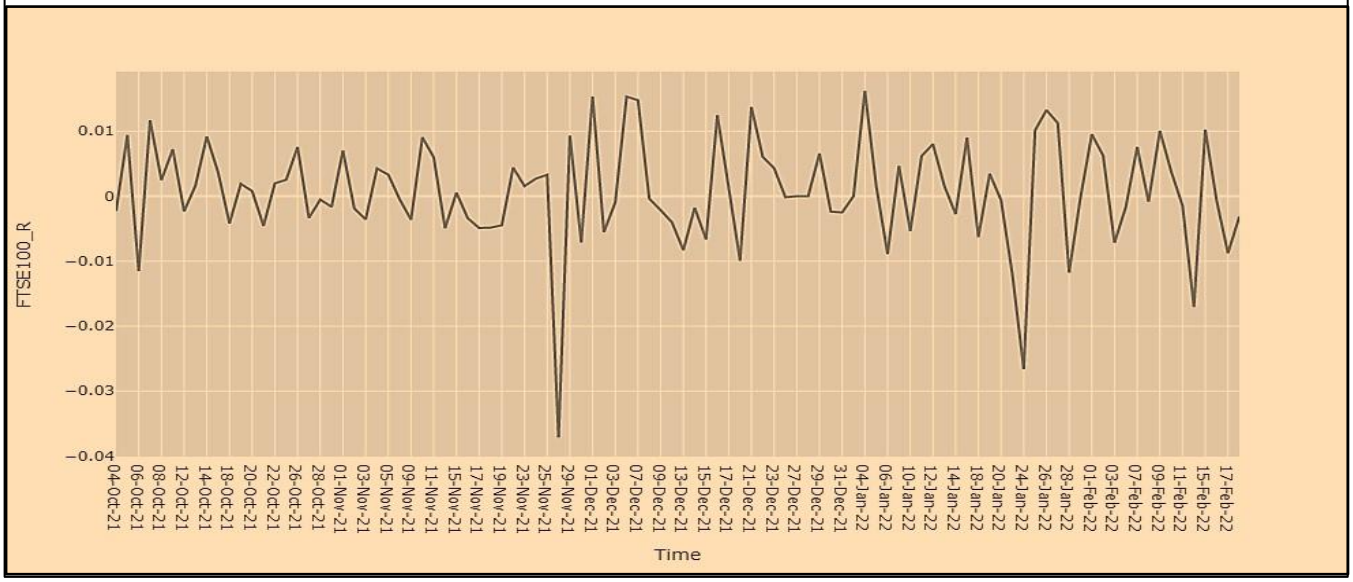
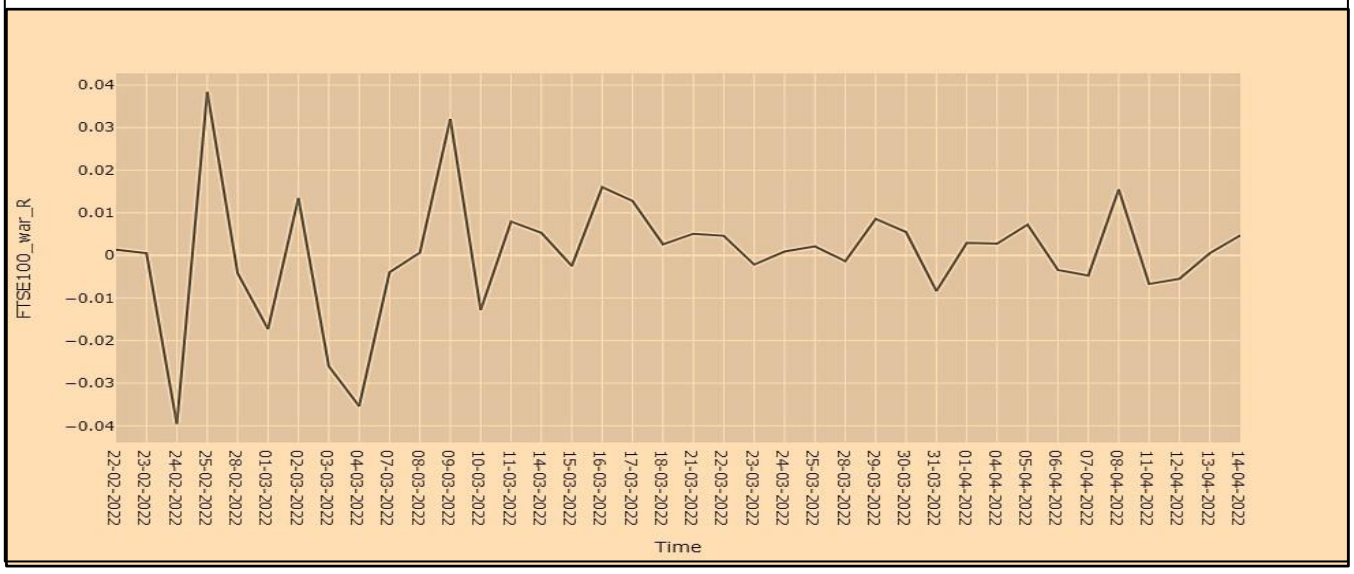


Figure 16: Log Returns of FTSE100 during war



Stationarity test of indices returns:

To check the stationarity of the indices returns, several tests has been performed.

Augmented Dickey-Fuller (ADF) test: This test is applied on all the returns of indices both before and during the Russia-Ukraine war. It tells that time series is stationary as p-value during both the period for all the indices was less than the significance level of 5%. Here, we reject the null hypothesis that time series is non-stationary.

Phillip and Perron Test: The p-value of all the indices log returns during both the period is 0. This gives strong evidence against the null hypothesis, that the time series is non-stationary. Thus, the result of this test shows that time series is stationary as p-value of 0 is less than 5% significance level.

ARCH LM Test: This test checks the amount of heteroscedasticity in the returns of all indices both before and during the war. The p-value of all the indices return is not significant. This means that p-value of the test is more than the significance level of 5%. This result indicates that we fail to reject the null hypothesis that there is no ARCH effect.

Ljung-Box Test: This test measures the serial correlation among the returns of the particular index. The p-value for each index for both the periods (Pre-war era and during-war era) is greater than 5% significance level. Here, results depict that we fail to reject the null hypothesis that returns are independently distributed and thus, there is no presence of serial correlation.

Table 3-Result of stationarity test

	NIFTY50 (in Rs)		NASDAQ Composite (in USD)		EURO STOXX50 (in €)		FTSE100 (in £)	
	Pre-War era	During War era	Pre-War era	During War era	Pre-War era	During War era	Pre-War era	During War era
ADF Test	-7.79379 (0)	-5.96610 (0)	-9.83905 (0)	-2.82789 (0.0544)	-4.68868 (0.000088)	-4.12966 (0.000865)	-7.70499 (0)	4.58882 (0.00014)
Phillip and Perron Test	-9.484(0)	-6.026(0)	-9.856(0)	-5.251(0)	-10.838(0)	-6.023(0)	12.464(0)	-7.287(0)
ARCH LM Test	12.04698 (0.44191)	10.835(0.37051)	17.55325(0.12994)	9.04557(0.52778)	14.74604(0.25562)	9.26406(0.50719)	2.97145(0.99574)	21.99996(0.15105)
Ljung-Box Test	7.07449 (0.21516)	1.293875 (0.93556)	2.528535(0.77219)	5.919689 (0.31411)	10.43269(0.06386)	1.383946(0.92606)	7.613976(0.17883)	5.751564(0.33115)

GARCH Modeling

- **NIFTY50 returns**

After applying the stationarity test, we found out that the returns of all the indices both during the Pre-war period and the war period are stationary. Here we will represent the GARCH model results of NIFTY50 returns for both the period. Table 4 and 5 represents the results of GARCH (1,1) model of NIFTY50 returns.

The mu coefficient indicates that the investor gets the return of -0.02799% per day before war but as war started the investors gets the positive return of 0.071701%.

The coefficient of ARCH (alpha [1]) was positive but insignificant, this indicates that there was no existence of the ARCH effect before and during the war.

The coefficient of GARCH (beta [1]) appeared to be zero and insignificant, which implies that volatility clustering was not present before the Russia-Ukraine war. But during the war the coefficient appeared to be positive and significant, which implies that volatility clustering was present. Our analysis suggests that NIFTY50 experienced volatility during the war, and this volatility had a substantial impact on future returns.

Table 4 – Result of GARCH model of NIFTY50 returns before war

Mean Model	Coefficients	Standard Error	t-statistics	*p*-value
mu	-2.7998e-04	1.728e-03	-0.162	0.871
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	8.3463e-05	1.499e-04	0.557	0.578
alpha[1]	0.2540	0.951	0.267	0.789
beta[1]	0.0000	2.223	0.000	1.000

Table 5 – Result of GARCH model of NIFTY50 returns during war

Mean Model	Coefficients	Standard Error	t-statistics	*p*-value
mu	7.1701e-04	1.814e-03	0.395	0.693
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	1.9131e-05	1.767e-11	1.083e+06	0.000
alpha[1]	0.0500	0.163	0.307	0.759
beta[1]	0.8500	9.653e-02	8.805	1.305e-18

- **NASDAQ Composite returns**

Here we will represent the GARCH model results of NASDAQ Composite returns for both the period. Table 6 and 7 represents the results of GARCH (1,1) model of NASDAQ Composite returns.

The mu coefficient indicates that the investor gets the return of 0.046925% per day before war but as war started the investors gets the negative return of -0.038544%. The negative returns show that as war started investors suffered from losses.

The coefficient of ARCH (alpha [1]) was positive but significant before the war, this indicates that there was existence of the ARCH effect before and during the war. On the order, insignificant p-value of alpha exhibits that there was no presence of ARCH effect during the war.

The coefficient of GARCH (beta [1]) appeared to be positive and significant during both the period, which implies that volatility clustering was present before and during the Russia-Ukraine war. Though beta coefficient is significant during both the period, beta coefficient during the war was 89% while before war it was 88%. This shows that there was a little increase in volatility during the war.

Table 6 – Result of GARCH model of NASDAQ returns before war

Mean Model	Coefficients	Standard Error	t-statistics	*p*-value
mu	4.6925e-04	3.467e-07	1353.330	0.000
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	4.1832e-06	4.351e-11	9.615e+04	0.000
alpha[1]	0.0999	5.581e-02	1.791	7.334e-02
beta[1]	0.8801	7.193e-02	12.235	2.022e-34

Table 7 – Result of GARCH model of NASDAQ returns during war

Mean Model	Coefficients	Standard Error	t-statistics	*p*-value
mu	-3.8544e-04	3.055e-03	-0.126	0.900
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	-3.8544e-04	3.055e-03	-0.126	0.900
alpha[1]	0.0100	0.221	4.523e-02	0.964
beta[1]	0.8900	0.164	5.435	5.467e-08

- **EURO STOXX50 returns**

Here we will represent the GARCH model results of EURO STOXX 5O returns for both the period. Table 8 and 9 represents the results of GARCH (1,1) model of EURO STOXX50 returns.

The mu coefficient indicates that the investor gets the return of 0.072125% per day before war but as war started the investors gets the negative return of -0.12953%. The large amount negative returns show that as war started investors suffered from huge losses.

The coefficient of ARCH (alpha[1]) was positive but insignificant, this indicates that there was no existence of the ARCH effect before and during the war.

The coefficient of GARCH (beta[1]) appeared to be positive and significant during both the period, which implies that volatility clustering was present before and during the Russia-Ukraine war. Though beta coefficient is significant during both the period, beta coefficient during the war was 78% while before war it was 58.43%. This shows that as the news about the war spread in Europe, EURO STOXX50 became highly volatile.

Table 8– Result of GARCH model of EURO STOXX50 returns before war

Mean Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
mu	7.2125e-04	1.117e-03	0.645	0.519
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	2.5940e-05	4.009e-06	6.471	9.742e-11
alpha[1]	0.2118	0.327	0.647	0.518
beta[1]	0.5843	0.241	2.425	1.532e-02

Table 9– Result of GARCH model of EURO STOXX50 returns during war

Mean Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
mu	-1.2953e-03	1.600e-03	-0.810	0.418
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	4.8842e-06	6.128e-10	7970.605	0.000
alpha[1]	0.2000	0.272	0.736	0.462
beta[1]	0.7800	0.135	5.780	7.485e-09

- **FTSE100 returns**

Here we will represent the GARCH model results of FTSE100 returns for both the period. Table 10 and 11 represents the results of GARCH (1,1) model of FTSE100 returns.

The mu coefficient indicates that the investor gets the return of 0.072914% per day before war but as war started the returns to investors increased to 0.17437%.

The coefficient of ARCH (alpha[1]) was positive but insignificant, this indicates that there was no existence of the ARCH effect before and during the war.

The coefficient of GARCH (beta[1]) appeared to be positive and significant during both the period , which implies that volatility clustering was present before and during the Russia-Ukraine war. Though beta coefficient is significant during both the period, beta coefficient during the war was 78% while before war it was 98.01%. This result shows a decline in return volatility during the war period.

Table 10– Result of GARCH model of FTSE100 returns before war

Mean Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
mu	7.2914e-04	2.715e-06	268.608	0.000
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	1.7173e-06	1.477e-11	1.163e+05	0.000
alpha[1]	2.7373e-05	0.101	2.720e-04	1.000
beta[1]	0.9801	9.613e-02	10.196	2.063e-24

Table 11– Result of GARCH model of FTSE100 returns during war

Mean Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
mu	1.7437e-03	7.267e-05	23.995	3.173e-127
Volatility Model	**Coefficients**	**Standard Error**	**t-statistics**	***p*-value**
omega	4.1415e-06	1.641e-10	2.523e+04	0.000
alpha[1]	0.2000	0.188	1.062	0.288
beta[1]	0.7800	8.771e-02	8.893	5.925e-19

Value at Risk

Here we will analyze the % amount of loss i.e., Value at Risk of each index. Table 12 represents the results of the same.

Mean returns for all the indices except EURO STOXX during the pre-war period were less as compared to mean returns during the war. This result depicts that EURO STOXX50 was largely impacted and saw a dip in its mean returns during the war as compared to other indices.

Standard deviation of returns measures the volatility in the returns of the indices. Below table shows that all the indices were more volatility during the war period as compared to pre-war era.

Below table shows the Value at Risk of each index for both pre and during the war. Value at Risk is a measurement of risk. The amount of VaR of each index tells the amount of loss that will be incurred on an index at 5% confidence level. For each index we can see the increment in VaR during the war period as compared to pre-war period. This indicates that the amount of loss to the investors during Russia-Ukraine war increased. For NIFTY50, the risk of loss i.e., VaR increased from 1.7516% to 2.264%. For NASDAQ Composite, the risk of loss increased from 2.4579% to 3.284%. For EURO STOXX50, the risk of loss increased from 1.73641% to 2.77446%. For FTSE100, the risk of loss increased from 1.294296% to 2.351477%.

Table 12- Value at Risk of each index before and during the war period

	Mean Returns		Standard Deviations of Returns		Value at Risk	
	Pre-War era	**During War era**	**Pre-War era**	**During War era**	**Pre-War era**	**During War era**
NIFTY50 (in Rs)	-0.000147	0.000408	0.010559	0.014014	-0.017516	-0.02264
NASDAQ Composite (in USD)	-0.0007249	-0.0003854	0.0145024	0.019732	-0.024579	-0.03284
EURO STOXX50 (in €)	0.0002289	-0.00169435	0.0106958	0.01583734	-0.0173641	-0.0277446
FTSE100 (in £)	0.0006695	0.000460255	0.0082758	0.0145758	-0.01294296	-0.02351477

Covariance Matrix

A covariance matrix is a square matrix that shows the covariance between each pair of elements of a given random vector.

Covariance between the two indices will increase when an event occurred has a global impact. This event is Russia -Ukraine war, which has severely impacted every country. If any event has only impacted one country and not others than covariance between the two indices won't increase. All the diagonal values are the variance of a particular index. Table 13 and 14 below shows the covariance matrix of all the indices during the pre-war period and the war period.

Table13- Covariance matrix of the indices during pre-war period

	Nifty50_R	Nasdaq100_R	EuroStoxx50_R	FTSE100_R
Nifty50_R	0.000112	0.000049	0.000053	0.000046
Nasdaq100_R	0.000049	0.000210	0.000060	0.000021
EuroStoxx50_R	0.000053	0.000060	0.000114	0.000062
FTSE100_R	0.000046	0.000021	0.000062	0.000068

Table14- Covariance matrix of the indices during war period

	Nifty50_R	Nasdaq100_R	EuroStoxx50_R	FTSE100_R
Nifty50_R	0.000196	0.000051	0.000144	0.000137
Nasdaq100_R	0.000051	0.000389	0.000109	0.000075
EuroStoxx50_R	0.000144	0.000109	0.000251	0.000136
FTSE100_R	0.000137	0.000075	0.000136	0.000212

If we compare the pre-war period covariance between the two indices to the war period, we can see that covariance during the war period increased as compared to pre-war period.

Instead of just one pair of indices showing an increment in covariance, it can be noticed from the below table that each pair of indices shows an increase in covariance. Thus, from the above analysis we can infer that the Russia-Ukraine war has a global impact as it has globally impacted the amount of returns generated from the indices. As the value of covariance of each index is positive, the positive covariance means the asset returns of two indices move together.

Thus, we can conclude that in times of fear and uncertainty i.e., in high volatility period, correlation spikes and as a result compound losses to the investor.

Portfolio Volatility of returns

As part of the research project, NIFTY50, EUROSTOXX50 and FTSE100 were taken in Rs, €s and £s, respectively. The index returns were then converted to common currency $s to calculate Portfolio Value at Risk.

The result depicts the portfolio mean, standard deviation and Value at Risk of four indices. Our portfolio consists of four indices namely NIFTY50, EURO STOXX50, NASDAQ Composite and FTSE100. Each index is provided with equal weights of 0.25. Table 15 demonstrates the Portfolio Mean, Standard deviation and Value at Risk of portfolio.

Table 15 – Results of portfolio volatility and loss

	Pre-War Era	**During War era**
Portfolio Mean	0.0001145289	-0.0004400529
Portfolio Standard Deviation	0.00735530397	0.0109320698
Value at Risk	-0.011983869	-0.018421708

These weights were then matrix multiplied by individual average returns of indices to get portfolio mean returns. Portfolio mean returns declined from 0.01145289% to -0.04400529%. This shows that the mean return of the investors declined during the Russia-Ukraine war.

The increase in portfolio standard deviation from 0.735530397% to 1.09320698%, means that volatility during the war period increased as compared to pre-war era. Portfolio standard

deviation means portfolio volatility which is calculated by using the weights of each index and individual volatility represented in the covariance matrix.

Value at Risk in above table represents the amount of portfolio loss incurred by the investor. Loss incurred by the investor increase from 1.1983869% to 1.8421708%.

If the investor would invest in the portfolio worth $100,000 having four indices with equal weights, then we can calculate the amount of Portfolio VaR during the two periods. The portfolio VaR would represent the amount of loss incurred by the investor on the portfolio made up of NIFTY50, NASDAQ Composite, EURO STOXX50 and FTSE100.

Portfolio VaR before the war:

$100,000* $0.011983869= $1198.3869

Portfolio VaR during the war:

$100,000* $0.018421708= $1842.1708

Thus, the above two figures represent that the amount of loss to the investor increased from $1198.3869 to $1842.1708. Therefore, investor increment in the amount of loss during the war was $643.7839 as compared to pre-war era.

Conclusion

Using the data of daily closing prices of NIFTY 50, NASDAQ Composite, EURO STOXX50 and FTSE 100, it was found that the returns of all the stock indices taken under consideration saw increase in volatility during war period as compared to pre-war period. We also observe that Russia-Ukraine war increases the covariance amongst all the indices i.e., extent to which all the four indices move in same direction (here in positive direction i.e., if one index increases other also increases) increased during war period as compared to before war began. When the daily returns of each index were subjected to GARCH(1,1) process, it was found that the level of sensitivity exhibited by each index is different when the comparison is done between pre-war period and during war period - We see that the NIFTY50 returns experienced significantly increased volatility whereas NASDAQ Composite returns showed only a little increase (i.e. 1%) during war period , EURO STOXX50 also witnessed increase in volatility by approximately 20% and FTSE1OO returns show an exceptional behavior by witnessing reduction in volatility during war period as compared to before. By using Value at Risk technique and calculation of portfolio volatility of a portfolio consisting of all the four

indices with equal weightage, it was observed that during the war period amount of loss faced by global stock markets increased.

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