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Relationship between the Rainfall Index and Stock/Agri-commodity Market Indices: Empirical Evidence from India

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Abstract

The rainfall, stock, and agri-commodity indices are the economic indicators for Indian economy. Therefore, research is needed to explore the complex relationship between rainfall and economic indicators and its long-term implications. Only a few studies are available on this relationship, and no study gives complete, conclusive evidence on this relationship. Therefore, the present study focused on determining whether there is any relationship between the rainfall index and stock/agri-commodity indices. This study employed the advanced statistical tools like ADF test, correlation, Granger causality test, and GARCH (1,1) model. The research utilized the monthly average rainfall index and the Sensex index from 1991 to 2020. Similarly, the study employed the monthly average Guarex agri-commodity index for the period from 2018 to 2020. The study found that there is no relationship and causality relationship between the rainfall index and the Sensex index. The GARCH (1,1) model shows that the rainfall index has no impact on the volatility of the Sensex index. There is a moderately negative correlation between the rainfall index and the Guarex index, and rainfall affects the volatility of the Guarex index. This shows that the rainfall index can be a distinct asset class that can be traded through rainfall derivatives. In order to launch rainfall derivatives in India, NCDEX and Skeymet Industries have already approached the SEBI for permission.

Keywords: Guarex Agri-Commodity Index, Rainfall Index, Rainfall Derivatives, Sensex Index, Unique Asset Class

1. Introduction

Rainfall variability is the source of financial losses for farmers, manufacturers, construction companies, financial lending institutions, service industries, and others who are directly or indirectly affected by rainfall risk. The BSE Sensex is the economic indicator of the top thirty BSE-listed companies. The Guarex agri commodity index is the price index of the Guarex agri commodity, which is listed and traded on the National Commodity and Derivatives Exchange (NCDEX). The study looks at how the Sensex and the agri-commodity indices relate to the rainfall index. The study of rainfall weather factors in conjunction with financial and commodity market indicators drew investors, farmers, hedgers, speculators, insurance companies, reinsurance companies, and others affected by rainfall variability. Certain studies present conflicting and equivocal findings regarding the correlation between rainfall and stock/agri commodity indices. For example, temperature affected investors' decisions, which led to volatility and lower returns on the Sensex and Nifty stock market indices. Along with weather variables, economic factors also determine stock market prices (Sigo, 2017). The post-monsoon BSE SENSEX return showed positive returns and was higher than the pre-

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monsoon BSE SENSEX return. Accordingly, the BSE SENSEX returns were impacted by the monsoon (Vachhrajani *et al.,* 2014). The weather variables, like rain and snow, were unrelated to stock returns (Hirshleifer & Shumway, 2003). The present study is being conducted in order to present solid, empirical evidence regarding this relationship. The empirical study result helps to consider the rainfall index as a unique asset class like stock and commodity indices to trade in the weather risk market. This rainfall index may be used as a distinct asset class for trading purposes in order to resolve the rainfall risk in India. Furthermore, the inclusion of the rainfall index as a distinct asset class in the rainfall risk market (which comprises insurance, reinsurance, and rainfall derivatives) could provide investors with an additional avenue for diversification and hedging against rainfall-related risk.

The rainfall derivatives contracts can be designed as Over The Counter (OTC) as well as exchange-traded products. Several research studies have tried to design the rainfall derivative contracts based on the Deficit Rainfall Days/Excess Rainfall Days (DRD/ERD) indices, just like the Heating Degree Days/Cooling Degree Days (HDD/CDD) indices for the temperature derivatives. Rainfall derivatives contacts are viable rainfall risk hedging tools for the weather risk market. The purchaser of DRD/ERD contracts receives payoff for the difference between the strike DRD/ERD indices (i.e., the agreed rainfall index) and the actual DRD/ERD indices. The strike quantity of the DRD/ERD is based on the historical average rainfall where hedgers wish to take the rainfall derivative contracts. For example, if the historical average rainfall for June to September in a particular area were 600 mm, a four-month RIBF contract strike DRD/ERD would be approximately 600 mm. The actual rainfall over a period of four months determines the payoff of the rainfall derivatives contracts. A predetermined rupee value for each mm, either excess or deficit, would determine the payoff of the rainfall derivatives contracts. The payoff is either received or paid depending on whether the actual rainfall is above or below the predetermined rainfall level. However, the rainfall derivatives market will be useful only if it is liquid. This requires the rainfall derivatives contracts to be listed on any stock exchange. This would not only benefit the traders in India but also contribute to the overall stability and efficiency of the financial market. The reminder of the paper is organized as follows: In the second part, the paper includes an available review of the literature on the relationship between the selected variables and its gap. In the third section, the paper briefly describes the methodology used to analyse the empirical data by using various statistical and econometric tools. Eventually, the paper will demonstrate the results and conclude.

2. Review of Literature

The total available literature is divided into two parts. The first part explains the literature available at the global level, and the second part explains the literature available in India. Both parts provide valuable insights into the diverse range of literature from different regions.

Jeong (2012) looked at how the stock market return and trading volume were affected by weather factors like temperature, relative humidity, sea level pressure, and precipitation. The study found a significant correlation between temperature, humidity, sea level pressure, and precipitation and the return of the SPY stock indices. Silva *et al*. (2017) studied the impact of extreme rainfall on the share prices of food industries in Brazil. Rainfall had a 76.5% significant impact on BSF Brazil, resulting in a 0.66% average loss the next day. It was the least affected industry because it was concerned about holding weather derivatives. According to the study, JBS had a 52.38% effect of rainfall and BSF had a 76.56% effect of extreme rainfall, with only a 0.66% loss in share value because this company was taking weather derivative positions. Wang and Markellos (2016) studied the impact of weather on 31 countries' stock index trading volumes. The study considered weather variables like cloud cover, precipitation, and temperature. The empirical analysis shows that precipitation and temperature were positively linked to trading volume, while snow had a negative impact on trading volume. Shahzad (2019) showed that meteorological factors had an impact on Shanghai and Hong Kong stock market performance. High volatility was seen for temperature, wind speed, rain, and cloud

cover when compared to other chosen meteorological variables. This suggests that meteorological factors may have had an impact on the stock market performance in Taiwan and Shenzhen.

Bhanumurthy *et al*. (2013) analysed the impact of rainfall variability on the price of agricultural commodities in spot and futures markets in India. The correlation matrix depicted a high correlation between spot and futures prices, while the rainfall correlation with the other selected variables was weak and insignificant. The co-integration result revealed that there was a strong long-run correlation between agricultural commodity futures prices and spot prices and that rainfall significantly affected both spot and futures prices of agricultural commodities in the long run. Sheikh *et al*. (2017) reported that sadness and rainfall had significant positive effects on returns and condensed the volatility in the Indian stock markets, while the moon's size or temperature increased the volatility in the Indian stock markets. Kathiravan *et al*. (2019) investigated the connection between meteorological variables and stock market indices. The analysis included market indices like the BSE Sensex and CNX Nifty as well as the returns of Delhi meteorological variables including humidity, temperature, and wind speed. The correlation matrix shown that the returns of meteorological data and stock market indices had no relationship. In the end, the author came to the conclusion that these findings can be used to diversify portfolios by investors, speculators, and stock exchange regulators. Bajaj (2019) recognized the consequence of the monsoon rainfall on the Indian stock market as well as the impact of the monsoon rainfall on the volatility of returns in NSE stock indices. The study found that the effect of the monsoon present during the month of September and the return of the Nifty 50 and Nifty 500 indices caused an increase in volatility during this September month. But no effects were found in the monsoon month for the return of the Midcap 100 and the Nifty Small Cap 100. The author finally opined that the monsoon effect was found only for the top Nifty 50 and Nifty 500 stocks listed on the NSE. Narula *et al*. (2021) examined the correlation between rainfall and the Nifty 50 sectoral indices. The correlation research showed a negligible and insignificant relationship between precipitation and stock index returns. As a result, the Nifty 50's returns are unaffected by the level of rainfall. The study's other component, the GARCH model, demonstrated that precipitation had an inverse relationship with stock index return volatility, i.e., that as rainfall increased, stock index return volatility decreased, and vice versa. Nagarajan *et al*. (2021) examined the impact of the Indian Summer Monsoon Rainfall (ISMR) forecast announcement on the Cumulative Average Abnormal Return (CAARs) of NSE CNX 500 stocks. In the post-announcement period, CAARs were found to be positive for forecasts of normal ISMR and negative for forecasts of below-normal ISMR. However, for the ISMR pre-announcement, the CAARs were favourable for forecasts that were both normal and below normal. Thus, the author deduced that ISMR had an impact on the Indian economy and business performance. Dileep and Kotreshwar (2022) examined the relationship between the Nifty index and the rainfall index for the years 1991–2020. The results of the empirical analysis showed that there was no correlation between the study's variables and no Granger causal connection. The GARCH (1,1) model also shows that the rainfall index has no impact on the Nifty index. This suggests that fluctuations in rainfall do not significantly influence the performance of the Nifty index. Further research could explore other potential factors that may affect stock market movements in India.

3. Research Gap

The previous studies compared weather factors like temperature, cloud cover, humidity, wind speed, snowfall, and other weather variables with the stock and commodity market indices' returns and volatility. Some studies have shown the effects of weather variables on stock and commodity market indices' returns and volatility. Only a few studies on the relationship between rainfall and stock/commodity market indices are available. In the case of India, only a few studies were available to review, and they did not consider the data for a longer study period of 30 years. Even the available studies have shown inconclusive results, and there is no conclusive proof of the relationship between rainfall and stock market/agri commodity indices.

Therefore, it is considered necessary for the study to draw an empirical conclusion on the relationship between the selected variables. The rainfall may be directly or indirectly related to the stock and agri-commodity indices. Therefore, the present study empirically tested the relationship between the selected variables. Thus, a thorough analysis is carried out to ascertain the link between the chosen variables. The results of this analysis will contribute to the existing body of knowledge in this field.

4. Research Methodology

The purpose of current research is to analyse the interrelationship between rainfall and Sensex stock market/Guarex agri commodity indices. The specific objectives and hypotheses are listed in the next section.

4.1 Objectives

1. To investigate the relationship between the rainfall index and the BSE Sensex index.
2. To ascertain whether the rainfall index is Granger Cause the BSE Sensex index.
3. To examine the impact of the rainfall index on the volatility of the BSE Sensex index.
4. To investigate the association between the rainfall index and Guarex agri-commodity index.
5. To analyse the impact of the rainfall index on the Guarex Agri Commodity index volatility.

4.2 Hypotheses

1. H_0: "There is no interrelationship between the rainfall index and the BSE Sensex index."

H_1: "There exists an interrelationship between the rainfall index and the BSE Sensex index."

2. H_0: "The rainfall index is not Granger Cause the BSE Sensex index."

H_1: "The rainfall index does Granger Cause BSE Sensex index.

3. H_0:"The volatility of the BSE Sensex index is not affected by the rainfall index."

$H_{1:}$ "The volatility of the BSE Sensex index is affected by the rainfall index."

4. H_0: "There is no relationship between the rainfall index and the Guarex agri commodity index".

H_1: "There is a relationship between the rainfall index and the Guarex agri commodity index".

5. H_0: "The Guarex Agri commodity index is not affected by the rainfall index".

H_1: "The Guarex Agri commodity index is affected by the rainfall index".

The study employed the Augmented Dickey Fuller test (ADF) test, correlation, Granger causality test, and GARCH (1,1) tools. The ADF test was used to check for stationarity, the correlation was used to analyse relationships between variables, and the Granger causality test was used to determine if one variable could predict another. Additionally, GARCH (1,1) was used to model and forecast the selected variable volatility. The current study makes the assumption that one rainfall index point corresponds to one millimeter of rainfall. The study used the closing prices of the Guarex and Sensex indices. The selected variables are converted into returns. Eight lags were used in the study, and they were chosen using the Vector Autoregressive (VAR) lag selection criterion. The research employed the subsequent equations:

$$BSt=C1*RIt\text{-}i + C2*BS\ t\text{-}j + u1t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

Rainfall Index (RI), Coefficient of NSE Guarex (C1), Lag Period for BSE Sensex (t-i), Lag Period for Rainfall Index (t-j), and Residual for Equation (u1t) are the acronyms used.

To determine the impact of the rainfall index on the Sensex and Guarex indices, the GARCH (1,1) model is used rather than the OLS regression. Because the data has a heteroscedasticity effect because the variance of the error terms is asymmetrical or unequal (Shah *et al*., 2018). The conditional and mean equations for the GARCH (1,1) model used in this study are listed below:

$$\sigma_t^2 = \omega + \alpha r_{t-1}^2 + \beta \sigma_{t-1}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$BS_t=C_0+C_1\ BS_{t-1}+C_t\ RI_t+\varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$GI_t=C_0+C_1\ GI_{t-1}+C_t\ RI_t+\varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where the ARCH term is r_{t-1}^2 and the GARCH term is σ_{t-1}^2.

In the following, BS stands for the BSE Sensex index at time t and time t-1, GI for the Guarex agri commodity index at time t and time t-1, RI for the rainfall index at time t, C for the constant, ″ε″ for an error term, and ″ω″ for the constant.

4.3 Data

The study was restricted to the period from 1991 to 2020 because of the non-availability of recent year's data. For statistical analysis, the study included monthly BSE Sensex and rainfall data over a 30-year period, from January 1991 to December 2020. The Guarex index data was available from 2018 onward. Therefore, the study employed the monthly Guarex agri-commodity index for the period 2018–2020. The monthly average rainfall data for all 36 meteorological subdivisions was obtained from the Indian Metrological Department website, http://www.imd.gov.in. The BSE Sensex data from http://www.nseindia.com/ and the Guarex agricultural commodities index data were collected from the NCDEX website, https://www.ncdex.com.

5. Empirical Analysis of Rainfall Index and Stock and Commodity Market Indices

The results of the ADF test, correlation analysis, descriptive statistics, and the GARCH model are covered in this section. The rainfall, Sensex, and Guarex data were loaded into the SPSS and E Views software to get the outcome of the tests. Based on the objectives and hypotheses of the research, the empirical data is evaluated. The tools used in this study are based on past literature: Bhanumurthy *et al*., (2013); Abdul *et al*., (2015); Vijayakumar *et al*., (2015); Syed *et al*., (2017); Shah *et al*., (2018); Kathiravan *et al*., (2019); Bajaj *et al*., (2019); Narula *et al*., (2021); and Dileep & Kotreshwar (2022).

5.1 Results of Descriptive Statistics

The empirical analysis begins with the descriptive statistics. Table 1 displays the findings of the descriptive statistics for the rainfall, Sensex, and Guarex indices. The mean value shows the average monthly value of the rainfall, the Sensex, and the Guarex agri-commodity indices. The rainfall index has 114.7198, the Sensex has 13626.81, and the Guarex has 4945.148. The minimum monthly rainfall, Sensex, and Guarex values are 1.744444 mm, 982.3200, and 4156.896, respectively. Similarly, the maximum monthly rainfall, the Sensex, and the Guarex indices are 404.7500 mm, 47751.33, and 5566.300 mm, respectively. In terms of volatility and dispersion, the rainfall index is at 112.1083, the Sensex is at 11767.40, and the Guarex index has a value of 429.7851. The higher the standard deviation, the greater the risk, and the greater the risk, the greater the returns on the Sensex and Gaurex indices. The skewness values of the rainfall and Sensex indices are positively skewed, with values of 0.886427 and 0.836549, respectively. The Guarex index is negatively skewed and falls under the left tail, with a value of -0.164187. The kurtosis value of rainfall, the Sensex and Guarex indices are positive, with values of 2.383607, 2.501553, and 1.889550, respectively. According to the Jarque-Bera test, the calculated p-values are less than 0.05; therefore, the rainfall and Sensex indices are not normally distributed. As a result, reject the null hypothesis of "normal distribution" and accept the alternative hypothesis of "non-normal distribution" for rainfall and Sensex indices. The p value of the Jarque-Bera test indicates that the Guarex agri-commodity index data are normally distributed.

5.2 Results of Augmented Dickey-Fuller Test

The stationarity between the rainfall, Sensex, and Guarex indices is examined using the ADF test. The selected time series data should be stationary to run the selected statistical tools in this study. The ADF test statistics show the logged values of selected indices and the differenced values of selected indices. The null hypothesis of the ADF test is that the Rainfall, Sensex, and Guarex indices all have a unit root or are non-stationary. The alternative hypothesis is that the selected indices are stationary. If the p-value is less than the significance level of 0.05, reject the null hypothesis and conclude that the indices

are stationary. If the p-value is greater than or equal to 0.05, accept the null hypothesis.

Table 2 shows the results of the ADF unit root test at 5% significance levels, along with the corresponding P values. The rainfall index's ADF test statistic value is -4.101530, which is higher than the critical value of -3.144920 and the P value, which is less than 0.05. As a result, the rainfall index is stationary at level. In contrast, the Sensex and Guarex's ADF test statistics values are 1.364404 and -0.728054, respectively, which are below the test critical values of -2.863974 and -3.119910 at 5% significance levels. Similarly, the Sensex and Guarex have corresponding P values that are greater than 0.05. Therefore, the Sensex and Guarex indices are non-stationary at level. Therefore, the null hypothesis, "existence of a unit root," is accepted for Sensex and Guarex and rejected for the rainfall index. Thus, the outcome demonstrates that the Sensex and Guarex indices are non-stationary at level, i.e., their mean and variance values do not remain constant over time.

The ADF test at first difference shows that the test statistic values of the Sensex and Guarex indices are -18.11878 and -6.591713, respectively, which are greater than the critical values of -2.869396 and -3.119910 at a 5% significant level. The tests' P values are less than 0.05. Therefore, for the Sensex and Guarex indices, the null hypothesis that the existence of a unit root exists is rejected. In light of the findings, it can be concluded that the Sensex and Guarex indices are stationary at their initial difference (I(1)). It indicates that over time, the Sensex and Guarex indices' mean, and variance remain constant. This suggests that the Sensex and Guarex indices do not exhibit a trend and are likely to revert to their mean values over time. The stationary nature of these indices implies that they may be suitable for time series analysis and forecasting.

5.3 Outcomes of Correlation

The most popular method for establishing an association between the variables chosen for the study is Pearson's correlation. The study establishes the association between the selected variables, and the results are shown in Table 3. Correlation values range from -1 to +1. A correlation value of +1 indicates a perfect positive relationship, while a value of -1 indicates a perfect negative relationship. The closer the correlation value is to 0, the weaker the relationship between the variables.

The correlation matrix between the Rainfall, Sensex, and Guarex indices is shown in Table 3. Rainfall and the Sensex index have correlation values of 0.008 and -0.242, respectively, with a P value of 0.876 for the Sensex index and 0.385 for the Guarex index. This shows the weak relationship between rainfall and the Sensex index. This demonstrates that there is no correlation between rainfall and the Sensex index for the period 1991–2020. As a result, the null hypothesis "There is no interrelationship between the rainfall index and the BSE Sensex index" is accepted, and the alternative hypothesis "There exists a interrelationship between the rainfall index and the BSE Sensex index" is rejected.

The correlation between the Guarex Agri Commodity Index and the rainfall index is -0.242, with a significance

Table 1. Descriptive statistics of rainfall index, BSE SENSEX and Guarex agri commodity index

Variables	Rainfall Index	BSE SENSEX	Guarex Agri Commodity Index
Mean	114.7198	13626.81	4945.148
Median	59.43472	8992.105	4975.590
Maximum	404.7500	47751.33	5566.300
Minimum	1.744444	982.3200	4156.896
Standard Deviation	112.1083	11767.40	429.7851
Skewness	0.886427	0.836549	-0.164187
Kurtosis	2.383607	2.501553	1.889550
Jarque-Bera Probability	52.84431 (0.000000)	45.71556 (0.000000)	0.838081 0.657678
Total Observations	360	360	15

Source: E views output, calculated by the researcher

Table 2. Results of ADF test for rainfall index, sensex and guarex

Variables	ADF Test Statistics	Test Critical Values	Probability	Inference
At Level I(0)				
Rainfall Index	-4.101530	-3.144920	0.0103	Stationary
Sensex Index	1.364404	-2.863974	0.9989	Non-Stationary
Guarex index	-0.728054	-3.119910	0.8056	
At First Difference I(1)				
Sensex Index	-18.11878	-2.869396	0.0000	Stationary
Guarex index	-6.591713	-3.119910	0.0002	

Source: E views output, calculated by the researcher

level of 0.385. This demonstrates that there is a negative correlation between the rainfall index and the Guarex agri-commodity index. As a result, the null hypothesis, "There is no relationship between the rainfall index and the Guarex Agri commodity index," is rejected, and the alternative hypothesis, "There is a relationship between the rainfall index and the Guarex Agri commodity index," is accepted. It denotes a moderately negative relationship between the Guarex agri-commodity index and the rainfall index.

5.4 Results of Granger Causality Test

After confirming the stationarity of selected variables, the study moved on to determine the Granger causality between the rainfall and the Sensex indices. The Granger causality test is not applied on the Guarex index due to the limited number of observations.

The Granger Causality Test results from Table 4 demonstrate that the results have a P-value that exceeds the level of significance (alpha = 0.05). As a result, accept the null hypothesis "The rainfall index is not Granger cause the BSE Sensex index" and reject the alternative hypothesis "The rainfall index does Granger cause the BSE Sensex index". It means that the past values of the rainfall index cannot be used to forecast or predict the values of the BSE Sensex index. Therefore, it can be said that there is no relationship between the rainfall and the Sensex indices in terms of causality.

The outcome of the correlation demonstrates that there is no correlation between the Sensex index and the rainfall index. Therefore, when there is no relationship between the selected variables, there is no causality relationship between the selected variables. These results are supported by the results of the correlation analysis.

5.5 Outcomes of GARCH (1,1) Model

It is necessary to determine whether there is any impact of the rainfall index on the Sensex index's volatility after it has been known that there is no relationship and no causality between the Sensex and the rainfall index.

At a 5% level of significance, the variance equation's findings in Table 5 with a probability value of 0.1351 indicate that the rainfall index had no impact on the volatility of the BSE Sensex index during the study period. Because the P value exceeds the degree of significance. Therefore, accept the null hypothesis, "The volatility of the BSE Sensex index is not affected by the rainfall index," and reject the alternative, "The volatility of the BSE Sensex index is affected by the rainfall index."

This conclusion is backed up by the findings of the Granger causality and correlation tests. These results demonstrated the lack of any association or causality between the rainfall index and the BSE Sensex index. As a result, the volatility of the BSE Sensex index is unaffected by the rainfall index. The correlation and Granger causality test results concur with the GARCH (1,1) results.

At a 5% significance level, the variance equation in Table 6 demonstrates that the rainfall index influences the volatility of the Guarex Agri commodity index during the study period. Because the P value is less than the significance level. Therefore, reject the null hypothesis "The Guarex Agri commodity index is not affected by the rainfall index" and accept the alternative hypothesis "The Guarex Agri commodity index is affected by the rainfall index."

Table 3. Results of correlation between the rainfall index, sensex and guarex

		BSE Sensex	Guarex Agri Commodity Index
Rainfall Index	Pearson Correlation	0.008	-0.242
	Sig (2-tailed)	0.876	0.385
	N	360	15

Source: SPSS output, computed by the researcher

Table 4. Results of granger causality test for rainfall index and BSE sensex

Hypothesis	F-Statistics	Prob.	Decision
The BSE Sensex index is not Granger Caused by the rainfall index	0.82369	0.5821	Accept

Source: E views output, calculated by the researcher

Table 5. Outcomes of GARCH (1, 1) model for rainfall index and sensex

GARCH (1,1)	Co-efficient value	Standard Error	Z-Statistics	P-Value
ARCH (1) α	0.075163	0.024811	3.029445	0.0025
GARCH (1)β	0.892127	0.033310	26.78277	0.0000
Rainfall Index	-0.000184	0.000123	-1.494344	0.1351
Total (α +β)	0.96729			

Source: E views output, calculated by the researcher

Table 6. Outcomes of GARCH (1,1) model for rainfall index and Guarex agri commodity index

GARCH (1,1)	Co-efficient value	Standard Error	Z-Statistics	P-Value
ARCH (1) α	–0.7223419	1.176630	–0.614823	0.5387
GARCH (1)β	1.542054	1.048768	1.470348	0.5387
Rainfall Index	0.897419	0.352280	2.547459	0.0109
R-squared	–0.201754			
Adjusted R-squared	–0.294197			

Source: E views output, calculated by the researcher

R-squared is a statistical measure of fit that shows how much the independent variable rainfall index explains the dependent variable Guarex index. Table 6 demonstrates that the rainfall index explains a -20.1754 percentage change in the Guarex index, while other variables such as temperature, air pressure, fertilizer, pesticides, insects, sown seeds, cultivation methods, and other weather and non-weather variables explain the remaining 79.8246 percentage changes. Adjusted R-squared is the modified version of R-squared that indicates whether additional variables were used to predict the change in the dependent variable. In Table 6, the adjusted R-squared shows a value of 29.4197 percent, which means additional predictor variables can be introduced to improve the regression model.

6. Conclusion

The proposed study examined the relationship between the Sensex stock market/Guarex agricultural commodity indices and the rainfall index. The study findings are consistent with the hypothesis that there is no relationship between the rainfall index and the Sensex index. The Guarex agri-commodity index and rainfall index have a moderately negative relationship. As a result, the Sensex stock market index and rainfall are independent, and the rainfall index and Guarex index are dependent. According to the Granger causality test with eight lags, there is no Granger-cause relationship between the rainfall index and the Sensex index. It implies that the values of the Sensex index cannot be predicted or forecasted using the past values of the rainfall index. The Granger causality test cannot be run on the agricultural commodity index due to the limited number of observations. Additionally, the GARCH (1,1) model shows that the volatility of the Sensex index is not affected by the rainfall index. While the Guarex agri-commodity index volatility is impacted by the rainfall index. This suggests that the relationship between rainfall and agricultural commodity prices is more significant than its impact on stock market volatility. Overall, these findings highlight the unique dynamics between weather patterns and different financial markets.

From these, it is inferred and concluded that the rainfall index is a unique and distinct kind of asset that is not associated with the Sensex index and is related to the Guarex agri commodity price index. This rainfall index is a simple index modeled with a few formalities, and it is transparent. This rainfall index trading does not have any physical delivery; it is always cash settled; therefore, it is a liquid asset. Investors can diversify their investments by using the rainfall index of any MSDs in India. Therefore, the rainfall index is traded through rainfall derivatives. NCDEX, the commodity exchange, has already suggested the design and methodology for the rainfall indexation. As per the newspaper source (Business Line, August 15, 2023), NCDEX is contracting with the Skeymet meteorological services to introduce weather derivatives like temperature and rainfall. Both organizations are seeking approval from SEBI to introduce rainfall derivatives in India. As a result, the rainfall index can be traded like a stock index on organized exchanges. But if the government will allow rainfall index trading by allowing the tax benefits and providing the infrastructure to the exchanges, then it will be helpful to build an efficient and sustainable rainfall risk market in the economy. The policymakers have to concentrate on framing the policies to introduce these weather indices to the organized capital market to trade and mitigate the rainfall risk. This will ultimately contribute to the overall economic stability and growth of the country. Furthermore, by integrating rainfall index trading into the capital market, it will attract more investors and enhance liquidity in the market. This will not only benefit farmers and businesses but also contribute to the development of the financial sector in India.

The present study yielded some useful inputs for considering the rainfall index as a distinct asset class for portfolio investment. Like stock market indices, this index can be used for investment diversification. Therefore, policymakers consider the study outcome of the rainfall index a unique asset and permit trading of it through

derivatives. This contributes to the development of a rainfall risk market for hedging rainfall risk for a diverse set of stakeholders, particularly the farming community.

The present study used only the monthly data rather than the daily rainfall, Sensex, and Guarex indices. Due to the non-availability of last year's data, the study considered the available rainfall data (1991–2020) for the analysis. Further studies can be taken to determine the relationship between rainfall and other financial and economic indicators.

7. References

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