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Comparison of Rainfall and GDP: Feasibility of Introducing Rainfall Derivatives in the Indian Weather Risk Market

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Abstract:

Purpose: *The rainfall is an economic indicator for the Indian economy. Because more than half of the Indian population is engaged in agriculture, and they depend on rainfall for their farming activities, along with farming, other sectors like manufacturing, transportation, banking, construction, and others are directly or indirectly affected by rainfall. The proposed study attempts to know the interrelationship between the changes in rainfall and the GDP growth rate. The study demonstrates the opportunity and feasibility of introducing rainfall index-based derivatives in the Indian weather risk market.*
Design/methodology/approach: *The study considered the average annual rainfall data of all 36 meteorological subdivisions collected by the Indian Meteorological Department (IMD). The GDP annual growth rate data was obtained from the World Bank's official website, https://www.worldbank.org. The study performed simple correlation and regression with the SPSS software.*
Findings: *The results of the correlation matrix show that there is a positive interrelationship between the selected two variables. According to the regression analysis, rainfall has a significant positive effect on India's GDP growth rate. This result shows that there is a need for rainfall index based derivatives in the Indian weather risk market to absorb the rainfall risk.*
Practical implications: *The result of this paper helps to rainfall-dependent industries to absorb the rainfall risk that affects their business revenue. Even insurance and reinsurance companies can also use these kinds of derivatives to hedge the pooled rainfall risk of the public. The government can take steps to frame the policies related to the trading of these instruments on the exchanges. The researcher can carry out further studies on the pricing of rainfall index-based derivatives.*
Originality value: *According to the authors' knowledge, this is the first empirical study to determine the interrelationship between the changes in rainfall and the GDP growth rate over a longer period of time.*

Keywords: *Rainfall Derivatives, Rainfall Index Based Futures, full-fledged rainfall risk market, GDP growth rate and Chicago Mercantile Exchange (CME).*

JEL Classification Numbers: *E32, K42.*
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1. Introduction

In a developing country like India, rainfall risk is purely financial. It is a major problem for agriculture and other rainfall-dependent industries. Mitigating the rainfall risk is the major challenge for the Indian government. Rainfall has a significant impact on agricultural production and the income of rainfall-dependent industries. This rainfall variability can't be controlled, but it can be managed through efficient rainfall risk market instruments.

Therefore, there exists a demand for rainfall risk mitigating tools and an efficient rainfall risk market. The rainfall risk market plays a vital role in indemnifying the losses of rainfall risk through risk sharing. Farmers, insurance and reinsurance companies, speculators, hedgers, and others who face rainfall risk are all stakeholders in these markets. The government is providing financial assistance to farmers for the rainfall risk (Table 1).

However, these are all burdens on the government and will never reach the intended beneficiaries. Insurance packages are inadequate and inefficient to address rainfall risk. Some academics believe that traditional tools alone will not solve the problem of rainfall risk. There is a need for a full-fledged rainfall risk market to resolve rainfall risk.

Weather derivatives are a new set of weather risk mitigation tools that are widely accepted the world over. Weather derivatives are contracts between two parties to expose their weather risks, like rainfall, temperature, humidity, and snowfall. The value of these contracts depends on the underlying weather index. The existence of weather derivatives traces its roots to the US. Because of the deregulation of the US energy market, the convergence of capital markets and insurance, and the extremely warm El Nino winter of 1997-1998. CME (Chicago Mercantile Exchange) started weather derivatives in 1996, and in 2010, CME started trading rainfall futures by listing it in the exchange.

CME Group is the world's largest derivative market. It is the market place where anyone can come and expose their weather risk. It is a combination of the CME, CBOT (Chicago Board of Trade), NYMEX (New York Mercantile Exchange) and COMEX (Commodity Exchange, Inc.) exchanges. These exchanges offer a wide range of weather derivative products for hedging their weather risk.

According to the CME Group Report (2014), CME lists more than 60 contracts like options and futures on rainfall, snowfall, and temperature. These rainfall index-based futures contracts are the tools to mitigate the financial losses that arise due to rainfall variability. This can be used not only by farmers, but also by others who are at risk of rainfall. It is currently needed for countries like India to absorb the rainfall risk, which affects the economy.

Table 1. *Government spending on Insurance and Interest Subvention Scheme*

Year	Spending on PMFBY and RWBCIS (in crores)	Spending on Interest Subvention Scheme (in crores)
2015-16	NA	13000
2016-17	11054.63	13397.13
2017-18	9419.79	13045.72
2018-19	11945.38	11495.67
2019-20	12638.32	16218.75
2020-21	9799.36	12744.11

Source: *Annual Report 2021 of Dept. of Agriculture, cooperation and Farmers' Welfare.*

2. Literature Review

The rainfall index-based futures are not known in many parts of the world as it is still in the infancy stage in India and there is not much literature available on this subject. The available literature was reviewed as under.

Anil (2007) concluded that the agriculture and power sectors in India are vulnerable to weather factors, i.e., agriculture is affected by the rainfall and the power sector is affected by the rainfall and temperature. These two sectors were the economic indicators, and the risk of these sectors couldn't be managed by insurance. Therefore, there is a need for an adequate, sustainable weather risk management system for the Indian economy. Abhijit (2008) concluded that weather risk causes a great amount of loss for weather-dependent industries like power, hospitality, transportation, and other businesses.

So, weather derivatives were the tool to hedge the financial losses, which were directly affected by weather variables. Rajiv (2008) determined the theoretical willingness to pay by considering the Jalwar district of Rajasthan in India for rainfall and soybean yield data for 23 years. The statistical correlation analysis showed that there was a 30% dependence of soybean yield on rainfall. Therefore, based on this rainfall dependence of soybean yield, the author concluded that weather derivatives were the perfect tool to hedge this yield risk.

Oliver *et al.* (2009) opined that the effectiveness of a weather risk hedge demands a principled contract design, i.e., one that includes weather index, strike level, tick size, and accurate weather data. However, these weather derivatives are subject to the inherent risk of basis risk. Anjali (2012) concluded that commodity futures contracts were a boon to farmers in terms of agri-commodity price risk. Weather derivatives futures contracts will also follow the same trend in the upcoming days. Therefore, weather futures contracts demanded strong regulatory support and infrastructure facilities for the weather risk market. The introduction of these markets helps to those who face the weather risk in India.

Ishan (2017) concluded that the introduction of weather derivatives was relevant for agricultural countries like India. Finally, the government should invest in weather stations, increase the availability of contracts, improve the structure of weather indexes, and raise farmer awareness of the success of weather derivatives. The author suggested policymakers, i.e., FMC and SEBI, take steps to amend the Act to introduce hedging products which were used by farmers.

Chengyi *et al.* (2018) opined that weather index futures could be a complement to weather index insurance because it covers high-probability events with low or medium risk. These weather index futures can be used not only by the farming community but also by the energy and utility companies by purchasing and selling the weather index futures.

Andrea et al. (2003) concluded that rainfall derivatives are useful tools to mitigate agricultural rainfall risk by laying the foundation for addressing weather risk by the reinsurance companies. If the government supports reinsurance companies, it will allow different countries to transfer their systemic rainfall risk to different countries. It would be helpful to create a global weather risk pool. For this, the government should concentrate on weather risk markets by providing infrastructure in weather stations, given the free availability of weather data and supporting transaction costs for the development of weather derivatives.

Karyly (2007) used the monthly revenue and monthly precipitation averages data for the period April 2000 to October 2001 of two Mid-West golf courses. According to the statistical analysis, firms can reduce revenue volatility by 80% by using weather derivatives, which would be a relief for golf course owners. The author concluded that weather derivatives were new instruments and would be useful for every business that was affected by the weather.

Neha (2013) suggested that India is an agrarian country where most of the population depends on agriculture and most of the agricultural land depends on rainfall. So, there exists a rainfall risk due to rainfall variability. Therefore, weather derivatives are the new instrument that can be used to hedge these weather problems. According to Ishan Kekre and Girish (2017), the success of rainfall risk markets was dependent on well-developed weather stations, an efficient index structure, and raising farmer awareness.

Dileep *et al.* (2021) concluded that rainfall index based futures were the complement to rainfall index based insurance. The present condition of the financial markets demands a sustainable and full-fledged rainfall risk market to expose the rainfall risk. These markets were given an opportunity to hedge and speculate on the rainfall risk.

Shivakumar and Kotreshwar (2013) developed the general framework for the creation of index-based Risk Transfer Products (RTP). The authors proposed the unique rainfall index as the Monsoon Outcome Index (MOX), measured for each Meteorological Subdivision (MSD). The statistical properties of these MOX values indicated a large potential for launching a new breed of rainfall risk market instruments for risk absorption. Finally, they suggested a policy initiative by the government and exchanges to engage capital markets in absorbing the weather-related risk.

Kotreshwar (2015) modified MOX as a new set of rainfall indices, i.e., ERDs and DRDs, for quantifying rainfall variability. The statistical analysis of these indices indicated the wide range of scope for launching rainfall index-based derivatives. Bhartha and Koreshwar (2020) analysed the rainfall indices of selected meteorological subdivisions by using various statistical tools. The statistical properties of these indices show that there was an opportunity to design the rainfall derivatives to hedge rainfall risk and that these rainfall indices act as building blocks for designing the rainfall derivatives.

The past literature shows that rainfall derivatives contracts are feasible hedging tools for agricultural rainfall risk. They were not focused on how to design, implement, and trade rainfall index-based futures and other fundamental issues for trading rainfall derivatives. So, this paper fills this research gap.

3. Rainfall Indexation

The study considered the new set of rainfall indices, i.e. Deficit Rainfall Days (DRDs) and Excess Rainfall Days (ERDs). These indices are constructed on par with the Heating Degree Days (HDD) and Cooling Degree Days (CDD) as an underlying for temperature derivatives. DRDs and ERDs can be determined separately for each of the rain gauge stations or meteorological subdivisions that serve as a benchmark for designing the rainfall derivatives contracts for trading in both OTC and organised markets.

The underlying variable being rainfall, let R_i denote the rainfall (in millimetres) measured on ith day, and R_x denote the average daily rainfall (in millimetres). The average daily rainfall, R_x, should serve as the reference level of rainfall in millimetres. The value of R_x is based on the past rainfall data for any chosen length of the period. The standard underlying variable, then, would be simply the difference between the daily average value of rainfall (in millimetres), i.e., Rx, and the actual value of rainfall (in millimetres) on ith day, i.e., R_i. The rainfall days generated on a given ith day is given as:

$$DRDi = Max. \{Rx - Ri, 0\} \quad (1)$$

Similarly,

$$ERDi = Max. \{Ri - Rx, 0\} \quad (2)$$

4. Rainfall Index Based Derivatives

Rainfall derivatives are a part of weather derivatives. These rainfall derivatives are used to overcome the losses due to adverse rainfall over a period of time. Rainfall derivatives include contracts like futures, options, and swaps. The purpose of rainfall index-based futures is to reduce the volatility of revenue and hedge the costs incurred by the volatility of revenue due to rainfall variability. Rainfall index-based futures are contracts between two parties to expose their rainfall risk. The value of this contract depends on the value of the rainfall index.

This rainfall index is calculated based on the standard rainfall and actual rainfall of the place where they want to hedge their rainfall risk. These rainfall index-based futures are the short-term contracts, and it can be designed either for months or for one full season. Rainfall derivatives are a versatile tool for mitigating rainfall risk. It is for a large number of agricultural business participants, as well as industries that are equally affected by rainfall variability.

Rainfall index-based futures are the pioneers for the development of a global rainfall risk market pool. It is supportive of the emergence of an ART (Alternative Risk Transfer) product, which leads to the development of a sustainable, full-fledged, rainfall risk market. These ART products facilitate a wide range of opportunities for farmers to hedge their rainfall risk. The structure of the rainfall index and the application of rainfall index based futures are explained in further sections.

5. Justification for Selecting the Variables

The Gross Domestic Product (GDP) is the economic indicator for the Indian economy. It explains the total monetary value of the outcome or production of all goods and services of a country in a specific period of time. It includes the consumption of people, investment, government spending, and exports of the country. As shown in Table 2, the majority of a country's GDP contributors are rainfall dependent.

For example, agriculture and related industries, manufacturing, construction, electricity, transportation, financial institutions, and other services-related industries. Table 2 clearly indicates the effect of rainfall on various sectors in the economy and their percentage contribution to the GDP. As we theoretically well know, if sufficient rainfall happens, it leads to good production in the agriculture and rainfall-dependent industries.

A sufficient supply of goods and services helps to stabilise prices and ensures that goods and services are readily available to consumers. This is helpful to export the surplus production and help earn the foreign reserve. The country's large foreign reserves enabled it to be self-sufficient. Therefore, our country’s GDP growth rate directly or indirectly depends on the rainfall. Therefore, these two variables, i.e., rainfall changes and GDP growth rate, can be considered for the purpose of comparison. For comparison, the study looked at rainfall and GDP growth rates. The below Table 2 shows the rainfall risk faced by the various sectors and their respective contributions to GDP.

Table 2. *Rainfall affected to various sectors of our economy*

SL NO.	Sector	Impact of Rainfall	Contribution to GDP (in Percentage)
1	Agriculture, Forestry and Fisheries	Crop Yield, Storage of pets, Fish habitat loss	20.19
2	Mining and quarrying	Delay in Production	1.63
3	Manufacturing	Reduced demand and increase in the raw material cost	14.43
4	Electricity, Gas, Water Supply and other Utility Services	Lack of production and delay in services	2.7
5	Construction	Delay in Activity	7.16
6	Public Administration, Defense and other Services	Delay in services and Problems of Security	15.42
7	Financial, real estate and Professional Services	Non-Performing Assets and Conversion of Agricultural land into Commercial land	22.05
8	Trade, Hotel, Transport, Communication and Services related to Broadcasting	Budget overrun and delay in services	16.42

Source: *Ministry of Statistical and Programme Implementation.*

6. Research Methodology

The present study is purely based on secondary data to analyse the relationship between the rainfall changes and the GDP growth rate for the period from 1961-2020. The objective of the present study is to examine the opportunities and feasibility of introducing rainfall index based futures in the Indian weather risk market. The other specific objectives are:

1. To find the correlation between rainfall changes and the GDP growth rate over the last 60 years.
2. To investigate the impact of changes in rainfall on GDP growth rates over the last 60 years.

The following hypotheses are tested in the present study:

1. NH1: There is a negative relationship between the rainfall changes and the GDP growth rate.

2. NH2: There is no effect of rainfall changes on the GDP growth rate.

The study considered the average annual rainfall data of all 36 meteorological subdivisions collected by the Indian Meteorological Department (IMD). The GDP annual growth rate data was obtained from the World Bank's official website, https://www.worldbank.org. The study performed simple correlation and regression with the help of SPSS software. For the purpose of analysis, the rainfall index is converted to rainfall changes as follows:

$$Ri = (P1-P0)/P0 \quad (3)$$

Whereas Ri represents the return of the given index, P1 represents the current month index value, P0 represents the previous month index value. Here one rainfall index equals one millimetres of rainfall. The study used the regression to check the effect of rainfall changes on the GDP growth rate. Therefore, the study used the following regression equation.

$$GGRt = \alpha+\beta 1RC+\varepsilon t \quad (4)$$

Where:
GGR: GDP growth rate for t time period, RC: Rainfall Changes, α: Intercept, β1: Slope Co efficient, t: Time period, εt: Error term for the t period.

7. Results and Discussions

This section provides the results of the relationship between the rainfall index and the GDP growth rate from 1961 to 2020. In order to know the relationship, the study used correlation and regression analysis. The results of each test are presented below.

7.1 Results of Correlation

Correlation between variables explains the strength of the relationship or connection between two or more variables. It helps to know how much one variable is related to another variable. Its value lies between +1 and -1. The correlation between rainfall changes and the GDP growth.

Table 3. *Results of Correlation*

		GDP Growth Rate
Rainfall changes	**Pearson Correlation**	0.379**
	Sig. (2-tailed)	0.003
	Number of Observations	60
Note: **Correlation is significant at the 0.01 level		

Source: *SPSS output of the data sourced from IMD and World Bank for 1961 to 2020.*

Table 3 displays the correlation between the rainfall changes and the GDP growth rate for annual data for the period 1961 to 2020. The rainfall changes have a positive correlation with the GDP growth rate, with a value of 0.379. Therefore, the hypothesis "There is a negative relationship between the rainfall changes and the GDP growth rate" is rejected and the alternative hypothesis namely "There is a positive relationship between the rainfall changes and the GDP growth rate" is accepted. It implies that the association between rainfall changes and the GDP growth rate is positively correlated and statistically significant. It explains that if one unit change in rainfall changes, it would lead to an increase in the GDP growth rate of 37.9%.

7.2 Results of Regression

Regression is a technique to assess the strength of a relationship between one dependent variable and one or more multiple independent variables. It helps to predict the value of the dependent variable from the independent variables. It clearly demonstrates how one independent variable affects the dependent variable. The regression between rainfall changes and the dependent variable GDP growth rate is revealed in Table 4.

Table 4. *Results of Regression*

Variables	Bete Coefficient	R^2	F Statistics	P value
Rainfall changes on GDP Growth Rate	0.379	0.143	9.957	0.003
Note: Predictor- Rainfall Changes Dependent Variable- GDP Growth Rate				

Source: *SPSS output of the data sourced from IMD and World Bank for 1960 to 2020*.

Table 4 shows the effect of rainfall changes on the GDP growth rate for the period from 1961 to 2020. Here, the Beta coefficient tells us the changes in the GDP growth rate with respect to the changes in the rainfall. That is, if a single unit change in rainfall causes a 37.9% change in the GDP growth rate, the R^2 value describes how much of the variation in the GDP growth rate is explained by changes in rainfall.

Here, rainfall accounted for the 14.3% variability in the GDP growth rate in this regression model. Finally, F statistics show whether the model is fit or not. By observing the above table at a 1% significance level, this model is fit based on the P value of F statistics.

Therefore, the null hypothesis "There is no effect of rainfall changes on GDP growth rate" is rejected and the alternative hypothesis namely "There is an effect of rainfall changes on GDP growth rate" is accepted.

8. Model Rainfall Index Based on Futures Contract

The rainfall index based futures are the contracts to buy or sell the rainfall index at a predetermined index value today, to be settled at a date in the future. Basically, an index based futures contract is a derivative contract whose value depends on the underlying index.

The present study examined alternative methods of measuring rainfall indices and adopted the DRDs and ERDs indices as standard metrics, which can be used as building blocks for designing rainfall futures contracts.

A model Rainfall index based futures contract involves specification of the following terms:

1. **Contract Size:** The contract size is simply an index number that needs to be converted into a monitory value by a 'multiplier' which for instances is 15 for SENSEX. The multiplier is called lot size of the contract. This is necessary for determining the value of a futures contract. The chosen multiplier may be a sum, say Rs 1000. This means that contract size is 1000 times the DRD/ERD index points, if the DRD index is 150 points, the contract value is 150000.
2. **Product Description:** Empirical derived value of DRD/ERD indices are the products for each specified MSD or any other region or city.
3. **Tick Size:** It is the predetermined decimal applied to each index point. For instance, if the decimal is decided to be 0.1, then the tick size of the contract will be (=Rs 1000*0.1=Rs.100 per contract).
4. **Mode of Settlement:** The mode of settlement is compulsorily on cash basis. This is because DRD/ERD indices are not physically deliverable.
5. **Contract Month:** As core part of monsoon covers a period of 4 months from June to September. These months are ideal for trading rainfall index based futures contracts.
6. **Ticker Symbols:** As the underlying for rainfall index based futures is either DRD or ERD index, the ticker symbol could be DRDX or ERDX as the case may be.

Based on the terms described above, a model Rainfall index based futures contracts for North Interior Karnataka Meteorological Subdivision (NIK MSD) can be designed as shown below.

Designing rainfall index based futures contracts need monitory values for the DRDs and ERDs. Suppose each unit of DRD and ERD index is equivalent of Rs.1000. Then, for a given month with accumulated 20 DRDs, the nominal value of DRD futures contract shall be Rs.2000 (20*100). A model rainfall index based futures contract is represented below.

Table 5. *Contract Specification for the rainfall index based futures*

A Model Rainfall Index Based Futures Contracts (Specifications)	
1. Contract Size	Rs. 1000 times the respective DRD/ERD index.
2. Product Description	DRD/ERD of 36 MSDs of India
3. Tick Size	0.1 Index point (=Rs100 per contract)
4. Contract Months	DRDs= June, July, August, September (4 months)
5. Settlement Procedure	Cash Settlement: Final Settlement procedures for months DRD futures
6. Position Limit	All months combined: 10000 contracts
7. Pricing Unit	Rs. Per index point (1 index point= 1MM of rainfall)
8. Ticker Symbols	AGRX*

Note: **A symbol for Agri Index*
Source: *Own study.*

The profit and losses would depend upon the difference between the rainfall index at which the contract position opened and the rainfall index at which it is closed.

Considered the following Long Position example:
Position: long position to buy the DRDs. If the deficit rainfall in the upcoming days continues, buy the DRD index strike level at 200 DRDs.
Profit: if the DRDs index rises by more than 200 points.
Loss: if the DRDs index decreases by less than 200 points.
Profit and loss: The profit and loss would be equal to 1000 times the difference in the two indices, i.e., the index number at the beginning of the contract and the index number at the end of the contract. If on the last day of the contract, DRDs equals 220 points, there should be a profit of 20 points, which is equal to Rs. 20000 (20*1000). If the DRDs equal 180 points, there should be a loss of 20 points, which is equal to Rs. 20000 (20*1000).

Considered the following Short Position example:
Position: short position to sell the DRDs. If rainfall exceeds 200 DRD points in the coming days, sell the DRD index strike level.
Profit: If the decrease in the DRD index is below 200 points,
Loss: if the increase in the DRD index is above 200 points.
Profit and loss: If on the last day of the contract, DRDs equals 180 points, there should be a profit of 20 points, which is equal to Rs. 20000 (20*1000). If on the last day of the contract, DRDs equal 220 points, there should be a loss of 20 points, which is equal to Rs. 20000 (20*1000).

9. Feasibility and Effectiveness of Rainfall Index-based Futures for the Mitigating the Rainfall Risks

The effectiveness of rainfall index based futures contracts depends on the kind of crops, geographical location, and time period of the rainfall derivatives contracts. Proper design and implementation of rainfall index-based futures result in them being effective instruments for mitigating rainfall risk. As a result, proper design and exchange traded rainfall index-based futures can be demonstrated to be an effective tool for hedging rainfall risk. The effectiveness of rainfall index based futures exists when the contracts written and the rainfall index measured location are the same, and by this, we can completely reduce the basis risk.

Melanie *et al.* (2003) opined that as long as the rainfall risk market is incomplete, there is scope for the new instruments to improve the risk return trade off. The relationship between weather derivatives and other conventional financial assets shows a relatively lower correlation and suggests that weather derivatives can be an excellent diversification vehicle.

The temperature-based weather derivatives are popular in other countries because they face a problem with temperature. For instance, 20 to 30 percent of US economy depends on temperature. The Kamiar Mohaddes, an economist and co-author of the working paper "Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis" (2019) at the University of Cambridge, opined that the United States will be one of the countries to suffer a lot because there is a sharp increase in the US average temperature; it costs 10.5 of its GDP by 2100. So, they developed the temperature derivatives well in advance. On the same line, around 55% of the Indian population depends on agriculture, and agriculture is frequently affected by rainfall variability. As a result, these rainfall index futures aid agricultural farmers and agri-based industries in mitigating rainfall variability.

The rainfall index-based futures avoid malpractices, insider problems, or any other fraud on the participants. Rainfall index based futures are the transparent contracts. Because the rainfall futures contract value depends on the rainfall index, and this index can’t be manipulated by anyone. The rainfall index measure works in a mechanical manner and it is not under the control of a human being. Even the rainfall is uncontrollable, so there is no chance of manipulation in this kind of contract.

10. Conclusions

This paper examined the opportunities and feasibility of introducing rainfall index based futures in the weather risk market. The statistical analysis of rainfall changes with the GDP growth rate shows that there is an opportunity to introduce rainfall index based futures in the Indian weather risk market. Because the hypothesis of the study proved that there is a significant positive relationship between the selected variables and there is a significant positive effect of rainfall changes on GDP growth rate.

It means that both selected variables go in the same direction, i.e., if rainfall changes go upward, GDP growth rate also goes in the upward direction and vice versa. Similarly, rainfall changes positively affected the GDP growth rate. It means one unit change in rainfall changes leads to a 14.3 % change in the GDP growth rate. Therefore, by considering the statistical analysis and the theoretical review of literature, we can conclude that there is an opportunity and feasibility in the Indian weather risk market to introduce the rainfall index based futures.

Now it is time to create a sustainable and full-fledged rainfall risk market to expose the rainfall risk of farmers and others who face it. To effectively hedge rainfall risk and complete the rainfall risk market, rainfall index-based derivatives must be introduced. Rainfall risk markets are complete when they enable everyone who is exposed to rainfall risk, including insurance and reinsurance companies, to hedge their exposure in this market.If these markets are successfully introduced and run, there will be a sustainable and full-fledged market for rainfall risk.

The Securities and Exchange Board of India (SEBI) recently considered the proposal to allow trading of weather (temperature and rainfall) as a commodity on the commodity exchanges. SEBI is analysing the pricing model for weather derivatives and infrastructural issues to introduce the weather derivatives. Now SEBI is examining the feasibility of introducing weather derivatives on the Indian commodity exchanges. The government needs to take action to provide the infrastructure and support for the development of these markets. If these products are traded on exchanges, it will give an immense opportunity to escape from the rainfall risk. So, it is time to learn about it and educate the farmers to absorb the agrarian distress.

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Appendix 1. *Selected sample data*

year	GDP growth (annual in %)	Rainfall changes (annual in %)
1960		
1961	3.722742533	20.6028813
1962	2.931127737	-13.77861381
1963	5.994353261	0.50014965
1964	7.452950122	1.193111793
1965	-2.63577011	-20.77542997
1966	-0.05532877	8.011915192
1967	7.82596303	6.56344767
1968	3.387929176	-4.35836334
1969	6.539700296	4.89526518
1970	5.157229736	11.92013855
1971	1.642930384	-4.285285589
1972	-0.553301312	-22.30488397
1973	3.295521135	23.12006223
1974	1.18533626	-6.116344409
1975	9.149912015	17.38944818
1976	1.663103637	-12.82506969
1977	7.254764586	11.32346897
1978	5.712532089	-1.050027691
1979	-5.238182703	-17.80799684
1980	6.735821528	17.29779666
1981	6.006203624	-0.236277154
1982	3.47573324	-10.0997973
1983	7.288892901	19.87805194
1984	3.820737856	-10.11652142
1985	5.254299223	-2.329004121
1986	4.77656417	-4.781381274
1987	3.965355634	0.260956626
1988	9.62778292	23.14278535
1989	5.947343328	-15.6219754
1990	5.533454563	19.56068394
1991	1.056831433	-13.26185941
1992	5.482396022	-5.399108751
1993	4.75077622	8.471866132
1994	6.658924067	5.436684658
1995	7.57449184	-0.824117123
1996	7.549522249	-7.272524656
1997	4.049820849	1.858572991
1998	6.184415821	5.959495254
1999	8.845755561	-8.667524066
2000	3.840991157	-6.175541264
2001	4.823966264	4.658435537
2002	3.803975321	-10.77365272
2003	7.860381476	19.82518107
2004	7.922936613	-7.780162695
2005	7.923430621	8.168319429
2006	8.060732573	-4.66477168
2007	7.660815065	6.746269993

2008	3.08669806	-7.515714937
2009	7.861888833	-11.60775211
2010	8.497584702	24.73494195
2011	5.241315001	-6.632562436
2012	5.456388753	-8.256000705
2013	6.386106401	16.82640991
2014	7.410227605	-16.00805653
2015	7.996253786	1.309560884
2016	8.256305502	0.680021167
2017	6.795383419	7.405283039
2018	6.532989011	-8.876520623
2019	4.041554187	22.73912346
2020	-7.964610411	1.446982686

Appendix 2. Result of correlation from SPSS

Correlations

		GDP growth (annual %)	V6
GDP growth (annual %)	Pearson Correlation	1	.379**
	Sig. (2-tailed)		.003
	N	60	60
Rainfall changes	Pearson Correlation	.379**	1
	Sig. (2-tailed)	.003	
	N	60	60

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 3. *Resul of Regression*

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.379[a]	.143	.129	3.1667561

a. Predictors: (Constant), Rainfall changes