Mitigating Agri-business Risk Through Weather Derivatives

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INTRODUCTION

Agriculture industry in India is largely dependent on weather. Financial instruments like commodities futures and options help farmers in managing risks related to price. The overall earnings depend not only on price but also on volume of production. Agricultural volumes are largely affected by rainfall, temperature, and other weather phenomenon. Such volumetric risks cannot be hedged by future contracts in commodities.

Weather derivatives are innovative financial instruments that help in mitigating volumetric risks associated with vagaries of weather. A financial weather contract can be defined as a "weather contingent contract whose payoff will be in an amount of cash determined by future weather events. The settlement value of these weather events is determined from a weather index, expressed as values of a weather variable measured at a stated location" [16].A financial weather contract can take the form of a weather derivative (WD) or of a weather insurance (WI) contract.

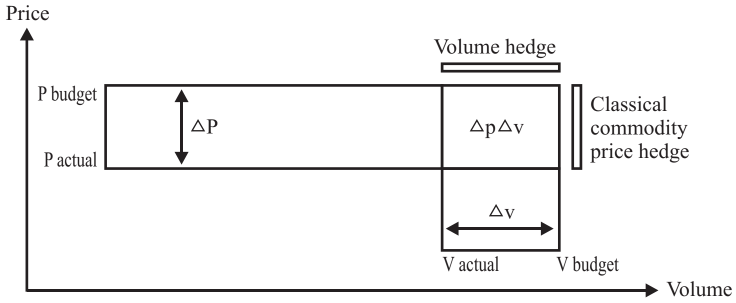

Fig1: Cross Hedge for the sale of weather sensitive products[15]

Using a combination of commodity price future and weather contracts, an organization or individual can hedge its revenue risk (price x volume)[15]. Cross hedge is illustrated in figure 1.

Payments in weather derivative contracts are based on state of widely available indices like rainfall index. Hence, there is no need for farm-level assessment of loss. This greatly reduces transaction costs relative to crop yield insurance. The value of the index does not depend on the individual actions of market participants. Thus, there is no adverse selection or moral hazard involved.

WDs also have important differences with respect to traditional commodity price derivatives. The fundamental difference is that the underlying of a WD is not a traded good.

WEATHER AND AGRICULTURAL YIELD

Monsoon is the chief source of rainfall for India. Being an agricultural country, the monsoon plays a pivotal role in India economy, as any variation in the monsoon can lead to variation in agricultural output, and when the Indian agriculture suffers, it will also affect a lot of secondary industries, which depend on agriculture. Approximately, more than third of India's total GDP is susceptible to weather related risks. Only 40% of cultivated area has access to irrigation infrastructure although only 20% of this land is effectively irrigated. About 80% of the agricultural land depend on rainfall. India sustains 16% of world's population on 24% of land resource. Agriculture contributes 24% to the Indian GDP and is a source of livelihood support to two-thirds of the population in India.

Fig 2 shows the strong correlation between rainfall in mm (during Jun-Sept) and food grain production in million

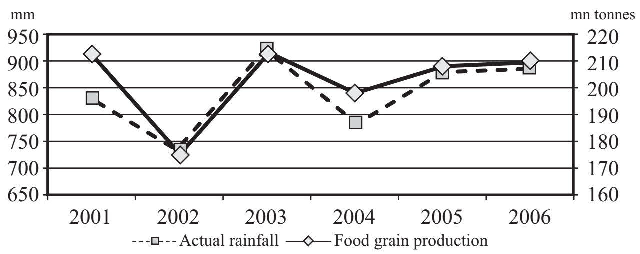

Fig 2: Correlation between rainfall and food grain production in India

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tonnes. (Coefficient of correlation: 0.86)

Crop specific studies also show a strong correlation between yield and rainfall in India[3]. Agricultural losses as compiled by General Insurance Corporation of India's crop insurance cell[11] are tabulated in Table 1.

Cause	Proportion of loss
Drought/Low Rainfall	70%
Floods/Excess Rainfall	20%
Storms/Pest/Negligence/Earthquake	10%

Table 1: Causal analysis of agricultural loss[11]

Rainfall uncertainty causes maximum loss to agriculture. As a large fraction of India's population is still agriculture dependent, the impact of this on the lives of people and overall economy is very high.

Year	Number of meteorological sub-divisions			Percentage of districts with normal / excess rainfall	Percentage of long period average rainfall for the country as a whole
	Normal	Excess	Deficient / scanty		
1998	20	13	2	83	105
1999	25	3	7	67	96
2000	23	5	7	66	92
2001	28	1	6	68	91
2002	14	1	21	39	81
2003	26	7	3	75	102
2004	23	0	13	56	87
2005	25	8	3	73	99

Excess: +20 per cent or more of LPA; Normal: +91 per cent to -19 per cent of LPA;
Deficient: -20 per cent to -59 per cent of LPA; Scanty: -60 per cent to -99 per cent of LPA.
Source : India Meteorological Department.

Table 2: Monsoon performance 98-2005 (Jun-Sept)

(Source: www.indiabudget.nic.in)

The impact of rainfall is not same for all the crops but specific in nature. Table 2 shows crop-wise risk factors associated with rainfall.

Crop	Risk Details	States	Number of farmers	Area covered farmers	Sum Insured (in acres)(Rs. mn)
Soybean	Deficit rainfall	RJ, MP	4,112	16,418	66
Oranges	-Deficit rainfall -Prolonged dry spell	RJ	453	1,223	6
Generic product for all filed crops	-Deficit & Excess rainfall	AP, MP, MH, Jharkhand, KK, Orissa, RJ and TN	19,100	22,000	66
Grapes	-Deficit & Excess rainfall, Temp	MH, AP	365	395	20
Paddy	-Prolonged dry spell -Excessive rainfall	Punjab	1,625	7,643	30
Cumin	-High relative humidity	RJ	686	688	6
Coriander	-Frost like temperature -Unseasonal rainfall	RJ	2,075	2,200	6
Fenugreek	-Excessively high temperature during days with high RH	RJ	70	260	2
Kinnu	-Excessively high temperature -Deficit rainfall	RJ	62	80	4-Deficit rainfall
Wheat	-High temperature -Unseasonal rainfall		Punjab, Haryana	874	8754
Cotton	-Deficit rainfall	MH	100,018	100,084	160
Total			**150,000**	**180,000**	

Table 3: Crop-wise risks in the year 2005-06 and its economic impact[11]

WEATHER DERIVATIVES

Rainfall index

For trading in weather derivatives, it is imperative to have a reliable rainfall index. A central agency can formulate such a rainfall index that can be used for financial transactions. NCDEXRAIN[16] is a rainfall index of NCDEX which tell us what percentage of cumulative normal expected rainfall (till the date of the index) it has actually rained taking into consideration average actual rainfall at both Colaba and Santa Cruz weather stations in

Mumbai.

Cumulative rainfall index

Cumulative rainfall index is the total rainfall received in a region from a reference base date to the date of exercise of option.[1] It can be defined as -

$$R_C = \sum_{i=1}^{n} r_i$$

Where,

R_C = Cumulative rainfall index

r_1 = Rainfall on ith day from a reference date

n = Number of days from reference date to current date

Weighted rainfall index

Cumulative rainfall is easy to understand for the farmers and simpler to use. However, it suffers from a drawback. It takes into account total rain, including the days when rainfall does not have significant impact on crop production. Rainfall during a certain month is more important than others. This indicates a need for measuring "effective" rainfall (rainfall on desired stage of crop growth cycle) than "total" rainfall. While cumulative rainfall is easy to understand and use, weighted rainfall index is a better measure.

Weighted rainfall index is more useful as it measures "effective rainfall" during a period. The index can be calculated as -

$$R_{WD} = \frac{\sum_{i=1}^{n} w_i r_i}{\sum_{i=1}^{n} w_i}$$

w_i = Weight of Rainfall for ith day from a reference date

R_{WD} = Daily weighted rainfall index

The difficult aspect of this method is estimation of weights for different days. Weights can be assigned based on bucket period instead of individual days. The size of bucket should not be too large reducing effectiveness nor too small making it difficult to estimate the values for all weights. The index for period weighted index can be calculated as -

$$R_{WP} = \frac{\sum_{i=1}^{n/k} w_i \sum_{j=i*k-k+1}^{i*k} r_j}{\sum_{i=1}^{n/k} w_i}$$

Where

k = number of days per period

R_{WP} = Period weighted rainfall index

Weights can be estimated through qualitative as well as quantitative measures or a combination of both. In qualitative model, expert opinions can be taken to estimate the weights. Delphi method can be used for finalization of weights.

Quantitatively, the weights can be calculated by solving for.

$$Max\ Corr\ (R,O) = \frac{\sum_{k=1}^{m} (R_k - \overline{R}) x (O_k - \overline{O})}{\left[\sum_{k=1}^{m} (R_k - \overline{R})^2\right]^{1/2} \left[\sum_{k=1}^{m} (O_k - \overline{O})^2\right]^{1/2}}$$

Where

$R_k = \sum_{i=1}^{N} w_k r_{ik}$ Annual weighted average effective rainfall.

N = Number of periods per year

m = Number of years of observation

r_{ik} = Total rainfall during i th period of year k

O_k = Output during k th year.

Suitable models can be developed considering correlation analysis. For example, yield model for Sorghum genotype M35-1 is as below[19]

Model No.	Model	R^2
1	Y= 1.62 (RF5)+1.99(RH28)+282.4(TX10)-151.6(TN12)-60009.2	0.93
2	Y= -18.9 (RH28)+560.9(TX10)-324.2(TN12)+119.7(TN14)-13033.4	0.94

RF 5 = Rainfall during the 5th week after sowing (WAS)
RH28 = Afternoon relative humidity during WAS 8
TX10 = Maximum Temperature during WAS 10
TN 12 = Minimum Temperature during WAS 12
TN14 = Minimum Temperature during WAS 14

Fig 3. Crop weather relation in Rabi Sorghum

(Source: www.agrometbijapur.org/3.pdf)

High value of coefficient of determination illustrates the strong dependency of yield and weather elements. Suitable crop specific weather contracts can be formulated based on such models.

Weather Contracts

European put and call options & their combinations can be used as instruments for hedging weather risks. The underlying asset in case of weather derivative is rainfall or temperature index.

Put options

Payoff for European Put option = $p*max(0, K - R)-h$

Where,

p = Payable amount per mm reduction in rainfall

h = Option price

K = Threshold limit (Strike)

R = Rainfall level

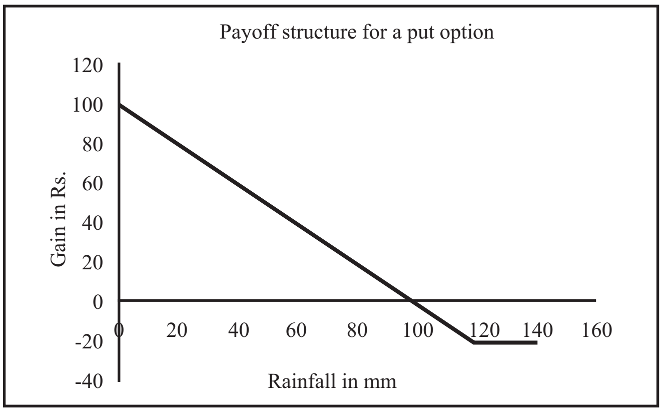

Fig 4: Payoff structure for a weather put option

Call options

Payoff for European Call option = $p*max(0, R-K)-h$

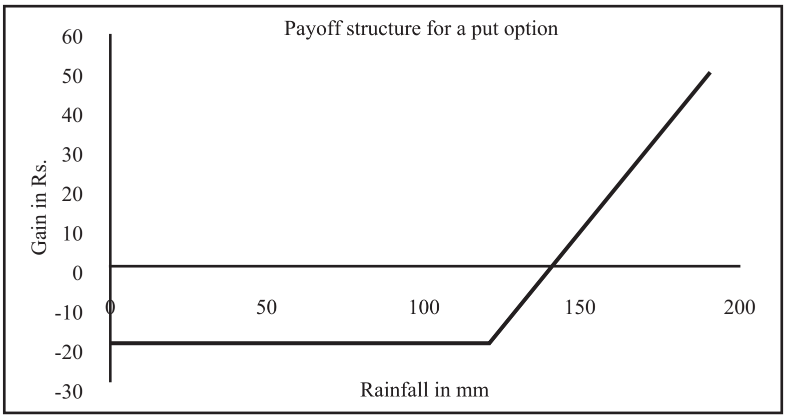

Fig 5: Payoff structure for a weather call option

Swaps

Swaps are privately negotiated financial contracts in which two parties agree to exchange, or "swap", specific risk exposure over a predetermined period of time. There is no "cost" for swap. When used in connection with floating price energy contracts, swaps afford a buyer and seller protection from adverse price movements, in exchange for giving up the ability to capitalize on benefit price movements.

A Cap is used to minimize risks due to extreme situations. Payoff for collars with caps can be calculated as

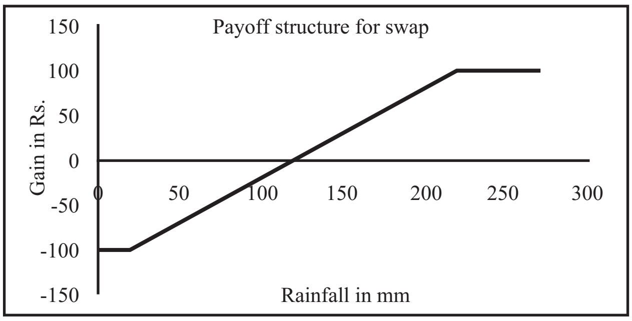

Fig 6: Payoff structure for a weather swap

Payoff for swap with cap = p*Min(Max(0,R-K),C) p*Min(Max(0,K-R),F)

Where C = Ceiling cap

F= Floor cap

Weather Collars

Weather collars can be used to protect the buyer from extreme fluctuations in weather. Collars are constructed using a combination of put and call options. A producer buys a rainfall put option with a low strike level and sells a call option with a high strike level. If rainfall settles between the two strike levels (the strike range), there is no payout to either the buyer or the seller of the hedge[10].

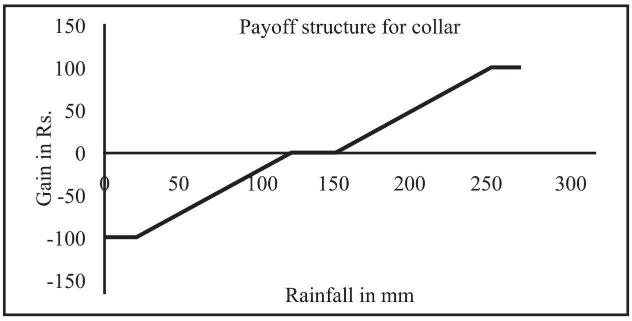

Fig 7: Payoff structure for a weather collar

Payoff for collar with cap = p*Min(Max(0,R-K1),C) p*Min(Max(0,K2-R),F)

Where K1,K2 are strike thresholds.

Digital Options

Digital options have a discontinuous payoff. They are also called binary options.

Payoff = h if R<K }
F if K>R }

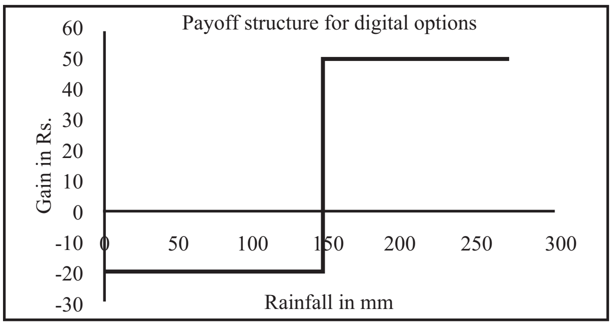

Fig 8: Payoff structure for a digital weather option

Strangle

Yield risk profile for most crops is non-linear in nature. A complex derivative instrument is required to manage such risk profiles. Yield of the crop increases with rainfall upto a certain threshold. Excess rainfall results in decreased yield. The yield risk profile for most crops is as below -

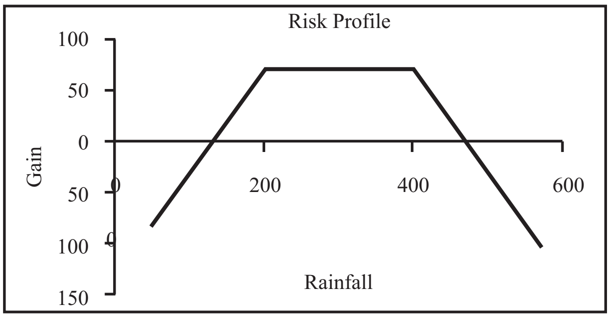

Fig 9: Risk profile for maize crop

The risk can be hedged through a combination of call and put option as in strangle[9]. The payoff diagram for strangle option is as below. The net yield risk in such an arrangement is nullified.

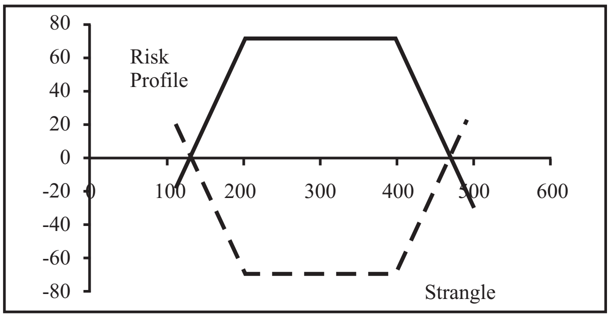

Fig 10: Payoff structure for a strangle

PRICING WEATHER DERIVATIVES

Pricing of weather derivatives is a tricky issue. Traditional techniques of option pricing or Black-Scholes model for pricing of options cannot be applied for weather derivatives as the underlying index is not a tradable commodity. Also, weather does not follow random walk hypothesis and has a mean reverting tendency. Besides this, the underlying is in a state of continuous change. Several techniques have been developed for pricing of weather derivatives. However none of them are without any drawback. There remains a need for globally agreed options pricing method.

One of the approaches developed in the insurance industry is Burn analysis. It is a simple method and tries to calculate average payoff in the last X number of years. The analysis depends on historical data for options pricing and does not use future forecasts which remains a critical objection. One key hindrance in this methodology is gathering the data and deciding the value of X years.

Monte Carlo Simulation is another methodology that can be used for pricing. However, the random walk hypothesis is not perfectly valid for weather. Mean reverting Monte Carlo simulation can account for some of the discrepancies.

Out of the various methods of options pricing, mean reverting Monte Carlo simulation and Burn simulation seem most transparent and practical.[10]

PREREQUISITES FOR A WEATHER DERIVATIVES MARKET

Weather derivative markets require a strong legal and economic framework. Government can play a critical role in development of a reliable and efficient weather derivative market. A central authority must be there for settlement of weather derivative contracts. Standardization of contract parameters and measurable matrices is required for establishing a reliable market. The underlying contract must be in terms of standardized index measured by a third party.

Such markets require a talent pool of meteorological scientists and accurate information. Adequate data about regional weather parameters must be publicly available. At least 20-25 years of data has to be available for analyzing trends in weather changes. The quality of data collected is crucial in making accurate prediction of future weather state. This mandates a proper meteorology infrastructure. Sufficient numbers of high quality instruments located at critical places are required for accurate information.

PRESENT STATE OFWEATHER DERIVATIVES MARKETIN INDIA

First, since introduction of weather index insurance products, over 0.6 million farmers have purchased weather insurance. There are 8 main direct insurers in India although 3 companies are actively working with weather index products-Agricultural Insurance Corporation of India; ICICI Lombard General Insurance Company; and IFFCO Tokyo General Insurance Company.[20] Weather derivative was discussed in finance minister's speech in 2005 showing the govt. support for the concept. First weather index transactions were done in 2004 with BASIX microfinance institution for Castor and Groundnut crops in Mehbubnagar and Andhra Pradesh against deficit rainfall. Insurance policies were purchased by 1500 small farmers. Participation level was found lower amongst more vulnerable sections. Educating farmers about the importance of weather derivative is important to convince them to buy such products. NGO's and self help groups can play a critical role due to their established trustworthiness in the respective locality. Tie ups with such groups would also enable easy implementation of awareness programs and actual buying of products.

While small scale projects have been done, it would not be possible to sell crop insurance across the country unless the weather is more closely mapped. Every region gets different amounts of rain and in the absence of weather bureaus in smaller localities; there is no source of reliable data. Without appropriate data, risk pricing becomes difficult. The futures and options markets too will need detailed information about weather patterns and forecasts before they can be useful to the economy. Meteorological data and forecast methodologies must be available in public domain for development of weather derivative markets.

CONCLUSION

Weather derivatives can be used by organizations and individual farmers to manage their volumetric risks. The revenue risks can be better covered using a combination of weather derivative and commodity future and options. This is all the more important in India where agriculture is the main source of income for a vast majority of population. Innovative instruments can be used for managing crop specific risk profiles.

Index contracts lower the cost to farmer and to society if incentives are established for government and insurance companies. Rural groups and small-scale farm operations could purchase these contracts when the cost is lowered. Farmers should be educated about usage of such derivative products along with agriculture insurance. NGOs and microfinance organizations can play an important role in educating farmers. Pilot experiment has been done by a private bank in association with other agencies in southern India[13,8]. More such studies need to be carried out.

Investment in infrastructure for developing weather stations[4], making weather data widely available, educating people and organizations, developing a central authority for settlement are some of the pre-requisites for developing a robust and sustainable weather derivative market.

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