2.1 Introduction

This chapter brings out the in-depth study done on existing literature. The study has been done in two parts. The first is on the various crop insurance schemes which have been floated in India, and the lessons learnt from these. This will also discuss the commodity derivative exchanges and commodity derivatives trading in India, and the lessons learnt from these. Part two will bring out the history of weather derivatives and structures commonly used. The second part also brings out methods which could be used for pricing weather derivatives and techniques for determining willingness to pay for such products. This will set the pace for the study on the prospects and challenges of introducing weather derivatives in India.

Part I

2.2 Crop insurance in India

2.2.1 Evolution and history

Crop insurance in India has been on discussion agendas ever since independence in 1947 (AIFF, 2007). A special study was commissioned in 1947-48 to go into and recommend the approach that should be adopted. A major bone of contention, which emerged was whether we should use an Individual Approach or a Homogeneous Area Approach, where the area comprises villages, which are homogeneous in respect of production of a particular crop. The special study pointed out that the individual approach would be difficult to administer and implement. Administrative costs would be considerably higher since fixing of premiums on actuarially sound basis would require a large number of reliable data of crop yields of individual farmers. The issue of moral hazard would also arise and could have a large effect on premiums.

The special study recommended the Homogeneous Area approach. However, this met with difficulties, as many states were not in favour of, and did not accept the Homogeneous Area approach.

The generally agreed principles of crop insurance (Vyas and Singh, 2006) are:
(i) The risk and uncertainty faced by individual farmers is passed on to the insurer, in return for which, the farmer pays a premium.

(ii) The premium is calculated based on the risk, which is taken on by the insurer.

(iii) A pre-decided sum of money is to be paid by the insurer to the insured, when a loss is incurred by the insured, due to causes beyond his control.

In 1965, the government introduced a crop insurance bill. The cover was to be provided by state governments, but the central government was to frame a re-insurance scheme, which would cover the indemnity obligation of states. However, once again, many states were not in favour of this scheme (AIC, 2007).

In 1972-73, the Life Insurance Corporation of India (LIC) come-up with a Crop Insurance Scheme for H-4 Cotton. It was implemented in some states. However, this scheme continued only upto 1978-79 and covered around 3000 farmers. The premium collected was Rs 4.54 lakhs as against claims of Rs. 37.88 lakhs (LIC, 2007).

In 1979, the nationalized General Insurance Corporation of India (GIC), introduced a Pilot Crop Insurance Scheme (PCIS). This covered cereals, oilseeds, cotton, potato and gram. The scheme was based on the Area Approach and it was agreed that risk sharing would be in the ration of 2:1 between GIC and state governments. The premium would also be subsidized upto 50%, which would be shared equally by the Central and State governments. This scheme continued for 6 years until 1984-85 and covered 6.27 lakhs farmers. The premium collected was Rs. 196.95 lakhs, while claims disbursed were 157.05 lakhs (AIC, 2007).

CCIS
In 1985, the government floated the Comprehensive Crop Insurance Scheme (CCIS). This scheme, originally suggested by Prof. Dandekar in 1976, was administered by the Government of India with active participation by state governments. It was linked to crop credit and adopted the Homogeneous Area Approach. Twenty states and 2 union territories implemented this scheme till Kharif, 1999. Of these, 5 states which had joined the scheme initially, opted out after a few years.
The total premium collected was Rs. 403.56 crores, whilst the total claims disbursed were Rs 2303.45 crores, resulting in a claim to premium ratio of 572% (Ifft, 2001). The total number of farmers covered was 763 lakh (Vyas and Singh, 2006).

An analysis of premium figures, show that claims made were approximately of the order of 9% of the sum insured. Administrative costs were about 6% of the sum insured. Thus, without subsidy, premiums would have been approximately 15% of sum insured. In actuality, subsidized premiums were of the order of 1-2% of the sum insured (Ifft, 2001).

The CCIS was a result of the Prof. V M Dandekar committee, which was set up by the government in 1976 to look into the issues and modalities of crop insurance in India. The committee pointed out that any scheme based on the Individual Approach would be impracticable to implement, and so recommended the Area Approach.

The main features of the CCIS were:

(i) It was compulsory for farmers taking loans from financial institutions for growing food crops and oilseeds.

(ii) Coverage was restricted to the entire amount of the crop loan subject to a maximum of Rs. 10000.

(iii) The subsidized premium to be paid by the farmer was 2% for cereals and millets and 1% for pulses and oilseeds. Of this, 50% was subsidized by the Central and State Governments on a 50:50 basis.

(iv) It was optional for state governments to join the scheme.

(v) Premium and claim sharing between the central and state governments was in a 2:1 ratio.

(vi) The scheme was promoted jointly by the Government of India, State Governments, GIC and participating banks.

Of the total claims of Rs. 2303.45 crores, 47% were paid in the state of Gujarat and 21% in Andhra Pradesh (AIC, 2007).

While the CCIS was still on, the government floated a new scheme called the Experimental Crop Insurance Scheme (ECIS) in 1997-98. This was very similar to the existing CCIS, but was meant only for small and marginal farmers in participating states. Hundred percent subsidy was provided in the premium,
which was shared by the Central and the State in a 4:1 ratio. However, this scheme was discontinued after just one season.

NAIS

From Rabi, 1999, the CCIS was replaced by the National Agricultural Insurance Scheme (NAIS), which was also called the Rashtriya Krishi Bima Yojna (RKBY). This was administered by the Ministry of Agriculture in the Government of India, and was implemented by the GIC.

Three policy goals were laid down for the NAIS.

(i) Social response – to provide support to farmers during crop failures
(ii) Risk management – for financial institutions to be able to provide rural financial services more efficiently, so that farmers would have better access to finance
(iii) Fiscal exposure – to control the government’s fiscal exposure during disaster years.

The objectives of the NAIS also included an encouragement to farmers to adopt progressive farming practices and the latest technology in agriculture.

The main features of the NAIS were:

(i) The crops covered included cereals, millets, pulses, oilseeds, sugarcane, cotton and potato.
(ii) Loanee farmers, i.e. those availing loans for growing the notified crops would have to compulsorily opt for the scheme, whereas non-loanee farmers could join on a voluntary basis.
(iii) The scheme was optional for states, but those opting had to continue for at least 3 years.
(iv) Comprehensive risk insurance covered yield losses due to non-preventable risks.
(v) Sum insured could be up to the value of threshold yield, which was based on the Average Yield of the notified area.
(vi) Premium rates varied from 1.5% of sum insured, for wheat, to 3.5% of sum insured, for oilseeds.
(vii) A transition to the actuarial rate regime for cereals, millets, pulses and oilseeds was to be made in 5 years.
(viii) A 50% subsidy in premium was allowed for small (land holding 5 acres or less) and marginal (land holding 2.5 acres or less) farmers, to be
shared equally between the central and state governments. This was to be phased out in 3-5 years.

(ix) The scheme was operated on the basis of ‘Area Approach’. The area was to be defined by the state and could be a Gram Panchayat, Mandal, Hobli, Circle, Phirka, Block, Taluka etc.

(x) Estimation of crop yield was to be done by crop cutting experiments with a minimum of 16 at Taluka level, sliding to a minimum of 8 at the Gram Panchayat (comprising 4-5 villages) level.

(xi) 3 levels of indemnity (90%, 80%, 60%) for low, medium and high risk areas were to be based on coefficient of variation in yield of last 10 years data. Threshold yield for the purpose of insurance, was the moving average (3 years yield), multiplied by the level of indemnity.

(xii) Claims were to be settled based on yield data, and paid to nodal banks which, at grass-root level, were to credit the accounts of individual farmers.

(xiii) Administrative and operating expenses were to be shared by Central and State Governments on a sunset basis.

(xiv) Re-insurance cover was to be obtained by GIC in the international reinsurance market.

Varsha Bima, 2005

In December 2002, the Agriculture Insurance Company of India (AIC) was set up. This was promoted by the GIC, NABARD and 4 other public sector insurance companies. The AIC took over crop insurance activities from the GIC in April 2003.

The Varsha Bima Scheme was introduced in Kharif 2004 as a pilot project in 20 rain gauge stations of the Indian Meteorological Department (IMD).

In 2005, the Varsha Bima Scheme was launched in 10 states, initially covering 140 IMD rain gauge stations. The scheme is intended basically to cover financial losses incurred owing to crop losses, which result due to adverse rainfall (AIC, 2007).

Premium rates have been fixed between 4 to 7% of sum assured, varying based on a particular crop's sensitivity to rainfall and on the local rainfall distribution.
Along with the Varsha Bima, the AIC also launched a scheme called the Sookha Suraksha Kavach (SSK), which is basically a drought insurance scheme, exclusively for the state of Rajasthan. It covers 23 districts and major crops. Premiums are in the same range as the Varsha Bima and vary between 4-8%. The main advantages of these schemes are:

(i) Quick settlement of claims
(ii) Flexible premiums for insurance
(iii) Lower administrative costs
(iv) Option of group insurance, where a group of farmers can opt for Varsha Bima or SSK by submitting a single crop-wise proposal, along with details of each individual forming the group.

However, one major disadvantage of the Varsha Bima, 2005, is that a farmer buying a policy under the scheme cannot cover the same crop in the same area through any other form of crop insurance (Raghuvanshi, 2005). So, in a sense, risk cover is limited only to adverse rainfall.

2.2.2 Weather insurance schemes by private agencies

Probably the earliest record of private forays into the weather risk market in India is the BASIX-ICICI Lombard venture in 2003 in Andhra Pradesh (Manuamorn, 2007). Whilst ICICI Lombard was the insurer, BASIX took on the role of selling the policies to the farmers. They were able to scale-up the venture more than 30 fold in a period of three years.

BASIX is a new generation livelihood promotion institution established in 1996, working with over 190,000 poor households in 44 districts and eight states. With its wide reach and its policy of working in backward areas, BASIX was a good intermediary between the insurance company on one hand, and the farmers on the other. BASIX initially started by promoting life insurance policies of insurance companies and then later, moved on to livestock and health insurance products. Its tie-up venture, in 2003, with ICICI-Lombard, was undertaken along with technical assistance from the World Bank.

What prompted the scheme was the plethora of problems which had plagued the CCIS and the NAIS schemes of the government. With the experience of these two schemes behind them, they went in for an index-based insurance rather than a yield-based insurance. ICICI-Lombard claims a higher level of
transparency, an easier to administer scheme and one which is scientifically developed and objective (ICICI, 2006).

The process adopted by ICICI Lombard in structuring their product involves the following steps (ICICI, 2006).
1. **Peril Identification**: An appreciation of the agronomic properties of the crop is done. This is followed by a detailed correlation analysis to see the way weather impacts crop yield/output of other economic activity.
2. **Index setting**: An index is created by assigning weights to critical time periods of crop growth. Weather data of the past is analysed and mapped onto this index in order to determine a threshold index.
3. **Pricing**: Pricing of the insurance is done based on expected loss, volatility of historical levels of the index, and management expenses.
4. **Monitoring**: This includes collection of weather data on a continuous basis.
5. **Claims settlement**: ICICI Lombard’s claims of ease of administration are based on the fact that the beneficiary is not required to file a claim for loss, in order to receive a payment.

The product was launched by the company in 2003 for a few crops. In Kharif 2005, policies were designed and sold in close to 100 locations covering 1 lakh farmers. In 2006, ICICI Lombard also ventured into weather insurance for salt and brick kilns. The deals entered into included:
1. Oranges in Jhalawar, Rajasthan – covering 782 farmers over 613 acres for a sum insured of Rs 18.3 million.
2. Coriander in Jhalawar, Rajasthan – covering 1036 acres for a sum insured of Rs 12.75 million.
3. Various crops in the states of Tamil Nadu and Andhra Pradesh.

Some of the lessons learnt from the BASIX-ICICI scheme were:
1. The scheme started with coverage for the entire season, but within a year moved on to smaller durations within a season.
2. The scheme started with premium being charged based on the land-holding of the farmer, but then went on to a charge per acre of cultivation.
3. No government support was sought for the scheme.
4. Whilst initially, payout was determined as a proportion of the percentage deviation of rainfall from the pre-decided threshold, it was later modified to absolute deviation.
5. ICICI-Lombard transferred the risk to international markets by reinsuring the risk with reinsurers.
6. A lot of effort was put in by BASIX in educating the farmers and making them understand the processes involved.
7. Instead of crop-specific insurance, the emphasis was on area-specific insurance products.

In 2004, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) conducted a survey to assess the impact of the ICICI insurance product in the Anantpur and Mehboobnagar districts of Andhra Pradesh. A sample of 1052 farming households were interviewed, which included buyers as well as non-buyers of the insurance. Some of the salient findings were:
1. Farmers who are aware about and understand insurance are the ones who are willing to pay for it.
2. Farmers' perceptions of what the weather is likely to be (and so the impetus for them to buy the insurance) does not necessarily coincide with historical data.
3. Other risk-coping methods eg. sale of animals, poultry etc. affects the farmers' interest in weather insurance products.
4. Some of the farmers perceived the product as a gamble, rather than a risk-hedging method.

2.2.3 Comparison with crop insurance schemes in other countries

USA
In the United States of America, crop insurance is subsidized by the governments, but is administered through private companies. Hail insurance, however, is not subsidized; and so is offered by insurers, along with the subsidized government policies.

Premium rates are based on the history of crop losses. But here, ‘Adverse Selection’ is not a major issue, since rates are set higher for areas which have a higher risk (Raghuvanshi, 2005).

South Africa
Crop insurance in South Africa first started in 1929, when a group of farmers started a pool scheme. In the first few years, most of the crop insurance schemes were subsidized by the government. But now, for the last 20 years or so, no subsidy is given by the Government.
After the withdrawal of subsidies to crop insurance, several insurance players entered the market and there is an ever growing market in the area of crop insurance. The South African experience illustrates the benefits of crop insurance even after subsidies are withdrawn (Ravikumar, 2006).

Canada
Similar to India, Canada follows an Area Approach. However, Turvey and Islam, 2006 indicate that the Area approach has been inequitable and inefficient. Empirical research from 537 farms indicates that the Individual Approach to crop insurance is better.

2.3 Lessons learnt from crop insurance in the Indian context
Crop insurance schemes in India cannot really be viewed as success stories. However, consolation can be drawn from the fact that failures in public crop insurance schemes have happened not just in India, but also in the developed world (Ifft, 2001). Private players have had a better success rate (Raghuvanshi, 2005).

There are, however, many lessons to be learnt from the many crop insurance schemes that India has experimented with – and these could provide inputs to the design of newer financial risk management products like weather derivatives. Some issues we discuss are:

1. Premiums will have to be based on true risk-levels. Crop insurance needs to be a facility available for risk management. A farmer, in any agricultural system, will avail of crop insurance if he feels that his risk management needs are met by the crop insurance scheme. Raghuvanshi, 2005 argues that if a farmer faces risk of such a magnitude that he cannot survive without subsidized insurance then this implies that the cropping system, itself, is not sustainable.

2. If the government stays in the crop insurance market, through provision of subsidies, it would not be possible for private players to enter the market. This would curb experimentation with innovative financial products for risk management. Skees, 2000, documents this as one of the reasons for the underdevelopment of private crop insurance. Subsidized crop insurance crowds out private players and stifles innovation.

3. The problem of adverse selection arises when, as in government administered or government subsidized schemes, a common premium is
charged across the board for all. In this case, the worst farmers are the ones who are likely to avail of the insurance, thus making the number and amount of claims to be unreasonably high. This then, would lead to either an increase in premiums on a continuous basis, or a rising amount of subsidy. Thus for a scheme to become financially viable, premiums would have to rise continually.

The case of adverse selection is evident in the NAIS, as we note that the states of Punjab and Haryana, which produce the most, did not participate in the scheme.

4. The Area Approach is easier to administer, but this results in many problems. Often farmers with no loss end up being able to claim since the Area Yield was found, through crop cutting experiments, to be lower than threshold yield. On the other hand a farmer, who has suffered a loss, might not be able to claim because the Area yield was declared as being higher than the threshold yield.

However, in the Individual Approach to crop insurance, the problem of moral hazard arises. This is when the insured is less vigilant or puts in less effort to avoid a loss, since he knows that he is insured and would stand to get a claim in the event of a loss.

5. It is important to understand the situation and the needs of villagers. Their daily lives, how they structure their needs, and the occupations they engage in, would give insights while planning and designing financial risk management products for them. Very often, farmers in India have no source of income other than from farming – and so they become highly dependant on the monsoons, especially in areas which are not irrigated.

6. A large part of Indian agriculture, being rain-fed, has a very heavy dependence on weather. Risk coping measures include the Minimum Support Price (MSP) given by the government for various crops, and forward trading which is available for farmers to lock-in the price for their crop. Nevertheless, crop insurance and/or products like weather derivatives are their means to cope with natural risks.

7. Crop insurance in India has become a sort of loan-insurance. The benefit actually goes to the providers of the loan, whilst the premium is paid by the farmer.

8. The government needs to be involved in the creation of, and if necessary, subsidy in, agricultural infrastructure and research. Private players would automatically move into the market and compete with innovative products, if the government moves out of the crop insurance market.
9. There is a major need for education and awareness.

In spite of the government's goals of the scheme being able to be financially viable in 5 years, the NAIS had an average loss ratio of around 350% in the first 4 years (firstinitiative.org, 2006).

As a result, in June 2006, the Government of India decided to reform the NAIS and to place it on an actuarial footing. It was decided to base premiums, more practically, on actual costs. The AIC is to receive premiums in full. This would include upfront subsidies, which would be provided by the Government. AIC would be responsible for settling all claims. This now sets the path for premiums which are market-based.

In 2006 also, a World Bank funded project offered technical assistance to the AIC in order that more effective crop insurance products could be developed. The emphasis is on pricing them on an actuarially sound basis and improving the scope for risk management. The project will be developing a series of pilot weather insurance schemes which is being implemented by AIC starting from the Rabi season of 2007-08.

Once an effective actuarially sound pricing system is in place, this would help the AIC in being able to access global re-insurance markets.

2.4 Commodity derivatives in India

2.4.1 History

It can be seen in most developed economies, that the derivative markets have usually been an integral part of the capital markets. Derivative markets have allowed the transfer of unwanted risk and so derivatives have been able to help in the allocation of capital across the economy in a more efficient manner. This, in turn, has contributed to increased productivity in the economy.

The history of forward trading in exchange based derivatives in India is not very old. However, as a precursor to these, there did exist a kind of forward trading in the form of Teji (Call option), Mandi (Put option) and Fatak (Straddles) in the unorganized Indian markets (Saxena, 2003).

When one goes through the global history of derivatives, it can be seen that the first derivatives contract was an agricultural contract which was entered into at
the Chicago Board of Trade (CBOT) about a hundred and fifty years ago-1859 to
be precise. Soon thereafter, trading began in derivatives of various products.
Trading in metals began in 1878 at the London Metal Exchange.

These derivative contracts continued in pockets for about a century until
technological changes led to the globalization of transactions. This, coupled
with the volatility in currency exchange rates, led to the development of currency
contracts in the late 1960s. At the Chicago Mercantile Exchange (CME),
currency derivatives were introduced in 1968 and then interest rate derivatives
in 1971. Energy indexes for energy derivative trading were introduced in 1974.

There are three basic users of derivatives: Hedgers, Speculators and
Arbitrageurs. Each is a player in the market and each has a particular role in the
market. Hedgers use derivatives to cover risk arising out of adverse movement.
Price risk would be inherent to any open position and this is what a hedger is
trying to protect himself against. The basic purpose of derivatives is to reduce
the volatility of a portfolio by reducing the risk.

Speculators use the volatility in prices to make a profit. If hedgers want to
reduce their risk in a volatile market, it is the speculators who provide the role of
a counter-party. They are ready to take the risk of price variation in order to
profit from price changes in the underlying.

Arbitrageurs are those who use market imperfections to make a profit for
themselves. They are the safest of the three classes of players and end up earning
risk-free profits from price differences in two different markets.

In India, the evolution of commodity derivatives trading has its genesis in the
cotton and oilseeds markets, which started in Bombay, in 1875 and in 1900
respectively. The raw jute and jute goods market started in Calcutta in 1912 and
the wheat market started in Hapur in 1913. Trading in bullion was first done at
Bombay in 1920.

The Indian Commodity markets are far behind those in developed countries.
This is mainly because of the long period of prohibition in forward trading in
major commodities. In 1939, cotton options business was banned in order to
restrict speculative activity. Just four years later, in 1943, the Defence of India
Act was utilized to prohibit forward trading in many commodities, including
oilseeds, foodgrains, spices, sugar and cloth. In 1946, the Essential Supplies Temporary Powers Act was put in place- and this continued the ban on forward trading.

After independence, in 1950, the constitution of India placed “Stock exchanges and future markets” in the Union List. In 1952, the Forward Contracts Regulations Act (FCRA) was passed by parliament. But the restrictions continued. In the aftermath of the war with China, futures trading in gold was prohibited. In the late 1960s, forward trading was banned in all commodities except for Pepper, Turmeric, Castorseed and Linseed. This was done at a time when domestic production of farm products was not enough to meet the local demand. In 1977 even Castorseed and Linseed were added to the list of banned commodities.

However, things looked up in slow and agonizing steps in the 1980’s. In 1980, forward trading was allowed in Potato and Gur. In 1985, it was allowed in Castorseed.

In the 1990s, the process of liberalization of the economy started. 1993 saw the setting- up of the Prof. K.N. Kabra committee. This recommended allowing futures trading in 17 commodities. It also recommended amendments to the FCRA, 1952 and the strengthening of the FMC, including registration of brokers with the FMC. The government accepted the report almost in-toto. Futures trading was permitted in all except Bullion and Basmati Rice. The FMC was strengthened with additional staff and the post of Chairman of the Commission was upgraded to Additional Secretary to the Government of India.

In 1999, the National Agricultural Policy was announced by the government. It brought out an intention to increase the coverage of the futures market in order to minimise wide fluctuations in commodity prices as well as to allow a means of hedging risk. The government set up an expert committee on Agricultural Marketing headed by Shri Shankerlal Guru. This committee strongly recommended the linkage of spot and forward markets, inclusion of more commodities in which trading could be permitted and a system of warehouse receipts, which could be national in nature – rather than being local or even regional.
In 1999 itself, the government appointed a committee under Shri K C Misra, who was at that time the Chairman of the FMC, to prepare a road map for setting up a national wide multi-commodity exchange. However, the committee members themselves were unable to resolve their own differences especially on the location of the exchange. This led to a loss of more than three years in the setting up of the exchange. In fact, later it was felt that setting up only one exchange might create unwanted monopoly and that multiple exchanges might be better. It was also felt that these should be set up with a clear message that there would be no promises of a government bail-out in case of failure because of competition.

In 2002, the Finance Minister, in his budget speech, announced the government's decision to allow futures and forward trading in all agricultural commodities.

The Indian commodity markets have not developed as much as they should have. Even today there is the very obvious worry of a ban in some commodity or the other. Forward trading in wheat has been banned in February 2007 in order to stem the overall price rise in commodities, and there is a fear in the markets that more commodities might get added to the banned list if inflation is not reined in.

In spite of apprehensions, the Indian markets have survived the many bans in the past, but this has been mainly because of a grey market which has carried on (Kolamkar, 2002).

When the slow development of the Indian commodity derivative markets are discussed, what comes into prominence is the fact that the other markets in India have not had similar problems. Even the securities market in India grew rapidly and today has modern infrastructure, systems and regulations, which allow it to be comparable with securities markets in other countries.

With a realization to this effect in the very recent past, there has been a need for leapfrogging to get over the lethargic growth of the commodities derivatives markets. The FMC has had to facilitate this, and has done so by studying and implementing some regulatory measures, which are in vogue in developed markets. Some of these are listed below:

(i) Daily mark to market margining
(ii) Time stamping of trades
(iii) On-line trading for new exchanges
(iv) One-third representation of independent directors on the Boards of existing exchanges.

These regulatory measures have, expectedly, met with a lot of resistance from traditional exchanges eg., the Bombay and Kanpur commodity exchanges.

Kolamkar, 2002 argues that the perception that a futures market has a volatility aggravating impact in shortage situations might not be true. It has to be appreciated that even in the shortage situation, the futures market helps to smoothen the demand for the commodity and has a salutary impact of reducing intra-seasonal price spread.

2.4.2 Comparison with financial derivatives in the USA

The Chicago Mercantile Exchange (CME) started trading currency futures in February 1972. In April 1973, the Chicago Board Options Exchange (CBOE) was set up to trade options on common stocks. This was the first time that an option was traded on an exchange (www.geocities.com/kstability/content/derivatives, 2007). In January 1976, Treasury Bill futures were traded in the CME. At the same exchange, in December 1981, the first cash settled contracts took place in the form of Eurodollar futures. This then led to the introduction of derivatives on stock index futures. In February 1982, the Kansas City Board of Trade (KCBT) listed futures on a composite stock exchange, followed by the CME listing of S&P 500 futures. In January 1983, the New York Futures Exchange (NYFE) listed options directly on stock index futures and in March the same year the CBOE listed options on stock indexes.

Another noticeable feature in the US markets is the self-regulation aided by the National Futures Association (NFA), which was registered with the Commodity Futures Trading Commission (CFTC) in 1982. This body, comprising of members from various industries, is a self-regulatory organisation which helps bring about ethics and integrity in the market. In the last 10 years, consumer complaints have decreased by 60%, while volumes of futures trading have doubled (Sahadevan, 2006). With a large amount of responsibility being taken on by the NFA, the CFTC has passed on its role of screening and registering people applying to conduct business in the futures industry. The NFA has made rules to help protect the interests of investors, to aid floor-trading practices etc.
In fact, the CFTC has even transferred the responsibility of registration of brokers, to the NFA.

2.5 Lessons learnt from the history of derivatives

There are a lot of lessons to be learnt from the process of introduction of derivatives trading in securities which have been to quite an extent extrapolated to trading in commodity derivatives. Lessons from both these experiments need to be kept in mind when the introduction to weather derivative trading takes place in India. As such, a thorough review of the process of introduction of derivatives trading in securities in India would be apt.

There were, expectedly, many hurdles faced prior to the introduction of trading. The first and foremost were the legal and regulatory issues, most of which were addressed by the J R Varma group which went into these aspects. There then was the resistance to allowing the introduction of derivatives mainly from people who were apprehensive about the processes involved and the issues of safety. There were the major challenges of building awareness and educating the community about derivatives. Finally there was the aspect of the need for active marketing of the products which were designed.

The resistance to the introduction of derivatives and the subsequent protests were more emotional than objective (Narain, 2003). They were mostly aimed at the risk involved in derivatives trading, the issue of a lack of maturity of the Indian investors and the potential of large losses for individual investors who might plunge into the markets without sufficient knowledge and without sufficient research. Both, the L C Gupta committee and the J R Varma group, were of tremendous help since they publicly communicated the need for derivatives and their benefits as also the development of a sound regulatory framework. These, therefore, brought about a sense of confidence in the public when derivatives trading was actually introduced.

The challenge of education and training was very well taken up by the National Stock Exchange. Initially this was at a low key, but the persistence of the team at the Exchange finally paid out. The early training programmes were planned once in a week and the focus was only in Mumbai. But slowly, the frequency was increased and these were then spread across the country. Initially the programmes were only in English, but very rapidly they were also done in Hindi, Gujarati and Tamil.
In fact, once trading started, the awareness campaign by the NSE really took off. Workshops were held, not only for analysts, but also for members of the press. Then, press reporting on prices and volumes and market analysis by experts, which were reported by the media – all helped in increasing awareness amongst potential traders. Institutional participation, however, took much longer to come by. This could be attributed to many reasons including the approval processes required before an institution could get involved in derivative trading, the usual resistance to change and the lack of clear accounting procedures. An absence of clear guidelines on the tax liabilities of institutions involved in derivative trading also delayed the entry of institutions into the arena.

Another factor which helped in the spread of awareness stems from one of the recommendations of the L C Gupta committee, that broker-members and dealers in derivatives must pass a certificate programme considered adequate by SEBI. A web-based on-line objective type test was launched. The training programmes, coupled with the tests were highly successful.

What also helped, were the efforts of NSE to have a close working with colleges and academic institutions. The result was that the student community was involved right from the beginning.

The F & O business had a slow start. In the first year of trading, the average monthly traded value was in the region of Rs.240 crores. By June 2001, this figure touched Rs 800 crores. The first surge came in September 2001 when there was a surge in volumes in derivatives trading, the world over. The monthly traded volume in India touched Rs 5000 crores. The second big surge accompanied the introduction of stock futures for trading in November 2001 when volumes touched Rs 1200 crores per day.

2.6 The concept of derivatives exchanges

Since the move to the floating rate system in 1973, exchange rates, across the world, have shown a fair amount of volatility. Volatility has been even more pronounced in the case of prices of commodities. As a corollary to this, there are financial risks which affect a firm's business profits and hence cannot be ignored. A very large number of businesses across the spectrum, are affected by exchange rates and commodity prices. This could be either through a variation, from the planned, in input cost or through a variation in the earnings from sales.
It was to respond to these price volatilities that derivative investments were developed. Examples of derivatives include forwards, futures and option contracts.

As derivative instruments developed, there was an obvious need for a central place where these could be traded; where one could find buyers/sellers for a certain commodity derivative; and where one could trade with some degree of surety with respect to the counterparty.

A derivatives exchange can be defined as a trading forum or a system that links a central trading floor- where buyers and sellers meet, with a clearing house- which intermediates and validates deals. As stated earlier, besides being a meeting ground for buyers and sellers, the primary function of a derivatives exchange is to facilitate the transfer of risk among economic agents by offering mechanisms for liquidity and price discovery (Tsetsekos and Varangis, 2000). As confidence spreads amongst the various players and the stakeholders, the exchange brings together a large number of participants in the risk transfer game.

Commodity exchanges, like other exchanges, started with the traditional open outcry system. With the advent of modern technology, especially communications technology- a sea change has come about in the structure of derivative exchanges. Today, most commodity exchanges use electronic systems, which are considered much safer than the open outcry system. Just as an example, in an electronic system it is possible for the system itself to check for the availability of adequate margins before a trade is accepted.

Today, most exchanges function as very professional organisations, in a demutualised form, where they have moved away from the system of being governed and run by their members. This has the advantage of not mixing the two aspects of trading and governing the exchange.

Derivative exchanges grew rapidly with the realisation that the financial infrastructure of a country is strengthened through the links between speculators, hedgers and the cash markets. Derivative exchanges make more information publicly available- so that credit systems and capital markets are more responsive, transaction costs are lower and forward prices are more accurate (Tsetsekos and Varangis, 2000). In fact, improved price discovery is
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considered one of the major results of setting up of derivative exchanges the world over.

In any derivative exchange, specifications are written for standardised contracts, setting the contractual obligations between the parties. One of the main ways in which risks are managed is the setting of margins. This allows the clearing house to guarantee all transactions, in a sense acting like buyers to sellers and as sellers to buyers.

The basic elements in the structure of a derivative exchange would be:
1. regulatory mechanisms
2. trading systems
3. settling procedures
4. a clearing house and clearing systems
5. derivative products which can be traded

Systems of derivatives trading including the regulatory environment, will vary across countries. Whilst low or no regulatory mechanisms could very easily lead to chaos, a high degree of regulation and strait-jacketing could lead to a stifling of the market. The ultimate aim is to increase the investors' confidence.

Traditionally in India, trading in commodity derivatives was done in commodity exchanges which were product specific e.g., the Pepper exchange, the Wheat exchange etc. This was until 2003 when the Multi Commodity Exchange (MCX) and the National Commodity and Derivatives Exchange (NCDEX) were set up.

We now discuss some key issues with reference to commodity derivative exchanges in India.

(i) The key to success in developing the markets for commodity derivatives lies in creating liquidity. Markets are driven by hedgers, arbitrageurs and speculators. A major role in creating liquidity is played by speculators.

(ii) The lack of well-developed, organised spot markets and price discovery mechanism is a major impediment to arbitraging (Jagadharini and Putran, 2002).

(iii) For hedging, there is a need to provide awareness through education. Along with this is the need for a distribution chain for training.
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/awareness programmes, which would encourage a wider body of participation.

(iv) There would always be a need for some reference price (one method is through polling methodology), examples of which are the MIBID/MIBOR rates announced by the NSE, which are widely accepted.

(v) The spot market and the price discovery process in the spot market play a major role in commodity prices. These are affected by forces like the Minimum Support Price announced by the government for essential items, procurement by the Food Corporation of India, etc.

(vi) The structure of a commodity derivative exchange and its management would play a major role in its ultimate success. The trend today is towards having a demutualised, tax-paying, corporate structure. Under this kind of structure, the ownership of the exchange is separated from trading rights. This is a departure from the traditional structure where the members of the exchange had trading rights and at the same time, were also its owners. The demutualised structure, as has been adopted by the MCX and NCDEX, requires professional management of the exchange.

(vii) A departure from the traditional open outcry system to the electronic system has been adopted by most exchanges. Even in commodity derivative exchanges, there is a need for a nation-wide, automated electronic exchange where price-dissemination is on a real-time basis.

(viii) Contracts are designed to take into account the characteristics of the underlying. These would include quality and grades, life of the underlying product, effects of seasonality, effect of international markets. All these and other factors would lead to the size of the contract etc.

(ix) One of the major factors leading to the success of an exchange is the effectiveness of settlements. Efficient settlements include a daily mark to market settlement. Final settlement could either be through physical delivery or through cash settlement. In the case of commodities, the former course does result in problems of storage, inter-state movements etc. Of course, the option of 'physical delivery' would not be available in the case of weather derivatives.

In the case of commodities, when we take the course of physical delivery, issues of warehousing, a system of grading and quality of the product, the quality of the warehouse itself, warehouse regulations etc. arise. There is a move lately, towards warehouse receipts. These are taken to be equivalent to physical delivery.
Another major factor in the success of an exchange is the risk management measures adopted. Counter-party risk is taken care of by having a clearing house. Upfront margins and then a system of daily mark-to-market settlements are a common feature of commodity exchanges. Scenario analysis using software like SPAN® to determine Value at Risk of the portfolio, are used by exchanges (Jagadharini and Putran, 2002).

Portfolio limits are imposed for each of the players.

A lesson learnt from earlier commodity exchanges vis-à-vis present day exchanges, is that liquidity is directly proportional to the amount of transparency in dealings.

The FCRA, 1952, does not permit options on commodities. A large number of investors, especially farmers, are hesitant to enter the commodities market because of the non-availability of options (Ravikumar, 2006).

Banks could provide a large amount of liquidity in the commodities markets. A regulatory amendment to allow banks to trade in commodities would help.

Goods are still defined in the FCRA, 1952 as being limited to whatever can be delivered. For trading in weather derivatives to be possible, this would require an amendment.

Like banks, Mutual Funds and FIIs are not permitted to trade on commodity exchanges. Liquidity and volumes would increase substantially if they are allowed to participate. MFs and FIIs bring with them, experts who could play a vital role in tracking and bringing out global and other macro-factors, which play a role in commodities prices. This would be beneficial in price forecasting.

Dissemination of market-discovered prices would invite a greater market participation. This task becomes huge when we look at dissemination up to the farmer level and calls for investments as well as coordination with the ICT spread which is taking place in India at the rural level.

2.6.1 The LC Gupta Committee: major recommendations

The committee had conducted a wide market survey with brokers, mutual funds and financial institutions. It observed that there was an all round opinion that derivative products were required – mainly for hedging. The major recommendations of the committee were:
(i) There is a need for the development of a coordinated market for derivatives to cover market/systematic risk, interest rate risk and exchange rate risk.

(ii) The committee favoured the introduction of financial derivatives to facilitate hedging in a cost-efficient way against market risk.

(iii) SEBI and RBI should have coordination in respect of all financial derivatives markets.

(iv) There is a need for improvements in the cash market, on which the derivatives market will be based.

(v) Derivative trading should take place on a separate segment of the existing stock exchanges with an independent governing council.

(vi) Trading should be an on-line screen trading with a disaster recovery site.

(vii) Settlement should be through an independent clearing corporation/clearing house.

(viii) Clearing corporation must have adequate risk containment measures and to collect margins.

(ix) The derivatives exchange should disseminate trade and price information on a real-time basis.

(x) Arbitration and investor grievances cells to be set up in four regions.

(xi) The regulatory framework should be on a two-level regulation - exchange level and SEBI level with emphasis on self regulation under supervision and guidance of SEBI.

(xii) SEBI to approve rules, bye-laws and regulations. New derivative products must be approved by SEBI. Exchange must provide:

a) Economic purposes of the contract.

b) Likely contribution to the markets' development

c) Safeguards incorporated for investor protection and fair trading.

(xiii) Exchanges to decide to trading days and hours, expiration date of contracts etc.

(xiv) Membership criteria to be stringent. Clearing members to have a net worth of Rs 3 crores.

(xv) The clearing corporation to be restructured. Initial and mark-to-market margins must be stipulated based on levels of volatility.

(xvi) Cross margining was not favoured by the Committee.

(xvii) Funds transfer for margins etc should be through EFT (Electronic Fund Transfer). Exchange to have power/facility to disable defaulting member from further trading.
(xviii) Clearing Corporation may prescribe maximum long/short positions by members or exposure limits.

(xix) There should be a system of daily settlement of futures contracts. Final settlement price to be as per the closing price of underlying security.

(xx) There should be a unique order identification number, a regular market lot size and tick size, price bands for each derivative contract and an indication of maximum permissible open position.

(xxi) Brokerage to be prescribed by the exchange.

(xxii) Creation of a derivative cell at SEBI.

2.6.2 The JR Varma group: Major recommendations

The group was set up in June 1998 by SEBI to recommend a roadmap for effective implementation of the LC Gupta Committee report. The major recommendations were as follows:

(i) The exponential moving average method would be used to obtain the volatility estimate every day to calculate margin calls. The trading software could provide this information on a real time basis on the trading workstation screen.

(ii) The clearing corporation must lay down operational guidelines on collection of margin and standard guidelines for back office accounting at the clearing member and trading member level, to facilitate the detection of non-compliance at each level.

(iii) Clearing corporation must disclose details of margin collection failure at least on a quarterly basis.

(iv) Liquid net worth of a clearing member must be at least Rs 50 lakhs i.e. total liquid assets deposited with the exchange-less initial margin applicable to total gross open positions of all trades cleared through clearing member, to be at least Rs 50 lakhs.

(v) Clearing corporation to lay down exposure limits for a single bank which would include guarantees provided by the bank as well as debt/securities of the bank deposited by members as liquid assets for margin/net worth requirement.

(vi) At least 50% of the total liquid assets to be in the form of cash equivalents.

(vii) No position limits for individual clients – but if any person/persons acting in concert together own 15% or more of the open interest, then this is to be reported to the exchange. Failure to do so will attract a penalty.
(viii) Position limits for trading member: 15% of open interest or Rs 100 crore, whichever is higher.
(ix) No limits on the total market-wide open interest.

2.6.3 Comprehensive review of derivatives trading in India

In 2002, SEBI's Advisory Group on Derivatives reviewed some of the issues relating to the derivative market. These included the use of sub-brokers, stocks on which derivatives trading was permitted, settlement of options and futures contracts and use of derivatives by mutual funds. The group was also asked to do a review of the recommendations of the LC Gupta Committee. The major recommendations of the group were:

(i) Currency options and interest rate markets need to be more transparent. This should be done with the help of available technology.
(ii) SEBI and RBI should encourage trading in a variety of underlyings eg. Rupee-Dollar rate, interest rate, Mumbai Inter-Bank Offer Rate (MIBOR), etc.
(iii) Member wise position limits to be reviewed. Should be revised to 20% of the market-wise position limit in the stock.
(iv) Differences in margin collection dates (margins in the derivatives market are collected up front) between the derivative and cash markets to be removed so that the margin levels are harmonised.
(v) Only stocks which are in the top 500 in terms of market capitalisation and daily volumes, should be eligible for derivatives trading.
(vi) Some changes were proposed in the risk containment systems in the derivatives market.
(vii) For IPOs with a net public offer of or greater than Rs 5 billion, stock options and futures contracts should be offered from the time of listing in the cash market. This would help in efficient price discovery.
(viii) A new index should be eligible for derivatives trading if 90% of the weightage in the index is from constituent stocks, which themselves, are eligible for derivatives trading.
(ix) The minimum contract size of Rs 2 lakhs, should be done away with.
(x) Cross margining should be allowed at client level across the cash and derivative market, with a desirability that the clearing member be the same for both markets. Various conditions for cross margining were suggested by committee.
(xi) SEBI should not worry about physical separation of the cash and derivatives market, but should be concerned with separation of the legal
architecture of the derivatives segment through separate bye-laws, rules, regulations and Governing Council.

(xii) Sub-brokers, if any, should be registered with SEBI as trading members.

(xiii) Surveillance mechanisms in the derivatives market need to be different from those of the cash markets. There should be monitoring of open interest, cost of carry, impact cost and volatility. Timing of information disclosure by corporates should be monitored as this could affect contract prices at introduction and expiry.

(xiv) But unified surveillance of the cash and derivatives markets must be done both at exchange and SEBI levels.

(xv) Global surveillance practices should be studied.

(xvi) The derivatives cell at SEBI should be strengthened.

Part II

2.7 Weather derivatives

Weather Derivatives are a new, innovative and low-cost option for hedging risk. These could be used in many sectors, including agriculture, and would be especially relevant for developing countries (Hazell and Skees, 2005).

A weather derivative is a financial contract whose payout depends in a certain way on weather (Mraoua and Bari, 2005). The starting point would be an agreement to have a contract on a certain index which is dependant on the weather. The index could be related to rainfall, snow, temperature, wind, humidity, etc.

While various types of indices have been used to varying extents, the most common index used in the US and Europe is the temperature index. This is probably because one of the major factors for the growth of Weather Derivatives was the deregulation of the energy markets in the US (Alaton et al, 2002). The energy markets are highly temperature dependant as the American lifestyle calls for a large usage of energy in winters for heating and in summers for cooling. A small variation from the normal in the temperature leads to a large variation in the aggregate demand for energy. Consequently, this affects the planning for energy producers and distribution companies. Obviously then, they would look for a means to hedge their income risks and this led to the demand for Weather Derivatives.
Until a few years ago, 98-99% of Weather Derivatives traded were based on temperature (Garman et al., 2000). The most common derivative structures are based on cumulative Heating-Degree-Days (HDDs) or Cooling-Degree-Days (CDDs) for either a month or a season.

Degree-Day indices are mostly based on the number of HDDs, HDD\textsubscript{i} on a particular day \(i\), or the number of CDDs, CDD\textsubscript{i}, where HDD\textsubscript{i}/CDD\textsubscript{i} is obtained from.

\[
\text{HDD}_i = \max ((T_i - T_o), 0) \\
\text{CDD}_i = \max ((T_i - T_o), 0)
\]

\(T_i = \) average temperature on day \(i\) and \(T_o = \) a baseline temperature. Average temperature for a day \(T_i\) is usually taken as \(T_i = \frac{(T_i^{\text{max}} + T_i^{\text{min}})}{2}\).

The baseline temperature is taken as 65°F in the US, and 18°C in Europe. These are generally accepted as the temperature above which cooling would be required and below which heating would be required in order to achieve a comfortable ambiance. The way they are defined implies that HDDs and CDDs can never be negative. Also implied is the fact that on a particular day, both HDDs and CDDs may be zero, but at least one of the two will be zero.

The accepted baseline temperature of 65°F/18°C is based on conditions in the US/Europe and need not necessarily be true for Indian conditions. We would need to think of a different baseline for two reasons. The first is that the ambient conditions in India are different. In general, the average temperature is higher and this could possibly lead to a higher baseline temperature. The second is that the tolerance levels of Indians is higher – and they do not generally switch from heating to cooling at a particular temperature – but would probably have a band of tolerance. This could possibly lead to a different baseline temperature for HDDs and a different one for CDDs.

Besides normal structures, we could also have binary options. In this case the payout is either a fixed sum or zero. These kind of structures are generally confined to an event based index – e.g. the number of days it rained in the evenings in a month. This would be useful to event management companies, for example.

Contracts are structured differently in different exchanges. For example, on the Chicago Mercantile Exchange, the CME degree day index is the cumulative sum...
of HDDs/CDDs during a calendar month (Alaton et al., 2002). One contract is $100 times the degree day index. In the CME, options and options on futures are European style.

In general, the parameters for a weather option would be:

(i) Contract type – (American Call/Put, European Call/Put)
(ii) The period of the contract
(iii) The underlying index (Degree-days, rainfall etc.)
(iv) The weather station whose official readings would be used
(v) The strike level
(vi) The tick size
(vii) A cap on the maximum payout.

The last parameter, a cap on the max payout, is often used in Weather Derivative contracts to safeguard against extreme weather phenomenon.

The payout on a HDD call can be written as:

\[ p = \min \{ t \cdot \max ((T_0 - T_i), 0), h \} \]

Where t is the tick size and h is the maximum limit on the payout.

Thus \( p(T_i) = \begin{cases} 0 & \text{if } T_i \geq T_o \\ t(T_0 - T_i) & \text{if } L \leq T_i < T_o \\ h & \text{if } T_i < L \end{cases} \)

Where the equivalent limit on the temperature \( T_i, L = (T_0 - h/t) \)

The strike is typically set at between zero and one SD above the estimated expected index and the limit at around 2 SD – or the most extreme historical value for the index (Jewson et al., 2005).

Morocco has been using a rainfall index derivative for its cereal producers for a few years now. Programme Secheresse is a drought relief programme, which has gained immense popularity. In 2002, subscription to the programme was 80% of the 300,000 authorised hectares (Stoppa and Hess, 2003). But effects of moral hazard and adverse selection risk led to a World Bank sponsored project, which concluded that rainfall contracts would have better benefits. In Mexico, too, a pilot rainfall derivative scheme was developed for the region of Meknes, a wheat growing area in the north of Mexico.
The payout procedure followed is that a proportional payment is done when the indexed rainfall \((R_t)\) in the crop year is below a threshold level \((T)\). Specific weights are assigned to various growth phases of crop, since it has been established that some of the growing phases are critical with respect to water needs. The index \(R_t\) is calculated by summing the values of rainfall in each period ‘i’ by the specific weight assigned to the period. Thus:

\[
\text{Indemnity} = \begin{cases} 
0 \text{ if } R_t \geq T \\
\frac{T - R_t}{T} \text{ if } R_t < T 
\end{cases} \times \text{ Liability}
\]

The business structure in Morocco is that the rainfall index derivatives are sold in the form of a contract through MAMDA – a mutual insurance company, which is run by farmers’ representatives. The rural credit institution, CNCA, builds weather index insurance into farmer crop loans.

*Martin et al., (2001)* suggest a more flexible European precipitation option, where

\[
\text{Indemnity} = \begin{cases} 
0 \text{ if } x > \text{strike} \\
\frac{\mu (x - \text{strike})}{\text{strike}} \text{ if } \text{strike} \geq x > \text{limit} \\
1 \text{ if } x \leq \text{limit}
\end{cases} \times \text{ Liability}
\]

Where \(\mu\) is defined such that \(\text{limit} = \text{strike} \left(1 + \frac{1}{\mu}\right)\); \(\mu\) is thus an increasing payment factor.

### 2.8 The weather derivative market for industry

Since 2001, Price Waterhouse Coopers have been entrusted by the Weather Risk Management Association (WRMA), to carry out a survey to establish the size of the weather derivatives market. The survey results of 2006 indicate that the total value of trade was $45.2 billion, as compared to $9.7 billion the previous year. The Chicago Mercantile Exchange (CME) experienced significant increase in both, the number of trades, which increased by a factor of 4, and the value of those trades, which increased by a factor of 8. There was, however, a decline in the OTC market, which offset some of the increase, but relative to the size of the market, these declines were small.
The PWC survey also concluded that HDD remains the most common type of trade.

In India, one of the foreseeable major impediments to the growth of weather derivatives would be the lack of reliable weather stations in numbers which cover the vast geographical area of the country.

Some agricultural produce would not only require specific weather conditions, but also specific timings for those conditions. Turvey et al., (2006) take up the case of weather insurance for ice-wine in the Niagara Peninsula of Southern Ontario. Ice wine is a desert wine which is made from grapes picked in their natural frozen state at air temperature between -8°C and -12°C. If specific weather conditions are not met, the grapes go waste because by then they become "late harvest" grapes and fetch very low prices. A model has been developed in which the key insurable event is not only total harvestable hours, but also when they occur. Whilst the authors use a random strike price, they continue to use the best-available historical data in conjunction with Monte Carlo methods to estimate premiums for an exotic derivative product.

2.9 Valuation of weather derivatives

Valuation of most financial contracts are done for three reasons: (i) for pricing (ii) after a trade, to know the current value of the holdings and (iii) for purposes of regulation. The same principles apply to the valuation of weather derivatives.

In spite of the obvious need for universal pricing in the Weather Derivatives market, no standard pricing models are in place. Unlike other financial markets, there is no real common language in the weather market. Many market makers have developed their own models which they use only for their purposes and which they rarely share with others.

As a backdrop, it can be noted that one reason for the take-off of the options markets in the 1980s was the universally accepted Black-Scholes model for pricing. Such a model has not as yet been developed for Weather Derivatives pricing, which has universal acceptance.

Garman et al, (2000) bring out that the Black-Scholes model is inadequate for Weather Derivatives for the following reasons:
(i) Weather does not “walk” quite like the accepted “random walk” in asset prices. Instead, the phenomenon of mean-reversion comes into play.

(ii) Weather is not “random” – that is to say that because of its inherent nature, weather is approximately predictable.

(iii) Black-Scholes option payoffs are determined by the value of the underlying exactly at maturity. Weather derivatives usually provide for an averaging over time – more akin to “Asian” or average price options. In other words, they have a non-Black-Scholes payoff.

(iv) Weather Derivatives are usually capped.

(v) Underlying variables are not tradable prices and so pricing cannot be free of economy risk aversion factors – unlike the Black-Scholes model.

Most research into pricing of weather derivatives focuses on temperature based contracts. Various types of methodologies have been used, varying from simple approaches to complicated ones using factors which would be difficult to measure.

A large number of models proposed are Stochastic, using one factor models. Dischel (1999), Garman (2000), Meneu & Valor (2003) and Alaton, Djehiche & Stillberger (2002) have all used one factor stochastic models. Brody, Syroka & Zervos (2002) have extended the notion of Brownian motion to Fractional Brownian motion in order to better capture long-term interdependencies in temperature time series.

Martin, Barnett and Coble (2001) use a methodology for pricing based on the calculation of the expected loss in a contract by integrating over the probability distribution of the underlying. The authors recommended using the gamma distribution in the case of rainfall, as it could be fitted more accurately to precipitation observations than normal or lognormal distributions.

Equilibrium models have been used by Cao & Wei (1999) and Davis (2001). But these are difficult to use practically, because of the hard-to-measure factors used.

The CAPM brings out the proportionality of the excess return over risk free interest rate to the regression coefficient between performance of that investment and the performance of some wider market. So investments with low correlation are more desirable. Weather derivatives could therefore be a
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desirable form of investment since they have a low correlation with financial markets (Jewson et al, 2005). However, for Weather Derivatives CAPM would not hold too well since they are not yet accepted widely as a form of investment, thus resulting in a lesser demand than what would be inferred from the CAPM. Also, a large number of contracts being OTC, prices do not follow market dynamics.

Probably the simplest and most used models use the Burn analysis. Here payoff is calculated for a given contract over a set of historical outcomes for the underlying. The average payoff over a period of 20-30 years is taken as the fair price of the contract.

Bjordal and Skogen (2001) bring out the fact that pricing of rainfall derivatives cannot be done by directly using available stochastic models which have been applied to temperature based Weather Derivatives for two reasons:
(i) Precipitation cannot have a negative value, so differing from temperature
(ii) Temperature is continuous, whereas precipitation is discrete in nature. This itself would affect the stochastic model.

On the other hand, Burn analysis, where historical outcomes are used, can easily be adapted for rainfall derivatives. However, a major shortcoming is that it fails to distinguish weather patterns with high volatility. For example constant rainfall and highly volatile rainfall will be priced equally if the mean of both is the same. Another disadvantage is that Burn Analysis does not bring in probabilities of events more extreme than those in the historical period considered.

Burn analysis can be, in short, described as the amount that would have been paid out to a shorted put option every year for the past, say, 50 years. Nelken (2000) lists outs six essential steps in Burn Analysis:
(i) Collect historical weather data
(ii) Convert to degree days
(iii) Make corrections
(iv) Determine what the option would have paid out every year in the past
(v) Find an average of these amounts
(vi) Discount back to the settlement date
We could, of course, use a weather model directly, in which case simulated possible weather patterns in the future could be used instead of historical data to calculate payouts of options. This kind of a weather derivatives model is first calibrated with observed past data. Weather sequences are then generated using a Monte Carlo process. The average payout of the option under various scenarios is then calculated and this is taken as the expected payout of the option.

There would, in these processes, be a need for clean weather data. In fact, this would be crucial for the success of any Burn analysis. Dunis and Karalis (2003), bring out many interpolation techniques and filling methods for missing historical records of data. These include the Expectation Maximisation (EM) algorithm, the Data Augmentation (DA) algorithm, the Kalman Filter (KF) and the Principal Component Analysis (PCA). Of these, the authors find that PCA out-performs other methods and is easy to implement. It can be done in EXCEL. The advantages of using PCA for filling missing data are also brought out by Mraoua and Bari (2005).

Most authors model temperature using a mean-reverting property in the stochastic process. Typically, (Alaton et al, 2002) give:

\[ d T_t = \left\{ \frac{d T_t}{dt} + \alpha (T_t - T_m) \right\} dt + \sigma_t d W_t \]

Whose solution is \( T_t = \text{mean temperature at time t} \)

\[ = A + Bt + Cs \sin (\omega t + \phi) \]

\( \alpha (T_t - T_m) \) brings in the effect of mean reversion and

\( \sigma_t d W_t \) brings in noise with a standard Weiner Process.

The term, \( T_t \) incorporates seasonal dependence by bringing in a Sine function with \( \omega = 2\pi \) and a phase angle \( \phi. \) It also incorporates a trend effect – which could be attributed to global warming, urban heating effect etc. The trend is assumed to be linear.

The parameters A, B, C, \( \phi, \alpha, \) and \( \sigma \) are obtained from temperature data of at least the last 30 years.
Similar models can be used for precipitation modeling, albeit with minor aberrations. Emmerich, (2005), uses a similar model for rainfall in Germany.

Bjordal and Skogen, (2001), have used a one factor model for precipitation. They have chosen to model weekly – accumulated precipitation in order to capture seasonal trend and to reduce the volatility of the data set. Since precipitation has a lower bound of zero, a log-transformed model of the time series was found to be convenient.

2.10 Weather derivative pricing

Markets in the US and in Europe trade weather derivatives in two forms: Swaps and Options. Weather Swaps are similar to forward contracts, usually with a maximum limit on payout. In essence, two parties are only exchanging risks where one party gets the payment if rainfall is above the strike and the other if rainfall is below the strike.

So payoff from a long swap contract would be:

\[
p(x) = \begin{cases} 
  -L_{Rs} & \text{if } x < L_a \\
  t(x - K) & \text{if } L_a \leq x \leq U \\
  L_{Rs} & \text{if } x > U 
\end{cases}
\]

Where \(x\) is the index, \(t\) is the tick size, \(K\) is the strike and \(L_a\) and \(U\) are limits in units of the index. OTC contracts are usually traded with limits whilst CME contracts do not have limits and have daily settlements like futures (Jewson, et al, 2005).

A call option, on the other hand, would have payoff:

\[
p(x) = \begin{cases} 
  0 & \text{if } x < K \\
  t(x - K) & \text{if } K \leq x \leq L \\
  L_{Rs} & \text{if } x > L 
\end{cases}
\]

Just as with other options, we could have collars, straddles, strangles etc. We could also create baskets of options, which would be useful for companies/others who might have a weather risk at a number of locations.

While pricing, it is understandable that if there is one hedger and one speculator in a contract, than the strike can be expected to shift away from the fair value towards the speculator since he is taking on the hedger's risk. Such a shift is
normally calculated as a percentage of the Standard Deviation of the index. Or, we could say, in the long run, with repeated contracts, the speculator would make money at the cost of the hedger (Jewson et al., 2005).

However, it would have to be kept in mind that the risk for the seller of a contract is very high in the case of a single contract. He would then be forced to price it very high, in which case buyers would dwindle away. So this would be a market maker’s dilemma in the beginning.

Another issue in pricing is that of using forecasts. Two points emerge. The first is that accuracy of weather forecasting is highly dependant on the kind of equipment available. And so the success of weather forecasting would vary from country to country and region to region. On the other hand, forecasting in the case of financial markets is more dependant on human skills and experience. The second point is that forecasts in the financial markets play a large role in affecting the price of the financial instruments. On the other hand, weather forecasts play no role in affecting the weather.

Zeng (2000) talks of Prediction Based Pricing where, accepting that precise prediction of weather is infeasible, seasonal predictions of the probabilities that the temperature or rainfall will be above, near or below the climatic norm (P_A, P_N, and P_B) during 3 months periods are provided. So for a city, rainfall probabilities could be P_A=0.41, P_N=0.33, P_B=0.26. These are then used in a Monte-Carlo method, thus reflecting predictions into the pricing method.

The role of weather derivatives in risk management for agriculture in developing countries has been brought out by many researches. The vulnerability of agriculture to weather is especially pronounced in developing countries. Also of importance is the fact that agriculture has a link to many other sectors, thus creating a link between GDP of a developing country and the weather. The poor have very little means of risk management and resort to short term strategies like selling their assets in times of crisis. The number of farmer suicides in India at times of crop failure is a pointer to this.

Government interventions are there, but these have been to limited extents. The Minimum Support Price and government sponsored crop insurance schemes have absorbed a lot of public money, without being too sure of success rates.
Skees, (2002) brings out a Catch-22 situation as credit institutions realize that farmers’ incomes are subject to large risks and so they charge higher rates of interest. These are not affordable by the farmers, so they delay the adoption of new technologies.

Hess, et al.,(2003) have listed five key success factors of Weather Risk Management in emerging markets.  
(i) **Availability of good weather data.** The availability of comprehensive and accurate historical data for periods of at least 30 years.  
(ii) **End-users.** There is a lack of demand assessments in developing countries. This leads to a haphazard introduction of weather derivative products into the markets. Farmers could form the bulk of the demand for such products.  
(iii) **Facilitators.** The need for a large number of published pilot cases, in order to raise awareness levels.  
(iv) **Regulatory framework.** A robust regulatory framework within which weather derivatives are sold and traded.  
(v) **Risk transfer mechanism into international weather markets.**

In developing countries, market makers would have high entry barriers, but also higher margins in the long run (Hess, et al., 2003). In fact, global weather risk market makers would be willing to shoulder up-front costs in order to reap the benefits of a globally diversified weather market.

Varangis, et al.,(2003) point out that when a probability distribution is drawn-up for rainfall, weather derivatives risk protection can be sold in layers. Weather derivatives, which cover tail risk, (i.e. for extreme events with low probabilities) would be very expensive. The most efficient derivatives would be at layers closer to the mean of the probability distribution, whilst insurance would be better for tail risk.

Many papers suggest a demand for rainfall insurance and that this demand would be enough to cover the cost of risk plus Administrative Costs (Turvey, 2000).

While in most models, exogenous events like weather are assumed constant, and output of agricultural products is a function of inputs like fertilizer, labour etc, Turvey (2000) models the marginal response of crop yields to weather events.
Here inputs are kept constant and yields are evaluated based on relationships with exogenous weather factors.

A production function of the Cobb-Douglas type is assumed:

\[ Y = A R^{\beta_1} H^{\beta_2} \]

Where \( Y \) = Crop yield
\( R \) = Cumulative daily rainfall
\( H \) = Cumulative crop heat unit above 50°F
\( \beta_1 \) and \( \beta_2 \) are production coefficients or elasticities

So, marginal productivities of heat and rainfall are

\[ \frac{\partial Y}{\partial R} = \beta_1 \frac{Y}{R} \quad \text{and} \quad \frac{\partial Y}{\partial H} = \beta_2 \frac{Y}{H} \]

\[ \text{and} \quad \frac{\partial^2 Y}{\partial R \partial H} = \beta_1 \beta_2 \frac{Y}{RH} \]

So, for weather derivatives to be effective,

\[ \frac{\partial Y}{\partial R} > 0, \quad \frac{\partial Y}{\partial H} > 0 \quad \text{and} \quad \frac{\partial^2 Y}{\partial R \partial H} \geq 0 \]

Obviously, if \( \frac{\partial^2 Y}{\partial R \partial H} > 0 \), both \( R \) and \( H \) jointly impact yields. If \( \frac{\partial^2 Y}{\partial R \partial H} = 0 \), then either rainfall or heat events, or both – have no effect on yields.

If either \( \beta_1 \) or \( \beta_2 \) are not equal to zero, then specific-event weather insurance could be effective.

Geyser and Van de Venter (2001), have done a study on hedging maize yield in South Africa. They point out that before the application of weather derivatives can be tested, the relationship between rainfall and yield must be determined.

In the agricultural context, there are three types of risk:
(i) Price risk
(ii) Event risk
(iii) Yield risk
Whilst price risk can be hedged through forward contracts and future, event risk and yield risk can be hedged through insurance and weather derivatives.

Wynter and Cooper (2004), also state that it has been established that for grain farmers, the two most important variables are yield and price. While some of the risks associated with yield can be controlled eg. disease, weeds etc, risks due to weather are harder to manage. Kingwell (2000) suggests that farmers should focus on yield risk, an area they are often expert in, and leave price risk to others. Farmers, across the world, seem to go by this, as shown by the multitude of cooperative pools formed.

Geyser and Van de Venter (2001) also bring out the fact that weather derivatives and weather insurance will never entirely replace each other because of the many differences:

(i) Weather insurance is for the high risk, low probability scenario while weather derivatives best suit the low risk high probability scenario.
(ii) In weather derivatives, payouts are generally in proportion to the magnitude of the phenomenon. This is not usually so in weather insurance.
(iii) Weather insurance normally requires a proof of loss.
(iv) Weather derivatives are a traded security. So one can sell or buy back the contract.
(v) Weather derivatives are, generally, cheaper than weather insurance.

In India, the first experimentation with weather risk hedging was with the NAIS. This is a crop-yield based scheme, where farmers are compensated when the actual average yield of an area of a particular crop is less than the guaranteed yield (specified percentage of preceding 3 to 5 years average yield) in the area. This was not very successful (Ifft, 2001).

The Agriculture Insurance Company introduced a rainfall insurance scheme called 'Varsha Bima' in 2004. This is aimed to be a mechanism for providing effective risk management aid to those individuals and institutions likely to be impacted by adverse rainfall incidence. AIC introduced Varsha Bima – 2004 covering adverse deviations in rainfall during the Kharif 2004 season as a pilot project in 20 IMD rain gauge stations across 4 states. The expanded Varsha Bima 2005 was implemented in and around 130 districts/rain gauge station area across 10 states. The scheme was fine-tuned during Kharif 2006 for
implementation in about 140 IMD rain gauge station areas across 16 states, covering more crops and with more coverage options.

2.11 Contingent valuation

Arriving at a monetary value which should be placed on a service provided, is not an easy task. However, in order to aid in policy making and in order to act as a starting point for structuring weather derivatives, it is essential that we have some idea of the amount that people would be willing to pay for them. One of the methods, which has been used fairly extensively is the Contingent Valuation (CV) method.

Contingent Valuation uses surveys to obtain responses to hypothetical situations and then determines preferences through respondents' willingness to pay for a service which is proposed to be introduced or for an improvement in an existing service. The method is named so because it determines 'willingness to pay' values which are contingent upon a hypothetical situation or market which is described to the respondent.

The CV method was first proposed by Ciriacy and Wantrup (1947) in the Journal of Farm Economics, where they had proposed that individuals should be interviewed in a structured manner in order to determine their willingness to pay for a good or a service, as also to determine how the good or service could be improved to include the needs and desires of the individuals. Even at that time, they had, however, pointed out that the success or failure of a survey would significantly hinge on the method and quality of its design and execution. The first recorded use of the CV method is the use of questionnaires by economist Robert K Davis in 1963 to estimate the benefits of outdoor recreation in a Maine backwoods area. In 1967, Ronald Davis used the CV method in several studies of air pollution benefits. In 1970, Cicchetti and Smith used the method to estimate willingness to pay of hikers in a wilderness area, to reduce congestion caused by other hikers. In 1972, Darling used contingent valuation to value amenities in a California park. A year later, in 1973, Acton used the method to value exercise programmes which reduced the incidence of heart attacks. Other notable studies include valuations of aesthetic benefits from foregoing construction of a geothermal plant and benefits of government support to the arts.

Later, Mitchell and Carson's (1989) book on contingent valuation brought together various aspects relevant to CV, like psychology, sociology, market
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research, economics, etc. Thereafter, the CV method gained a lot of prominence, and is now used widely, for assessing a variety of investments (Hanemann, 1994).

The US Environmental Protection Agency (EPA) has played an important role in the development of the CV method, by providing funding for projects which focused on the use of CV for policy purposes.

CV methods have been widely used for non-market as well as for potential market goods. They have been used by Mitchell and Carson (1985) and by Smith and Desvousges (1987) for valuation of non-traded services. Simulated markets were used, with hypothetical questions being asked. From these, values for the potential services were derived.

McCarthy (2002) states that the value of an insurance will ideally be equivalent to the area under the appropriate demand curve, which is the change in welfare attributable to the use of insurance. In the case of weather derivatives, we would need to focus on trying to obtain data for estimating demand, in the absence of a market. Upfront, we have to accept that a CV method assumes that a hypothetical market would be comparable to an actual market. Since there is very little amount of actual data available, checking of the validity and reliability of a CV study becomes an important concern. Most of the methods of checking revolve around the approach of the study, the kind of questionnaire built up, the kinds of biases which might be present and the manner in which the survey is undertaken. Thus the specification of the scenario assumes importance.

A CV survey is usually in three parts, (Mitchell and Carson, 1989):

i) A detailed description of the service/good which is being valued and the hypothetical market in which it is made available. Detailed scenarios are read out and explained by the surveyor.

ii) Questions about the characteristics of the respondent which might influence his responses to WTP, eg., age, education level, income etc.

iii) Questions which elicit the respondent's willingness to pay for the service being valued.

The main objective of the survey would be to determine the maximum amount that a respondent is willing to pay for a service, before he would prefer to go without it. One very simple and obvious way would be to ask, in a straightforward way, the maximum amount that he would pay. However,
researchers have found that respondents are usually unable to come-up with a value. Desvousges et al., 1983, found that open-ended questions tend to result in a very large number of non-responses or a zero response. As a result, most researchers tend to aid the respondent by helping him in the process of valuing the good/service.

A number of elicitation methods have been developed by researchers and these have been tested in various situations. Some of these are enumerated below:

i) **Open-ended questions:** This method would be more appropriate where education and awareness levels are high. These type of questions would be prone to large errors when the respondents are unable to associate the correct answer with the question being asked. Also, this method, as indicated above, results in a large number of non-responses.

ii) **Bidding Game:** This is the oldest and most widely used method. It is close to an auction and gives the respondent a simple choice – either he accepts to pay or he declines to. It gives him the chance to mull the values in his mind and then take a decision. In this method, it is easy to get at the maximum amount that the respondent is willing to pay. The game can either be started with the highest value, which is subsequently lowered, or with the lowest value, which is subsequently raised.

iii) **Random Quotes:** Instead of moving up or down an amount, as is done in the bidding game, here the surveyor randomly quotes a value or a range of values within which the respondent is asked to indicate his willingness to pay.

iv) **Take It or Leave It:** Here no ranges are offered. A pre-decided price of the service or good is determined and this is indicated to the respondent, with a simple choice of either accepting it or rejecting it. Some researchers have called this method the Yes/No elicitation method.

v) **Take It or Leave It with Follow-up:** This method is a combination of methods. After the 'Take It or Leave It' question, if the respondent answers yes, then the surveyor quotes a higher amount, while if he has said no, then a lower amount is quoted.

vi) **Sealed Bid:** Similar to the open ended questions method, here the respondent indicates the amount he is willing to pay, and this is not questioned or discussed further.

vii) **Cards:** Various prices of the good/service are marked on cards which are displayed in front of the respondent. He is asked to choose the one which he feels indicates the most apt value for the service.
DeShazo (2002) found a problem with the open-ended question type of survey. In almost all cases where the respondent said Yes to a lower bound contract, when given the open ended question, his follow-up response was less than the value he had just said he would pay. The researcher explains this downward bias as a 'loss averting behaviour', by now indicating that the respondent's initial bid was the maximum amount that he would have paid, and he now indicates a lower amount hoping that it would influence actual contracts in the future.

2.11.1 Disadvantages in the CV method

Mitchell and Carson, (1989) bring out some of the drawback in surveys conducted for a contingent valuation. The first is that respondents might engage in strategic behaviour by giving answers which they feel would influence the policy in the service/good being proposed. The second is that respondents might not be motivated enough to answer correctly or meaningfully. And the third is that answers sought in a hypothetical market might not accurately predict behaviour in an actual market.

Sources of Bias

Unless watched out for, certain elements of bias can creep into an analysis of willingness to pay through a contingent valuation method. Some of the principal sources of bias are:

i) **Strategic Bias**: Respondents could tend to answer in a way which they feel might influence the outcome of the study in a manner which would be of benefit to them. For example, they might underbid in order to get a service at a lower cost. Alternatively, they might overbid in order to get the service activated quickly.

ii) **Compliance Bias**: Respondents might shape their responses in order to please the interviewer. This could especially happen when respondents don't have a strong or well-considered view on the topic.

iii) **Implied Value Cues**: Respondents could derive signals from the initial reference value suggested by the researcher. As an example, a Starting-Point Bias could result when the willingness to pay, indicated by a respondent, is influenced by a value which is first quoted in the scenario.

iv) **Anchoring Bias**: This could happen when, not knowing the service's actual value, the respondent regards the proposed amount as a value for the service and anchors his WTP on the proposed amount.

v) **Range Bias**: The respondent might create an artificial upper or lower bound in his mind based on the maximum or minimum amount quoted.
vi) **Relational Bias**: The respondent might link the proposed service to some other service in a way in which the latter's value acts as a cue for the proposed service – something which the researcher would not have intended.

vii) **Scenario Misspecification**: These may result either through erroneous descriptions in the survey or through errors in perception by the respondent. Of these, researchers find that errors caused by misperceptions in the minds of the respondents are the most problematic sources of errors in CV surveys.

However, what is important is the conclusion reached by Arrow, (1986), that neither empirical evidence nor theoretical arguments assert that strategic bias is liable to be significant in CV studies. The most important challenge is in being able to convey in a technically correct sense, the meaning, the structure, the benefits and possibly, the policies behind the good or service being proposed; and doing this in a manner in which the respondent perceives it as intended. Errors in CV studies are predominantly discussed in literature as occurring due to respondents having to value a good or service with which they are either not familiar, or about which they do not have sufficient knowledge. McCarthy (2002), brings out three issues which are of particular concern in developing countries:

i) Farmers not being familiar with the existence of formal institutions eg. Multi-commodity or other exchanges for trading weather derivatives.

ii) Their feeling that it is the government’s responsibility to offset effects of extreme weather eg. droughts.

iii) The farmers’ belief that if they under-represent, then the final pricing of an insurance or a derivative product would be lower. (Of course, this is dichotomous with the first, and would be more predominant only if respondents have experience with formal financial instruments.)

The above points do bring out the imperative requirement of first methodically training the surveyors and having them explain the service and the scenario with sufficient clarity to the respondents. This is especially so since scenario-misspecification can easily lead to erroneous findings.

Freeman (1993) has suggested that focus group discussions and pilot surveys could help in the use of comprehensible terminologies in the final questionnaire.
and in the surveyors being on the level of the farmers when the survey is undertaken.

Sampling issues
The basic aim of a CV research is to be able to generalize the findings to a much larger group, than the sample surveyed. Biases can come about from faulty sampling design as well as from faulty execution. To start with, in a CV study, the researcher has to decide on the population which would be affected by the hypothetical market. From this sampling frame, the actual sample would be selected. It is from this sample that WTP responses are solicited. Some of the possible biases which might creep in, during sample design and execution are:

i) Population Choice. Major errors come about in CV analyses when the population which uses a good or service is different from the one which pays for it. This problem is not envisaged in the case of weather derivatives.

ii) Sampling Frame Bias. The sampling frame is defined after identifying the population of interest. If the population and the sampling frame diverge, then this could result in a sampling frame bias (Mitchell and Carson, 1989).

iii) Non-Response Bias. Because of some amount of non-response which usually results in a survey, the valid WTP responses will be less than the number originally chosen in the sample size. This could be in two forms — an individual non-response, where a person chosen to form the sample doesn’t want to or is unable to participate in the survey, and a question non-response, where an individual doesn’t or isn’t able to respond to a particular question.

Quality
Very obviously, a CV study would be relevant only if its quality is good. However, Arrow (1986) brings out the fact that even a flawed CV study can provide insights for policy making when the shortcomings are taken into account.

A few criteria have been listed for CV studies by the Water Resources Council, 1979 and by the Department of Interior, 1986. Two of the important criteria are — having a sample size of at least 200; and the use of the bidding game elicitation method.
The most important aspect of a CV survey is how the researcher is able to elicit value. Hanemann, (1994), points out that the two most important issues relate to being able to confront respondents with a specific and realistic situation; and the use of closed-ended questions. What can be inferred from this is that it would be too abstract to ask a question like “What would you pay for a weather derivative?” and this would be unlikely to yield correct results, if any. On the other hand, asking “Would you be willing to pay Rs 30 for a weather derivative covering a return of Rs 1000?” would be more tangible.

It has to be made clear that the respondents do not have to make a payment during the conduct of the interview – but are only expressing their willingness to pay. Unless respondents understand the service, the mode of payment, the benefits etc., their answers would not be correct. This leads us to the essentiality of proper training for the surveyors, before they embark on the survey.

Using the data

Different statistical methods can be used to determine willingness to pay, from the data collected from the survey. A simplistic mean could give a WTP; or a median. Hanemann, (1994), points out that a median is more robust, since the mean is highly sensitive to the right tail of the distribution, i.e. to the responses of the highest bidders.

A better method would be to use a model on the bid amounts in order to obtain the WTP.

2.12 Willingness to pay

With the growing popularity of the CV method, more and more attention is being given to the statistical aspects of the analysis of data obtained from a survey. This has especially happened as there has been a pronounced shift from the use of open-ended questions, where respondents indicate an amount in rupees which they would be willing to pay, to the use of closed-ended questions, where respondents give a yes/no type of answer. In the latter case, the willingness to pay is then statistically obtained by introducing a model to the bid amounts which were put across to the respondents in the survey.

Haab and McConnel (2002) define willingness-to-pay as the maximum amount of income an individual will pay in exchange for an improvement in
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circumstances, or the maximum amount a person will pay to avoid a decline in circumstances.

Starting with an assumption that a farmer would be willing to pay in order to hedge his weather-related risks, and expressing his utility function as

\[ u[M, Y, V(y)] \]

where \( M \) is his endowment, which we could take as land owned by him, \( Y \) is his income and \( V(y) \) is the variation in his income, we could say that by paying a certain amount (ie., with a marginal decrease in his wealth), the farmer would be able to stabilize his income. In other words, by maximizing his utility function, he is actually trading between wealth and stability of income. Their willingness to pay should also be related to their capacity to hedge their risk or stabilize their income through other means eg. owning livestock which can be sold when required, or their having sources of income other than from cultivation, eg. a small business or remittances from family members.

Literature on measurement of preferences for risk reduction suggest that there is an insensitivity of willingness to pay for risk reduction to the magnitude of the risk reduction. But \textit{McCarthy (2002)} suggests that this is because respondents see any improvement as being good – and take relatively little account of numerical information regarding risk reduction. \textit{McCarthy (2002)} also brings out that while this problem is noticeable for cases where the size of risk is small, this is not so when the size of risk is much larger as is so in the case of rainfall risk hedging. Even \textit{Smith and Desvousges (1987)} imply that baseline problems with consistency in estimating WTP for risk reduction are severe only when the baseline risk is small. In the case of rainfall risk, this is fairly large.

In general, two approaches have been used for benefit estimation.

(a) Stated preference – which is elicited through questions based on a contingent or hypothetical scenario

(b) Behavioural preference – which is obtained through observation of responses to actual goods.

Since weather derivatives have not yet been introduced in India, behavioural preferences cannot be observed, and it would be the stated preferences in response to a hypothetical situation, which we would need to look at.
One of the empirical tools used to determine willingness to pay from a questionnaire type of survey, as indicated in the preceding paragraphs, is the Contingent Valuation (CV). But since the responses to the questions, in the nature of yes/no answers are essentially binary variables, we would need to create a model in order to estimate the dependant variable. Hanemann and Kanninen (1996) give the analogy from dose-response studies in biometrics, where the stimulus is the administered dose of some substance, and the outcome is a discrete measure of health status.

In the case of weather derivatives, the aim would be to collect data on and to analyse covariate effects on responses e.g. the effect of education, income, savings, landholding etc. could be used to describe tendencies towards preferences. Carson and Mitchell (1992) have shown the effect of 14 variables on the willingness to pay. The major advantage is that models with covariates can easily be used to expand the findings from a sample to a population, in a way which can be corrected by exogenous variables. The measures obtained by the CV method would be represented in terms of the difference between two expenditure functions, i.e., in the CV survey, we would ask the respondent what he is willing to pay such that the reduction in his income along with the availability of weather risk hedging, leaves his utility level unchanged.

Sarris (2002) brings out that the valuation of WTP for insurance would be different depending on how it is offered. If offered after the planting decision has been made, then the farmer can only reduce the variability of his returns. If offered before the planting decisions are taken, then he can reallocate the variable inputs; and so the WTP for the second case is likely to be higher. Another feature could be the availability of insurance only for a year or a scheme in perpetuity. In the latter case a farmer would be able to adjust his cropping patterns and take a long term view; in this case, the WTP is likely to be the highest. In the case of weather derivatives, these would be offered prior to the planting decisions and, although no commitment will be made, it would be implied that this would be a scheme in perpetuity.

The most important aspect of a WTP study is that of being able to generate in the minds of the respondents, a visualization of the service proposed, so that they are clear about what is in store. As an example, the respondents in the survey on WTP for weather derivatives, need to be explained clearly that by
paying, they can hedge only a limited amount of the risk. Also, in the case of rainfall insurance, there could very well be a variation in the rainfall received on his land and the rainfall measured by a weather station a few kilometers away. WTP may well be linked to where the weather station is placed, or the perception a farmer has on where the weather station would be with respect to his land.

A major problem experienced by researchers in WTP studies is that WTP responses could be influenced by events in the recent past. Thus, it is likely that WTP would be higher if the study is being done just after a drought period – or could be lower if the study is being done after a few years of average or higher than average monsoons.

2.12.1 Random utility model

Hanemann (1984) devised the basic model for contingent valuation questions where there were two choices. A respondent answers 'yes' to a payment if he perceives that the benefits by paying that amount would be greater than the cost of paying for it.

For a respondent \( j \), his utility is:

\[
u_{ij} = u_i(y_j, z_j, \varepsilon_{ij})
\]

\( i = 1 \) for yes and \( = 0 \) for no (i.e. a preference for status quo)  
\( y_j = \) income of \( j^{th} \) respondent  
\( z_j = \) vector of attributes and characteristics  
\( \varepsilon_{ij} = \) Non observable (inherent to the respondent) component of preferences

We can envisage an element of risk, such that if risk decreases from \( q_0 \) to \( q_t \), then utility changes from \( u_{oj} \) to \( u_{ij} \) i.e. the utility changes, for respondent \( j \), from \( u_{oj} = u(y_j, z_j, q_0, \varepsilon_{oj}) \) to \( u_{ij} = u(y_j, z_j, q_t, \varepsilon_{ij}) \).

Now, the respondent will say 'yes' to a payments only if

\( u_i > u_0 \)

The probability that the respondent \( j \) will say 'yes' is:

\[
Pr(\text{yes}) = Pr[u_i(y_j - t_j, z_j, \varepsilon_{ij}) > u_o(y_j, z_j, \varepsilon_{oj})]
\]

where \( t_j \) is the payment required to reduce risk from \( q_0 \) to \( q_t \).
Or, separating the deterministic and stochastic preferences:
\[ Pr(\text{yes}_j) = Pr[v_i (y_j - t_j, z_j) + \varepsilon_{ij} > v_0 (y_j, z_j) + \varepsilon_{oij}] \]

If we consider the deterministic part to be linear in the income and in the covariates, then:
\[ V_{ij} = \alpha_z z_j + \beta(y_j) \]

where \( z_j \) is an \( m \)-dimensional vector of variables related to individual \( j \) and \( \alpha_z \) is an \( m \)-dimensional vector of parameters, so that
\[ \alpha_z z_j = \sum_{k=1}^{m} \alpha_{ik} z_{jk} \]

So the change in deterministic utility will be:
\[ V_{ij} - V_{oj} = [\alpha_z z_j + \beta(y_j - t_j)] - [\alpha_o z_j + \beta_o y_j] \]
\[ = (\alpha_z - \alpha_o) z_j + \beta(y_j - t_j) - \beta_o y_j \]

If we assume the marginal utility of income to be constant in the two CV states i.e. \( \beta_1 = \beta_2 \), then:
\[ V_{ij} - V_{oj} = \alpha z_j - \beta t_j \]
where \( \alpha = \alpha_z - \alpha_o \)

So the probability of a 'yes' response is:
\[ Pr(\text{yes}_j) = Pr[\varepsilon_j < \alpha z_j - \beta t_j] \]
where \( \varepsilon_j = \varepsilon_{ij} - \varepsilon_{oj} \) (a single random term)

Assuming that the error term \( \varepsilon_j \) is independently and identically distributed (iid), with mean zero, the normal and the logistic are two commonly used distributions. Both model estimations can be done using SAS or LIMDEP.

Now for symmetric distributions, \( F(x) = 1 - F(-x) \)
So we can write:
\[ Pr(\text{yes}_j) = Pr[\varepsilon_j < \alpha z_j - \beta t_j] \]
Now suppose that \( \varepsilon_j \sim N(0, \sigma^2) \)
To use typical software packages we need to express \( \varepsilon_j \) in terms of a standard normal (\( N(0, 1) \)) variable.

Let \( \theta = \frac{\varepsilon_j}{\sigma} \), then \( \theta \sim N(0, 1) \)
So $\Pr(\text{yes}) = \Pr\left[ \theta < \frac{\alpha z_i}{\sigma} - \frac{\beta}{\sigma} t_i \right]$

$= \phi\left( \frac{\alpha z_i}{\sigma} - \frac{\beta}{\sigma} t_i \right)$

Where $\phi(x)$ is the cumulative standard normal i.e. probability that a unit normal variate is less than or equal to $x$.

This is the Probit model, which can be used for dichotomous dependant variables

When $\varepsilon$ is distributed logistic, it has mean zero and variance

$$\frac{\pi^2}{3} \sigma^2$$

then $\frac{\varepsilon}{\sigma_L} = \theta \sim \text{logistic} \left( 0, \frac{\pi^2}{3} \right)$

The standard logistic has a variance $\frac{\pi^2}{3}$ times the standard normal and so will have parameters $\frac{\pi}{3}$, i.e. $1.814 \times$ times the Probit parameters.

Now, the probability that a variate distributed as a standard logit is less than or equal to $x$ equals $(1 + \exp(-x))^{-1}$

$\Pr(\text{yes}) = \left[ 1 + \exp\left(-\left( \frac{\alpha z_i}{\sigma_L} - \frac{\beta}{\sigma_L} t_i \right) \right) \right]^{-1}$

This is the Logit model.

Most of the times, there are only slight differences between the probit and the logit models. Both are symmetric, but the logit has thicker tails.

Maximisation of the likelihood function yields unique estimates of the parameter function $\frac{\alpha}{\sigma}, \frac{-\beta}{\sigma}$.
As brought out earlier, WTP is the amount of money which, when paid by the respondent, makes him indifferent between the proposed scenario and the present state. 

\[ \alpha_i z_j + \beta(y_j - WTP_j) + \epsilon_j = \alpha_o z_j + \beta y_j + \epsilon_j \]

So \[ WTP_j = \frac{\alpha z_j}{\beta} + \frac{\epsilon_j}{\beta} \]

Where, \[ \alpha = (\alpha_i - \alpha_o) \]

From the above, it can be seen that there could be 3 sources of variation in willingness to pay:

(i) randomness of preferences
(ii) randomness of parameters
(iii) variations across individuals in the samples.

We could say that the expectation of WTP with respect to preference uncertainty, \( \epsilon \), is:

\[ E_\epsilon(WTP_j | \alpha, \beta, z_j) = \frac{\alpha z_j}{\beta} \]

and to get a consistent estimate of expected WTP, we can substitute the normalized parameter estimates into the above equation.

So

\[ E_\epsilon(WTP_j | \alpha, \beta, z_j) = \left[ \left( \frac{\alpha}{\sigma} \right) \left( \frac{\beta}{\sigma} \right) \right] z_j \]

Where the mean of \( z_j \) can be taken, to get the sample mean.

We must note that an important assumption in the linear RUM is that the marginal utility of income is constant across scenarios posed by the questions in the questionnaire.

Hanemann and Kanninen (1996) bring out two important aspects of models which are used to analyse responses to CV surveys. The first is that the models must make sense from the point of view of economic theory. Of course, this does place some restrictions on the statistical models that can be used. The second is
that the models should be able to accommodate the heterogeneity of preferences and the heterogeneity of the response behaviour during the survey, in the population of interest.