4.1 Introduction

In India, about 78% of the farmers are small and marginal and they are mostly poor (Agrawal, 2000). Besides not being in a position to use the right inputs for the crop, they are largely dependant on rainfall. Most crops are highly dependant on the vagaries of the monsoons. If rainfall is less than normal, yield is very low because of lack of water; if it is very high, particularly during blossoming, there is poor grain setting and also, the matured grains germinate on the panicles.

In this context, the development of financial instruments in the form of weather derivatives could help farmers in being able to hedge part of the volumetric risk in yield. Weather derivatives are a fairly new concept in India, which would be able to offer a means to manage the exposure to unpredictabilities in rainfall.

Oilseed crops occupy about 10% of the total cultivated area and contribute approximately 10% to the production of food crops in India (Deosthali et al., 2005). Noticeable efforts have been made towards increasing the yield of soyabean over the years, and it has increased by 490% from 1983 to 2004. The real increase in area under soyabean cultivation came about in 1989-90 with the use of a short duration (90 days) high yield variety. The average yield of Indian soyabean, however, at 1.074 tonnes/ha is very low as compared to the world average of 1.3 tonnes/ha (Deosthali et al., 2005).

Soyabean is a legume crop, yet it is used widely as oilseed. It is now the second largest oilseed in India after groundnut. It grows well in warm temperatures and requires fair to heavy rainfall during its growth cycle. It is a highly nutritive crop and can supply much needed protein to the human diet, containing approximately 43% protein and 20% oil. In fact, it contains essential amino acids particularly glycine, tryptophan and lysine, similar to cow's milk.

Soyabean crop requires water especially during the germination, flowering and pod formation stages. A lack of water during the vegetative growth stage and
A theoretical analysis of willingness to pay during seed development can reduce yield considerably. On the other hand, excessive rainfall could affect germination.

The MSP (minimum support price) for soyabean, which is the government announced price aimed at ensuring remunerative prices to farmers for their produce, has varied from Rs 1002 per tonne in 1981-82 to Rs 933 in 1991-92 to Rs 930 in 2003-04 (at prices inflated to 2003-04), (CSO, 2006). More importantly, the yield per hectare, of soyabean in the district of Jhalawar in the state of Rajasthan has varied from 0.538 tonnes/hectare in 1981-82 to 1.387 tonnes per hectare in 2003-04. Whilst a large portion of the variability in yield could be attributed to technological developments, a substantial variability comes in due to weather related effects.

In the central, northern and western parts of India, where rainfall is high and winters are fairly cold, only one crop of soyabean is grown during the months from May to November. This is the Kharif crop. Typically, soyabean is sown in the month of June and is harvested in mid/end October.

In Rajasthan, the total production of soyabean in the 2006 Kharif season was 4.930 lakh tonnes with 5.803 lakh hectares being sown with the crop.

The theoretical framework in the Soyabean yield scenario is based on the model used by Simmons and Rambaldi (1997). It builds in some simplifying assumptions and includes the cost of and the gain from a possible hedge on the portion of yield variability, which could be attributed to rainfall dependence. An empirical analysis based on the gross production of soyabean in the district of Jhalawar in the state of Rajasthan is done to give a rough estimate of what would be the aggregate willingness to pay in order to cover yield risk.

Probably the only way to assess the inclination of soyabean growing farmers towards methods of hedging volumetric risk attributable to the vagaries of weather, is to physically carry out a survey. However, prior to this, a theoretical framework is attempted which would be able to give an estimate of the 'willingness to pay' for hedging the weather risks.

4.2 Theoretical model

For a farmer growing a crop, his expected utility can be expressed as
A theoretical analysis of willingness to pay

\[ E(U) = E(S) - C - R \]  \hspace{1cm} (1)

Where \( E(U) \) is the expected utility, \( E(S) \) is the expected sale price, \( C \) is the cost of inputs and \( R \) is a risk premium. The risk premium can be defined using the Pratt Coefficient (Pratt, 1964) of absolute risk premium, \( k \) as

\[ R = \frac{k}{2} E[(S - E(S))^2] \]  \hspace{1cm} (2)

So,

\[ E(U) = E(S) - C - \frac{k}{2} E[(S - E(S))^2] \]  \hspace{1cm} (3)

In actuality, the risk premium, \( R \), would be dependant on wealth of the farmer, but we assume it to be constant as has been done in other studies (Edwards & Simmons, 2004).

We consider yield in a one-year cycle, so that utility in period \( t \) is maximised with respect to information of period \( t-1 \). Yield is expected to follow a naive model, which includes a trend component, attributed to technological advancements \( T \) and a multiplicative error term \( (1+e) \) which is attributable to variation in weather.

\[ Y_t = (\bar{Y} + aT)(1 + e) \]  \hspace{1cm} (4)

(where \( \bar{Y} \) is the mean yield across the sample)

and production \( q_t = AY_t \) \hspace{1cm} (5)

Selling price is taken as the MSP announced by the government – which is generally the price at which the farmer is able to sell his produce. It is assumed that selling price follows a naive model:

\[ S_t = S_o (1+f) \]  \hspace{1cm} (6)

Where \( (1+f) \) is a multiplicative error term and \( S_o \) is the price at the start of the season

So income from sales = \( S_t q_t \)

\[ = S_o (1+f) A (\bar{Y} + aT)(1+e) \]  \hspace{1cm} (7)

Input costs can be taken as a total quantity decided upfront based on planned production \( q_t \) and can be written as the sum of fixed costs and variable costs
which are dependant on amount of production $q_t$. Variable costs would mainly include the cost of seed, fertiliser cost and cost of pesticides. Fixed costs would be dependant on area under cultivation and would include all other input costs.

So

$$C = C_t A + C_v q_t$$  \hspace{1cm} (8)

Expected utility can be written as:

$$E_o (U_o) = S_o q_t - C_f A - C_v q_t - k E_o \left[ S_o (1 + f) A (\bar{Y} + aT) (1 + e) - S_o A (\bar{Y} + aT) \right]^2$$

$$= S_o q_t - C_f A - C_v q_t - k S_o^2 (\bar{Y} + aT)^2 A^2 E_o \left[ (1 + f) (1 + e) - 1 \right]^2$$

$$= S_o q_t - C_f A - C_v q_t - k S_o^2 A^2 E_o \left[ e + f + ef \right]^2$$

For maximisation of utility with respect to planned production,

$$\frac{\partial E_o (U_o)}{\partial q_t} = S_o - C_v - k S_o^2 q_t E_o \left[ e + f + ef \right]^2 = 0$$

$$\therefore q_t = \frac{S_o - C_v}{k S_o^2 E_o \left[ e + f + ef \right]^2}$$  \hspace{1cm} (9)

We now consider the case where the farmer has an option to hedge the weather risk through purchase of weather derivatives.

We note that $e$ and $f$ are aberrations which can be hedged by the farmer. Whilst the farmer can hedge $f$ by going in for forward contracts, weather insurance or weather derivatives would be the only ways to hedge $e$. We will, in this analysis, assume that the farmer is not too concerned with price risk and is more concerned with volumetric risks. Thus, he will go in for hedging of $e$ to an extent within his means and his risk appetite.

We take $h$ as the proportion of $e$ which the farmer wants to hedge. We take the cost of hedging as $r$, so that the amount paid by the farmer is $rh$. This amount will be included in the cost of inputs so that:

$$C = C_t A + C_v q_t + rh$$  \hspace{1cm} (11)
and income from sales

\[ S_o(1 + f)A(\bar{Y} + aT)(1 + (1 - h)e) \]

Utility at time t can be written as

\[ E_o(U_t) = E_o(S_t) - C_i - \frac{k}{2} E_o \left[ (S_t - E_o(S_t))^2 \right] \]

or

\[ E_o(U_t) = S_0 q_t - C_f A - C_v q_t - rh - \frac{k}{2} E_o \left[ S_0 (1 + f)(\bar{Y} + aT)(1 + (1 - h)e) - S_0 q_t \right] \]

\[ = S_0 q_t - C_f A - C_v q_t - rh - \frac{k}{2} S_0 q_t^2 E_o \left[ (1 + f)(1 + (1 - h)e) - 1 \right]^2 \]

\[ = S_0 q_t - C_f A - C_v q_t - rh - \frac{k}{2} S_0 q_t^2 E_o \left[ h^2 \gamma - 2h \gamma \right] \]

where \( \Delta = e^2 + f^2 + e^2f^2 \)
and \( \gamma = e^2 + e^2f^2 \)

First order condition are got by differentiating \( E(U_i) \) with respect to planned production \( q_t \) and the amount of hedging \( h \):

\[ \frac{\partial E(U_i)}{\partial q_t} = S_o - C_v - k S_o^2 q_t E_o \left[ \Delta + h^2 \gamma - 2h \gamma \right] = 0 \]

(14)

and

\[ \frac{\partial E(U_i)}{\partial h} = -r - k S_o^2 q_t^2 E_o \left[ h \gamma - \gamma \right] = 0 \]

(15)

4.3 Empirical results

We obtain the model parameters from a dataset of soyabean production, inputs etc for the 23 years 1982 to 2004 at Jhalawar district in the southern part of the state of Rajasthan. Data on the yield of soyabean was obtained from the Directorate of Economics and Statistics, Government of Rajasthan, Jaipur. Rainfall data at Jhalawar for the same period was purchased from the Indian Meteorological Department.

In the first place, the yield of soyabean was regressed against time in order to obtain a value for \( a \) from the trend which we attribute to technology advancements and for the value of \( \bar{Y} \). We get
Using eqn (4), and values of the error term for each of the 23 years of the dataset, we obtain the mean value for $e$

$$e = -0.00087$$

with a variance $\sigma_e^2 = 0.0681$

Similarly using equation (6) and values of the error term in the MSP for the 23 years, we obtain the mean value for $f$

$$f = -0.00291$$

with a variance $\sigma_f^2 = 0.00104$

Minimum Support Price for soyabean for each year in the 23 year period 1981-82 to 2003-04 (www.indiastat.com) was inflated (using WPI) to 2003-04 levels and a mean obtained:

$$S_6 = 9720 \text{ Rupees per tonne}$$

The mean yield per year from 1981-82 to 2003-04:

$$Y_t = 0.933 \text{ tonnes/ha}$$

4.3.1 Correlation of yield with rainfall

Figures of yield of the soyabean crop in the district of Jhalawar were correlated with figures of rainfall in the 23 years in the period 16 June to 15 October. A positive correlation of 30% was noticed, indicating a fair degree of dependence on rainfall. Similarly, residuals of $Y_t$ indicated a positive correlation of 33.3% with rainfall in the same months.

4.3.2 Willingness to pay

In order to calculate the variable cost of inputs, $C_v$, the cost of seeds, fertilizer and pesticide used per ton of soyabean produced was arrived at. Data was available for the year 1996-97 for cost of fertiliser and seeds required per hectare of soyabean crop. Using the yield of soyabean in the same year, the cost per tonne of the produce was arrived at. This was then inflated to 2003-04 levels. Also, the total amount of N-P-K fertilizer consumed in the year 1996-97 was used in order to arrive at an approximation for that used for production of soyabean through a ratio of area sown for soyabean vis a vis gross sown area. A
similar calculation was done for pesticides, using the cost for Monocrotophos pesticide. Both these input costs were inflated to 2003-04 prices.

We obtained

\[ C_v = 3243 \text{ Rupees per tonne} \]

The Pratt coefficient of absolute risk premium, \( k \), is arrived at using the method defined by Rambaldi and Simmons (2000). Risk premium in this study has been calculated as the difference between the expected selling price and the actual selling price.

The coefficient of relative risk is arrived at from a study by Antle (1987) where he has done an econometric estimation of risk attitudes of farmers in Aurepalle village in Andhra Pradesh. The data is based on an experimental measurement of risk attitudes of the farmers in the same village (Biswanger, 1980). The relative risk premium arrived at was \( 0.144 \).

The coefficient of relative risk aversion is a "unit free" measure of risk aversion that allows comparisons between groups and between results from different studies. It is measured in our study as \( S \times k \). This gives us:

\[ K = 2.9826 \times 10^{-5} \]

These coefficients and variable values are used to solve for planned production \( q_t \) and the amount of hedge, \( h \). From eqns. (14) and (15), we get:

\[ 6477 - 0.019377 q_t - 0.00159 q_t h^2 + 0.00318 q_t h = 0 \]

and

\[ r - 0.00159 q_t^2 h + 0.00159 q_t h^2 = 0 \]

On solving these two equations, we can see that as \( r \) approaches Rs 0, farmers would be willing to hedge up to \( h = 1 \) i.e. They would be willing to hedge completely. However, \( h \) approaches 0 as \( r \) tends to Rs 531.4 per tonne.

Details of the data and the calculations are given at Appendix I to this thesis.
This translates to a theoretical willingness to pay of approximately 5.47% of the MSP.

As such, we could infer that the demand for weather derivatives as a shield against volumetric risk in the case of soyabean in the district of Jhalawar in Rajasthan exists and would be of the order of around 5.47% of the sale price that a farmer would get from his produce.

However, this is only an indicative figure for the soyabean cultivation in a selected area, and farmers in other areas, could possibly be willing to pay differently for weather derivatives. An ideal situation would be to ascertain actual willingness to pay through a survey.

Thus these products may need to be introduced selectively in certain areas for certain crops after area based surveys.

4.4 Conclusion

Based on the fact that there is an element of rainfall dependency on the yield of soyabean, we see that there exists a demand for weather derivative products. This study is done for soyabean production in a selected district in the state of Rajasthan and only indicates a theoretical demand for weather derivative products. For reaching conclusions on demand in specific areas, a demand survey of that particular area would yield conclusive results.