Risk in Agriculture - A Study of Crop Yield Distributions and Crop Insurance.

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Introduction

Agriculture is a unique business and is fraught with risks introduced by climatic, geographical, biological, political and economic factors that are mostly independent of one another. The efficient management of these risks is essential for successful crop production and consistent output of food. The Economic Research Service of the United States department of agriculture describes five categories of risks in agriculture.

1. Production risk: This risk results from the uncertainties associated with the biological growth of the crops caused by weather patterns, pest and disease incidence, and usage of various inputs like seeds, fertilizers and pesticides.

2. Price or market risk: This risk derives from the fluctuations in prices that the producers receive and from increase in the cost of production due to the prices paid by farmers for inputs.

3. Financial risk: Availability of credit and fluctuations in the interest rates contribute to the risk by increasing the cost of capital invested by farmers in crop production.

4. Institutional risk: Changes in government regulations and policies impose risk on agribusiness.
5. **Human or personal risk:** Usage of agricultural inputs like chemicals, fertilizers and agricultural machinery create personal health risks to farmers.

**Importance of crop yield information for agricultural supply chain.**

Accurate and reliable information about historical crop yields helps in effective management of risks caused by unfavorable situations and minimizes the consequences. Yield information helps companies in taking supply chain decisions like production scheduling, raw material procurement, inventory management and marketing. Reliable yield estimates help in establishing stable and orderly spot and futures market for commodities. Crop size and commodity production information has a direct influence on policies dealing with international trade, agricultural subsidies, incentive and crop support programs, procurement, stock management, distribution of grains and in determining crop insurance premia. Farmers use historical yield data to make product mix decisions, and to determine the risk of crop loss. Hence, understanding crop yield behavior is imperative for efficient management of agricultural supply chain.

Based on central limit theorem, most commodity studies assume that crop yields are normally distributed. This assumption of normality attributes equal probabilities of high and low historical yields for a crop. However, crop yields can exhibit extreme variability which is caused by weather conditions, geological qualities of the soils, biological and genetic capabilities of the crop varieties grown and applications of inputs like fertilizers.
and pesticides. Assuming normal distribution of yields results in an inaccurate estimate of risk because of incorrect estimation of likely yields.

**Literature review**

Agricultural economists are divided in their opinions about normality assumption. The predominant viewpoint is that crop yields exhibit non-normal and skewed distribution. Day (1965) conducted one of the earliest studies and concluded that yield distributions in agricultural crops do not exhibit normality. He observed an interaction between the shape of the yield probability function and the levels of nitrogen input given to a crop. He proposed that the degree of skewness and kurtosis vary depending on nutrient levels, specifically Nitrogen levels. Gallagher, (1987) is another strong supporter of non-normality. His experiments with US soybean yields resulted in skewed distributions with an upper limit on output and a high chance of occasional low yields. He introduced the concept of biological capacity constraint where the yield of a crop can never exceed the biological potential of the plant. But, weather conditions like early frost, extreme heat or blight result in low yields and cause skewness. Ramirez, Misra, and Field (2003), Ramirez, Misra, and Nelson, (2003), Atwood, Shaik, Watts, (2003), and Norwood, Roberts, Lusk (2004) strongly support non-normality of crop yields based on their experiments. However, Just and Weninger (1999) support normality assumption and believe that the evidence available to date is not enough to disprove normality of crop yields. They believe that using farm level spatial data will help in a better understanding of yield normality.
Nelson (1990), Goodwin and Ker (1998), and Ker and Coble (May, 2003) analyzed the impact of normality assumption on crop insurance and found that assuming normality of crop yields is disadvantageous as it results in fixing unrealistic premia for insurance policies.

A review of previous research produces strong support for the alternative hypothesis that crop yield distributions are non normal and rejects normality of crop yields. In view of this, this study tried to examine the normality assumption further by conducting quantitative and statistical analysis on yield data collected from India.

**Data Collection and Analysis**

Yield data for soybean and sugarcane crops was collected from the Directorate of economics and statistics, India and the agricultural departments of Madhya Pradesh and Maharashtra states. The following Six data sets were analyzed.

2. Soybean yields for India for 28 years from 1970-1997
3. Sugarcane yields for 45 districts of Madhya Pradesh state in the year 2002-03.
4. Soybean yields for 45 districts of Madhya Pradesh state in the year 2002-03.
The yield data was plotted as histograms and conclusions were drawn by observing the shape of yield distributions. Lilliefors test for goodness of fit was conducted on all the six data sets to test the hypothesis that crop yields are normally distributed.

Results and Discussion

The results of the Lilliefors test and shape and appearance of yield distributions in the histograms conclusively proved that sugarcane and soybean yields in India are not normally distributed across the years. Both the crops exhibit skewed distribution with right skewness. This indicates that the probability of higher than mean yields is more than lower than mean yields. However, the distribution of crop yields within a specific year across different locations in a state present a different picture. Crop yields for sugarcane and soybean within a specific year in different districts of Maharashtra and Madhya Pradesh exhibit non-normal distribution with strong left skewness. Indicating that lower than mean yields are more common than higher than mean yields.

Reasons for Skewed Distribution of Yields.

- A causal factor for skewness could be the genetic improvements and development of high yielding varieties of crops in India. Increased use of fertilizers, improved irrigation facilities, availability of farm machinery and
agricultural credit have contributed to the continuous improvements in crop yields in India and resulted in the skewed distribution of crop yields.

- Between 1999 and 2003, India has experienced 4 consecutive years of deficient rainfall. Soybean is a predominantly rain-fed crop and the failure of monsoon severely affected soybean yields and probably caused skewed distribution of yields with a higher probability of low yields. The deficit rainfall also created problems in Sugarcane grown under irrigated conditions. Depleted ground water levels coupled with drought conditions affected irrigation facilities and resulted in reduced yields in Sugarcane. These factors contributed to the left skewed distribution of yields in Maharashtra and Madhya Pradesh.

- Aggregated time series data that was used doesn’t reflect the spatial and farm level variations within the specific growing regions. Averaging the data eliminated variation and probably induced non-normality. Duplication of data such as reporting similar yields for many locations was observed in Maharashtra. This casts aspersions on the authenticity of the data collection methodology in terms of a random sample. The number of data observations available is not sufficient to conduct detailed statistical analysis. These factors might have given an inaccurate result of non-normality.

However, analysis of the data indicates a strong correlation between crop yields and rainfall and inputs like irrigation. There is a clear need for collection and analysis of
location specific weather which will provide a better understanding of the relation between weather parameters and yields.

**Crop Insurance:**

In the US, crop insurance has emerged as an effective risk management method for farmers. The important insurance policies available in the United States are listed below.

**Yield Insurance Plans**

- APH (Actual Production History) coverage
- Catastrophic (CAT) coverage.
- Group Risk Plan (GRP)
- Dollar Plan coverage.

**Revenue Insurance Plans**

- Crop Revenue Coverage (CRC).
- Revenue Assurance (RA) coverage
- Income Protection (IP)
- Group Risk Income Protection (GRIP).
- Adjusted Gross Revenue (AGR).
Impact of Crop Yield Distributions on Crop Insurance.

Crop insurance policies premia are fixed based on the estimates of expected crop yields. Assuming normality attributes equal probabilities to occurrence of low yields and high yields and unfavorable to farmers and insurance companies if crop yields are actually non-normal. When yields are right skewed, probability of high yields exceeds the probability of low yields. Assuming normality over estimates the probability of low yields and fixes a higher premium for the policies. This leads to farmers incurring more expense on insurance than required and may deter some farmers from buying insurance.

When crop yields are left skewed, probability of low yields is higher than high yields. Normality assumption underestimates the occurrence of low yields and accordingly fixes the premia. In reality, more farmers may experience lower yields and collect indemnity from the insurance companies thus causing excess financial burden to the insurance company. Thus, understanding crop yield normality or non-normality is essential for designing a crop insurance policy which can provide advantages to both the farmers and insurance companies.

Strategies for risk management.

Developing an efficient crop forecasting system for that combines climatic information with crop models will be useful in arriving at reliable yield estimates and helps minimize risk. Risk management strategies should combine crop insurance with a pre-harvest
marketing plan that includes strategies like hedging and forward contracting. Climate forecast information should be utilized to decide about insurance levels and other risk management techniques. New computer technologies such as the M Language and Semantic Modeling are very effective for organizing and analyzing spatial data. This analysis of spatial data will help farmers in efficient management of risks. With this new perspective, the analysis of historical crop yields will move in new directions.


**Online resources referred**

"Farm risk management: Risk in agriculture." USDA briefing room, Economic research service, US department of agriculture.

"Crop policies": Risk Management Agency US department of Agriculture.

Commodity report on Soybeans and Sugarcane. Food and Agricultural organization.