# An Analysis of Yield-Price Risk Associated with Cereal Crops

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***Research Article***

**Abstract:** The yield uncertainty arising due to vagaries of nature vitiates farmers production programmes and causes instability in production and income of the farmers. The situations also discourage credit institutions to advance loans for agricultural purposes. A serious crop failure means not only the loss of farmer's income but also the loss of investment in crop season to come. Hence it is of crucial importance to protect the farmers from yield and price risk. In this paper we have studied the yield and price risk in Marathwada region of major cereal crop Bajara which is rainfed. We have computed expected annual negative deviations, security indices and the risk equivalent prices for bajara crop for three districts where this crop is grown as main cereal crop. It was found that for Bajara crop the average Security Index for yield was 2.83% and for gross returns was 5.36%. Thus, considering risk in the crop yield Rs. 90.46 per quintal needs to be given to the farmers over and above the minimum support price (MSP) declared by the Govt.Further, considering the risk in yield and price fluctuations Rs. 171.46 per quintal needs to be given to farmers over and above the MSP declared by the Government.

**Keywords:** Probability Distributions, Probability of shortfall, Security Indices, (Social Security Index), Risk Equivalent Prices.

## 1.0 Introduction

The measurement of risk involved in crop production as well as prices of crops is of paramount importance as its study can suggest remedial measures of technical and social nature. A detail review for measurements of yield and price risk and development of social security index has been taken. According to Narain *etal* (1984) Coefficient of variation (CV) is an indicator of instability or risks in crop yield. Furthermore, they considered that the risk in crop yield and premium rates of crop insurance depends on values of CV. Dandekar (1995) considered coefficient of mean deviation (CMD) instead of CV for estimation of risk and premium rates. The term risk and uncertainty are often used interchangeably. However, there is difference between meanings of these two terms. Knight (1971) has defined risk as a situation where the outcomes as well as its probability are known and therefore, the expected results can be predicated. In the same paper he has defined uncertainty as a situation where the outcome is not clearly known or its probability is unknown. Ray (1985) has suggested that the probability of likely trend or tendency of risks that is loss recurring in future can be determined on the basis of past happening. Nadkarni and Ghosh (1978) have studied critically the problem of measuring risk in the crop yield. Botts and Boles (1958), Narain *et al* (1985) and others have assumed normality in crop yield data and used normal curve technique for estimation of premium rates. However, Day (1965) noted that the crop yield data follows Pearson's Type-I curve. Yeh and Sun (1980), Dandekar (1976 and 1985) and others have also observed non-normality of crop yield data. Here, it is interesting to note that Rustagi (1988) pointed out that the non-normality observed by most of these authors is either non-significant or may be because of time trend present in the data. In the present paper an attempt has been made to estimate the risk in the crop yield production and also the risk due to variation in the prices of crops.

## 2.0 Research Methodology

### 2.1 Measurement of Risk

Year to year fluctuation of a character from its trend represent its variability or risk. Coefficient of variation is the commonly used tool to quantify the risk. Different types of trend curves can be fitted and in general the trend giving highest $R^2$ was chosen for further estimations but here we observe that only $R^2$ is not sufficient to select the best suitable fit, hence the residuals are calculated and the trend having minimum values of residuals are considered for further estimation and the one giving highest $R^2$ was chosen for obtaining data adjusted for trend and for computation of risk. Generally coefficient of variation about mean is considered for knowing the variability or risk in crop yield. However, here the coefficient of variation suggested by *Pal and Bisaria (1990)* is considered for measuring the variability and risk in yield and price. According to them, for time series data, the deviations from trend constitute the risk. Therefore, area, yield and prices adjusted for trend were taken for measurement of risk. For this purpose, the data were fitted to linear, quadratic, exponential, cubic, fourth degree and logarithmic curves and considering the minimum value of the residuals the best fit was selected.

The crop yield was multiplied with corresponding prices to get gross returns per hectare at Minimum Support Price (MSP). Here it was assumed that year to year changes in gross returns represent the variability or risk in net income as prices of inputs and input used (i.e. cost of production) are known with certainty.

**Estimation of Trend Value**

Following different types of trends were fitted to the given data and best fit was use to estimate the values $\hat{X}_t$ of the variable.

| Sr. No. | Trends Fitted | Trend Equations |
|---|---|---|
| **1** | Linear fit | $Y = a + bX$ |
| **2** | Exponential fit | $Y = a b^X$ |
| **3** | Quadratic fit | $Y = a + bX + cX^2$ |
| **4** | Third degree polynomial fit (Cubic fit) | $Y = a + bX + cX^2 + dX^3$ |
| **5** | Fourth degree polynomial fit | $Y = a + bX + cX^2 + dX^3 + eX^4$ |
| **6** | Logarithmic fit | $Y = a + b\ln(X)$ |

**Coefficient of Variation adjusted for trend:**

After fitting the data to above curves the appropriate curve was selected and the value of CV was estimated. Thus the curve was selected on the basis of Comparative table by trends with its $R^2$ -Value (i.e. Coefficient of Multiple Determination). Coefficient of Variation (CV) was estimated by this formula. However, when linear or non-linear trend exists in the data, the CV around mean does not give the instability. Here, we have used the coefficient of variation developed by Pal and Bisaria,the CV has been estimated by both the methods and compared.

$$CV = \frac{\left(\sum\left(X_t - \hat{X}_t\right)^2\right)^{1/2}}{\overline{X_t}}$$

Where,

$X_t$ is actual value in t[th] year,

$\hat{X}_t$ is trend value in t[th] year,

$\overline{X}_t$ is mean of X,

n is number of years.

**2.2 Estimation of Risks in Terms of Probability of Obtaining Yields or Gross Returns**

Besides coefficient of variation, the risk in terms of probability of obtaining yields or gross returns below the 95 percent of the trend have been computed with the help of one of the following Probability distributions fitted to the given data. The distribution having best fit was used to find the probability.

**Parameter estimation of the distributions**

i. Normal Distribution
ii. Lognormal Distribution
iii. Gamma Distribution
iv. Beta Distribution
v. Weibull Distribution
vi. Exponential Distribution

**Probabilities of Shortfall**

The expected negative deviations worked out on the basis of probability of shortfall (by 95 percent of the trend value) and average absolute deviations (from trend) were used to derive “Risk Equivalent Prices”.

**2.3 Protection Coefficient (Social Security Index)**

Expected negative deviations indicate an estimated annual loss either due to yield risk or income risk (Yield and Price Risks). The share of expected negative deviation over average yield / gross returns of last three years indicate the extent of support to be extended to the farmers through some welfare strategies in order to protect the farmers against the yield and Price risks which are beyond the control of farmers.This index is termed as Protection Coefficient (Social Security Index) and both the words are used as synonyms in this study.

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**2.4 Expected Annual Negative Deviation (for Yield Risk & Gross Returns)**

Expected Annual Negative Deviation (Yield Risk)

= (Average Absolute Deviation in Yield) X (Probability of Shortfall in Yield)

**Expected Annual Negative Deviation (Gross Returns)**

= (Average Absolute Deviation in Gross Returns) X(Probability of Shortfall in Gross Returns)

**2.5 Protection Coefficient / Social Security Index**

Protection Coefficient (Social Security Index) for Yield

$$= \frac{\text{Expected Annual Negative Deviation}}{\text{Average Yield}} \times 100$$

Protection Coefficient (Social Security Index) for Gross Returns

$$= \frac{\text{Expected Annual Negative Deviation}}{\text{Average Gross Returns}} \times 100$$

**2.6 Probability as a Measure of Risk**

The probability of actual yield and gross returns per hectare failing 5 per cent or more below their respective trend values were estimated as

Probability [Trend Value – Observed Value ≥ (0.05 x Mean of Last three Years)]

OR

Probability [Observed Value – Trend Value ≤ (- 0.05 x Trend Value)]

Average of Such Probabilities is the probability of shortfall in yields or gross returns. The probability distributions viz., Normal, Log-normal, Gamma, Beta, Weibull and Exponential were fitted to the data and most appropriate distribution was selected on the basis of maximum Chi-Square. From this the probability of shortfall in yields and gross returns was estimated.

**2.7 Estimation of Risk Equivalent Prices (REP)**

Any deviation (Positive or Negative) from the trend constitutes the risk. Here, risk equivalent prices have been calculated which can be defined as "An increase in output prices (in percentage) needed to compensate the shortfall in the yield or gross returns per hectare". The REP was calculated both for yield risk and price risk separately usingthe expected negative deviation approach given by the formula suggested by Pal and Bisaria (1990).

**Risk Equivalent Price (REP) for Yield Risk**

= Protection Coefficient for Yield * Average Price (Last three years)/100

**Risk Equivalent Price for Yield and Price Risk (i.e. for Gross Returns)**

= Protection Coefficient for Yield and Price * Avrage Price (Last three years)/100

## Results and Discussions

### Analysis and Applications as Case Study:

The procedure proposed in research methodology has been applied for estimation of yield and price risks in cereal crop Bajara crop in Aurangabad, Beed and Jalna districts of Marathwada region. The yield data (2001-02 to 2010-11) were collected from Directorate of Agriculture, Maharashtra State, Pune. The Minimum support price data were taken from WEBSITE of Directorate of Economics and Statistics, Govt. of Maharashtra.

**3.1 Districtwise Data Analysis of Bajara Crop:**

Bajara crop is an important cereal crop in the Marathwada region. The production of the crops completely depends on the vagaries of nature. If there is a fluctuation in the rainfall, temperature, humidity, etc. it affects the production. As a matter of fact, there is a risk in the crop production as it depends on the vagaries of nature. Not only has that but the farmers had to face risk in the price fluctuations of the crops also. Thus, the farmers face two types of risks i.e. i) Risk in crop production and ii) Risk in price fluctuations. Therefore, an attempt has been made to measure risk in crop production and gross returns from the crop.

**3.2 Variability in Productivity:**

For the present study the Districtwise data of Bajara crop for three districts of Marathwada Region viz. Aurangabad, Beed, and Jalna is considered from 2001-02 to 2010-11. The Districtwise values of Arithmetic Mean (A.M.), Standard Deviation (S.D.) and Coefficient of Variations (CV %) are presented in Table 1. It can be reveled from Table 1 that the Mean average yield of the Bajara crop during the period under study (2001-02 to 2010-11) for Marathwada region was 867.90 q/ha. It was highest in Aurangabad 1010.47 q/ha followed by Jalna 908.70 q/ha and the lowest yield per ha. was 684.53 q/ha in Beed.As regards variability, the productivity was stable in Jalna 15.68% followed by Aurangabad 21.79%. More variability was observed in Beed i.e. 23.29%.

**3.3 Variability in Gross Returns:**

An attempt was also made to know the variability in Gross Return (Productivity X corresponding Minimum Support Price of the Crop). It was observed from Table 1 that average gross returns from Bajara crop for the region Rs. 15345.29/- per hacter. It was maximum Rs. 18228.20/- per hacter in Aurangabad district followed by Jalna Rs. 15823.37/- per hacter. The minimum gross return was in Beed Rs. 11984.30/- per hacter. As regards variability it was maximum 57.70% in Aurangabad followed by Beed 53.30%. The gross return was more stable in Jalna district 44.98%. It can be noted here that the variability was more in gross returns as compared to yield.

**Table 1:** Arithmetic Mean (A.M.), Standard Deviation (S.D.), Coefficient of Variation (CV) about Mean, Coefficient of Variation (CV) about Trend of Bajara Crop

| Bajara | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Marathwada Region | | | | | | | | | |
| Sr. No. | Name of the Districts | Yield | | | | Gross Returns | | | |
| | | A.M. (q/ha) | S.D. (q/ha) | CV (%) about Mean | CV (%) about Trend | A.M. (Rs./ha) | S.D. (Rs./ha) | CV (%) about Mean | CV (%) about Trend |
| 1 | **Aurangabad** | 1010.47 | 220.23 | 21.79 | 9.44 | 18228.20 | 10518.20 | 57.70 | 8.46 |
| 2 | **Beed** | 684.53 | 159.44 | 23.29 | 12.99 | 11984.30 | 6387.75 | 53.30 | 13.52 |
| 3 | **Jalna** | 908.70 | 142.49 | 15.68 | 9.95 | 15823.37 | 7117.58 | 44.98 | 8.21 |
| **Average** | | **867.9** | **174.05** | **20.25** | **10.79** | **15345.29** | **8007.84** | **51.99** | **10.06** |

### 3.4 Variability Adjusted for Tend:

Generally we estimate the variability i.e. CV % about arithmetic mean. But if the time series data is there and trend is present in the data, the references show that the variability adjusted for trend is to be used to measure the variability over the time period. Therefore, the trends were fitted to the data and the variability adjusted for trend was estimated. The fitted equations are given in Table 2 and Table 3. The variability presented in Table 1 indicated that the variability adjusted for trend was lower than that of CV% around mean. However, the same trend was observed in variability by both the methods. All the values of variability adjusted for trend (CV %) was less than that of CV% around mean.

**Table 2:** Underlying Trend equations in respect of Yield for Districtwise Data of Bajara

| Bajara – Yield | | | | | | | |
|---|---|---|---|---|---|---|---|
| Districtwise Analysis | | | | | | | |
| Sr. No. | Name of District | Name of Curve | Curve Equation | | | | |
| | | | a | b | C | D | e |
| 1 | Aurangabad | Forth Degree Poly. Fit | 1.5875 | -32.15 | 207.4 | -402.96 | 945.59 |
| 2 | Beed | Forth Degree Poly. Fit | 1.3978 | -24.832 | 124.3 | -123.5 | 548.86 |
| 3 | Jalna | Forth Degree Poly. Fit | 0.8051 | -13.041 | 48.082 | 62.625 | 618.5 |

**Table 3:** Underlying Trend equations in respect of Gross Returns for Districtwise Data

| Bajara – Gross Returns | | | | | | | |
|---|---|---|---|---|---|---|---|
| Districtwise Analysis | | | | | | | |
| Sr. No. | Name of District | Name of Curve | Curve Equation | | | | |
| | | | a | b | C | D | e |
| 1 | Aurangabad | Forth Degree Poly. Fit | 46.869 | -861.03 | 5296.6 | -10931 | 16159 |
| 2 | Beed | Forth Degree Poly. Fit | 42.799 | -764.14 | 4296.4 | -7628 | 11254 |
| 3 | Jalna | Forth Degree Poly. Fit | 29.594 | -486.62 | 2438.0 | -2979.4 | 10578 |

### 3.6 Estimation of Risk Equivalent Prices (REP):

Besides coefficient of variation CV %, probability of crop failure (PCF) and crop loss ratio (CLR), the risk in terms of probability of obtaining yield or gross returns below 95 percent of the trend have been computed by fitting Normal, Lognormal, Gamma, Beta, Weibull, Exponential distributions to the time series data of productivity and gross returns. Any deviations from trend constitute the risk. It is the negative deviations which is a deep concern to the farmers. Therefore, any policy options for the protection of the interest of farming community should take negative deviations into considerations.

### 3.6.1 Expected Annual Negative Deviations:

The expected annual negative deviations were worked out on the basis of average absolute negative deviations multiplied by probability of shortfall. The probability of shortfall was obtained by fitting appropriate probability distribution to the yield and gross return data for the years 2001-02 to 2010-11. It is presented in Table 4.

**Table 4:** Underlying Probability Distribution in respect of Yield and Gross Returns

| Districtwise Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sr. No. | Name of District | Yield | | | Gross Returns | | |
| | | Fitted Distribution | Parameters | | Fitted Distribution | Parameters | |
| 1 | **Aurangabad** | Lognormal | Mu | 6.90 | Lognormal | Mu | 9.70 |
| | | | Sd | 0.22 | | sd | 0.47 |
| 2 | **Beed** | Normal | Mu | 684.60 | Lognormal | mu | 9.31 |
| | | | Sd | 159.48 | | sd | 0.40 |
| 3 | **Jalna** | Weibull | A | 9.16 | Lognormal | mu | 9.60 |
| | | | B | 963.29 | | sd | 0.36 |

### 3.6.2 Probability of shortfall in yield and gross returns

The probability of shortfall in yield and gross returns are presented in Table 5. It is noted from Table 5 that the probability of shortfall in yield was ranging from 0.18 to 0.21 (i.e. 18% to 21%) at an average level it was 0.20 (i.e. 20%). It can be further noted from Table 6, that for Bajara crop the probability of shortfall for yield was less in Beed district 0.18 (i.e. 18%) and maximum in Aurangabad 0.21 (i.e. 21%). On an average the probability of shortfall in case of gross returns was 0.38 (i.e. 38%). In case of gross returns the probability of shortfall was minimum in Beed 0.30 (i.e. 30%). It was maximum in Aurangabad 0.52 (i.e. 52%).

### Expected Annual Negative Deviation in Yield and Gross Returns

Expected Annual Negative Deviations were worked out by following formula.

**Expected Annual Negative Deviations =**
**Average Absolute Deviations in Yield/Gross Returns x Probability of Shortfall**.

An expected negative deviation indicates an estimated annual loss either due to yield risk or yield and price risk. The expected annual negative deviation in the yield was ranging from 19.51 to 29.37. On an average expected negative deviation was 24.37.The expected negative deviations for gross returns for the districts ranged from 607.64 to 1223.00. On an average it was 830.94.

**Table 5:** Probability of Shortfall (PS), Expected Annual Negative Deviation (EAND)

| Bajara | | | | | |
|---|---|---|---|---|---|
| Marathwada Region | | | | | |
| Sr. No. | Name of the Districts | Yield | | Gross Returns | |
| | | Prob. of Shortfall | Exp. Ann. Neg. Dev. (Kg/ha) | Prob. of Shortfall | Exp. Ann. Neg. Dev. (Rs./ha) |
| **1** | **Aurangabad** | 0.21 | 24.23 | 0.52 | 1223.00 |
| **2** | **Beed** | 0.18 | 19.51 | 0.30 | 662.17 |
| **3** | **Jalna** | 0.20 | 29.37 | 0.33 | 607.64 |
| **Average** | | **0.20** | **24.37** | **0.38** | **830.94** |

**Risk Equivalent Prices (REP)**

By dividing the expected annual negative deviations by average yield and multiplied by 100. We get security index (SI).

**Security Index (SI) = (Expected Annual Negative Deviations/Average Yield) *100**

This indicates extent of support to be extended to the farmers in view of risk in crop yield or gross returns.

Using security index (SI), Risk Equivalent Prices (REP) were estimated by the formula.

$$REP = \frac{SI \times MSP\ of\ last\ year}{100}$$

The same procedure was repeated for gross returns.

An attempt was also made to estimate the security index and risk equivalent prices (REP) for the Bajara crop for all the districts of Maharashtra region. The values of Security Index and Risk Equivalent Prices are present in Table 6. It can be noted from Table 6 that, the security index (SI) for Bajara crop was maximum in Jalna 3.23%. It was minimum in Aurangabad 2.40%. On an average it was 2.83%. This indicated that to recover the Bajara yield loss of the farmers in the Marathwada region, the farmers have to pay additional 2.40% to 3.23% of the minimum support prices (MSP). Considering the MSP of 2010-11 i.e. Rs.3200 per/quintal, the farmers has to pay REP on an average Rs. 90.46. The maximum REP for Jalna district is Rs. 103.42/- per quintal and minimum in Aurangabad district is Rs. 76.74.

**Table 6:** Security Index (SI), Risk Equivalent Price (REP) of Bajara Crop

| Bajara | | | | | |
|---|---|---|---|---|---|
| Marathwada Region | | | | | |
| Sr. No. | Name of the Districts | Yield | | Gross Returns | |
| | | Security Index | REP (Rs.) | Security Index | REP (Rs.) |
| **1** | **Aurangabad** | 2.40 | 76.74 | 6.71 | 214.69 |
| **2** | **Beed** | 2.85 | 91.21 | 5.53 | 176.81 |
| **3** | **Jalna** | 3.23 | 103.42 | 3.84 | 122.88 |
| **Average** | | **2.83** | **90.46** | **5.36** | **171.46** |

Considering risk in gross returns of Bajara crop, the Security Index (SI) ranged from 3.84% to 6.71%. On an average it was 5.36%. It was minimum 3.84% in Jalna and maximum in Aurangabad district 6.71%. The REP was worked out considering the SI. It is observed from Table 6 that, the REP for gross returns was maximum Rs. 214.69 /quintal in Aurangabad and minimum Rs.122.88 /quintal in Jalna. It can be concluded from the Districtwise analysis that, for Bajara crop the average Security Index for yield was 5.36%. Thus, considering risk in the crop yield, Rs. 171.46 per quintal needs to be given to farmers over and above the MSP. Considering combinly the risk in yield and prices of crop i.e. gross returns, the minimum Rs. 122.88 to Rs. 214.69/- per quintal needs to be given over an above the MSP to protect the social security of farmers.

## 4. Conclusions

The present investigation based on time series data pertaining to yield and minimum support prices of Bajara crop grown in Marathwada region of Maharashtra State during 2001-2002 to 2010-2011. The objective of the study is to to quantify the risk in Yield and Price. The risk associated with production and gross returns have been measured with help of the concepts of coefficient of variation after elimination of underlying trends in the data and probability of shortfall in yields and gross returns thorough appropriate underlying probability distributions. Using the mean deviations, Probability of Shortfalls, and Expected Negative Deviations are estimated to derive Protection Coefficients (Social Security Index) and Risk Equivalent Prices (REP). The analysis carried over a period of study indicated that there is 20 percent probability of incidence of shortfall in yield resulting 2.83 percent loss in the yields of the Bajara in Marathwada. With regards to Risks in Gross returns, a probability of shortfall (PS) to the extent of 38 percent resulting a loss in Gross returns to the extent of 5.36 percent of average returns has been observed. Since the extent of proportion of loss in gross returns is more than yield, the farmers growing Bajara crop need to be protected to the extent of 5.36 percent in the form of additional price i.e. Risk Equivalent Price. Considering the average prevailing MSP of Rs. 3000/- the risk equivalent price (REP) worked out to be Rs. 171.46 per quintal. Thus the farmers in the Marathwada region need to be protected to that extent against of Rs. 171.46 per quintal.

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