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THE RELATION BETWEEN VOLATILITY IN THE GROWTH OF OUTPUT AND THE VOLATILITY IN GROWTH OF PRICE OF RICE PRODUCTION IN INDIA: EVIDENCE FROM ARCH/GARCH METHOD

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ABSTRACT

This paper estimates the extent of the growth of price volatility, the growth of output volatility and also analyses the relation between these two in case of rice for the four major rice producing states in India, namely Andhra Pradesh, Punjab, Uttar Pradesh and West Bengal, by using modern time series approach, for the period from 1963-64 to 2012-13. While the existing studies relating to the volatility analysis of Indian agriculture use conventional analysis of taking variance or coefficient of variation as the measures of volatility, the present study is based on the technique of measurement of volatility by using modern time series analysis. The distinguishing feature of the method is that the volatility or the volatility of the series is determined by the ARCH or GARCH method and the method of finding out the relation between the price volatility and the production volatility is much more dependent on time series econometric technique. The main findings of the paper is that one cannot find any relation between price volatility and production volatility for rice in case of three major rice producing states out of four. Only in case of Punjab there exists a both way relation between price and production volatility. Thus, in India for the majority of cases the extent of price volatility (output volatility) is determined by the factors other than output volatility (price volatility).

Keywords: Output volatility, Price volatility, volatility, ARCH model, GARCH model.

Article Classification: Q10, Q19, C22.

1. INTRODUCTION

Agriculture is a very important sector in India nearly 70% of the population depends on income from agriculture in rural area. Near about 75% of all rural poor are dependent on agriculture (Government of India, Planning Commission). The volatility in the agricultural sector can either

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came from agricultural output or price or both.

a) **Production volatility:** Production volatility is one of the main characteristic of Indian agriculture In case of India this production volatility is very much significant because farmers are unable to forecast correctly the amount of output in case of time of harvesting due to external factors such as weather, pests, and diseases. One of the main causes of losses in production is that in the time of harvesting farmers are stuck by adverse events.
b) **Price volatility:** One of the major sources of market volatility is the input and output price volatility in agriculture. Prices of agricultural commodities are extremely volatile because output price variability significantly affected by the both endogenous and exogenous market shocks. Segmented agricultural markets mainly affected by local supply and demand conditions, while more globally integrated markets will be mainly influenced by international production conditions.

Thus it is important to find out the relation between the production volatility and price volatility in Indian agriculture, specifically volatility in the growth rate of output and the volatility in the growth rate in the price. In other words one needs to know the extent of causality between these two series.

Variability in crop production is largely due to the risk and uncertainty involved in production process. Risk is defined as variability, which can be measured empirically. For empirical purpose sometime standard deviation of profit is taken as an absolute measures of risk and the coefficient of variation is taken as the relative measures of risk (Heady, 1952 and Dandekar,1976). Bliss and Stern (1982) use the expected utility maximization framework for analyzing risk in wheat cultivation in Palanpur district, India by assuming a linear production function. Rangaswamy (1982) used the standard deviation of net returns as the measure of risk. Sing and Nautiyal (1986) estimated the probability distribution of the profitability of fertilizer application in HYVs of wheat and paddy crops in four different agro-climatic region of Uttar Pradesh. The risk of achieving a minimum desire return or losing money is determined from the distribution of the profitability. Sankar and Mythili(1991) indentified the factors accountable for annual variations in the proportion of net sown area to cultivated area, cropping intensity, by using simple tools such as bivariate tables, correlation analysis and decomposition exercises. Mosnier, Reynaud, Thomas, Lherm, Agabriel (2009) concerned about the issue of agricultural production under both output and price risks.

Even though these studies are based on different specifications of model and estimation procedure but are devoid of the use of the modern time series technique for the

measurement of volatility. In fact, the perusal of the literature reveals that there is dearth in studies relating to the measurement of volatility in the agricultural sector by using modern time series approach. The present paper adds the literature in this direction and attempts to measure the volatility of growth in output and price in case of rice for four major rice producing states in India like Andhra Pradesh, Punjab, Uttar Pradesh and West Bengal for the period from 1963-64 to 2012-13 by using autoregressive conditional heteroskedasticity model (ARCH)/ generalized autoregressive conditional heteroskedastic model (GARCH) method. The paper also estimates the relationship between output and price volatility. Rice crop is chosen because India is the major producer and exporter of rice in the world. That state whose share is more than 10% in all India production is taken.

The structure of the present paper is as follows: in **Section 2** presents the methodology and data sources. **Section 3** discusses the results of estimation. Some concluding remarks are made in the **section 4.**

2. METHODOLOGY AND DATA SOURCE

The estimation of the volatility in the growth of output and price is obtained by using ARCH/GARCH method of volatility approach as explained in subsection 2.1 and 2.2 respectively. This is followed by Granger causality test to find out the causality between these two series. The growth rate in the respective series is calculated using the formula:

$$1 - \frac{y_{t-1}}{y_t}$$

2.1. The estimation of volatility: The autoregressive conditional heteroskedasticity model (ARCH)

One of the basic assumptions of the classical regression model is the *homoscedasticity*, i.e, the assumption of constant error variance: $var(e_t) = \sigma^2(e_t)$, where $e_t \sim N(0,\sigma^2)$. In the case of modern time series analysis it is assumed that the variance of the errors will not be constant over time. Thus, it is better to specify a model without constant variance. In the time series econometrics the variance of the random term of any particular year is expected to be correlated with the variance of the random term of the previous year. Thus the variance of the stochastic process becomes heteroskedastic. This phenomenon of the time series data is called *volatility clustering* or *volatility pooling* and hence can be taken as a measure of volatility. This characteristic shows that the current level of volatility may be positively correlated with its immediately previous

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periods. Using the ARCH model of Engle, 1982 one can estimate this phenomenon. For better understanding of the model definition of the conditional variance of a random variable e_t is required. In tune with Engle (1982) the conditional variance of e_t, (σ^2) is denoted as:

$$\sigma^2 = \mathrm{var}(e_f / e_{t-1}, e_{t-2}, \ldots) = E[(e_t - E(e_t))^2 / e_{t-1}, e_{t-2}, \ldots) \quad (1)$$

Since $E(e_t) = 0$, equation (1) becomes:

$$\sigma^2 = \mathrm{var}(e, / e_{t-1}, e_{t-2}, \ldots) = E[e^2 / e_{t-1}, e_{t-2}, \ldots] \quad (2)$$

Equation (2) represents that the conditional variance random variable e_t is equal to the conditional expectation of the square of e_t. In the case of the ARCH model, the autocorrelation in volatility is modeled by:

$$\sigma^2 = \delta_0 + \delta_1 . e^2_{t-1} \quad (3)$$

The above model is known as ARCH(1) and it shows that the conditional variance of the error term σ^2, depends on the immediately preceding value of the squared error.

This model can be extended to the general case of ARCH(q), where the error variance depends on q lags of squared errors.

$$\sigma^2 = \delta_0 + \delta_1 . e^2_{t-1} + \delta_2 . e^2_{t-2} + \ldots\ldots + \delta_q . e^2_{t-q} \quad (4)$$

where $\mathbf{e_t \sim N(0, \sigma^2)}$.

Since σ2 represents the conditional variance, its value must be strictly positive otherwise it is meaningless. So all the coefficients in the conditional variance equation must be positive: $\sigma_i \geq 0$, **for all i = 0,1,2,...,q .**

2.2. The estimation of volatility: The generalized autoregressive conditional heteroskedastic model (GARCH)

The limitation of the above ARCH model is that it does not consider the total volatility. The ARCH model represents only a part of total variance because it does not include the other part which show how the σ^2 varies over time.

The GARCH model has been developed independently by Bollerslev (1986) and Taylor (1986). This model shows the conditional variance of any variable to be dependent upon its own

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previous lags and the lag of the random term. The conditional variance of GARCH(1,1) model is specified as:

$$\sigma^2 = \delta_0 + \delta_1 . e^2_{t-1} + \mu_1 . \sigma^2_{t-1} \qquad (5)$$

The conditional variance can be split into three terms i) a long term average value (dependent on δ_0), ii) the information related to the volatility during the previous period ($\delta_1.e^2_{t-1}$) and iii) the variance of the previous period ($\mu_1.\sigma^2_{t-1}$).

The general form of the GARCH(q, p) model, where the conditional variance depends on q lags of the squared error and p lags of the conditional variance can be specified as:

$$\sigma^2 = \delta_0 + \delta_1 . e^2_{t-1} + \delta_2 . e^2_{t-2} + \ldots + \delta_q . e^2_{t-q} + \mu_1 . \sigma^2_{t-1} + \mu_2 . \sigma^2_{t-2} + \ldots . + \mu_p . \sigma^2_{t-p} \qquad (6)$$

In empirical purpose GARCH(1,1) model is well thought-out to be sufficient in capturing the evolution of the volatility. A GARCH(1,1) model is equivalent to an ARCH(2) model and a GARCH(q, p) model is equivalent to an ARCH $(q + p)$ model (Engle, 1982).

The unconditional variance of the error term e_t *for* GARCH (1, 1) model is constant and given by the following equation:

$$var(e_t) = \frac{\delta 0}{1-(\delta_1+\mu_1)} \qquad (7)$$

If $\delta_1+\mu_1<1$ then var $(e_t)>0$.

The present paper obtain the value of volatility of both growth of output and price by estimating the GARCH(1,1) model. The estimated value of the conditional variance is taken as a measure of volatility. Before estimating the model one has to checked the presence of ARCH effects in the series. This paper uses the Engle (1982) test for checking the ARCH effect which needs estimation of optimum lag. To find out the optimum lag this paper uses the figures of the correlogram. It shows that the second partial correlation coefficient is significant, in all cases, suggesting an optimum lag of two for each. Thus ARMA(2,2) series is used to carry out the heteroskedasticity test.

2.3. The Granger causality test

In the modern time series simple correlation may sometime leads to spurious or meaningless correlation between the two series. The Granger (1969) approach examine whether x causes y or

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not. For answering this question Ganger used the concept that how much of the current *y* can be explained by past values of *y* and then to see whether adding lagged values of *x* can improve the explanation. *y* is said to be Granger-caused by *x* if *x* helps in the prediction of *y*, i.e. if the coefficients on the lagged *x*'s are statistically significant. The Granger causality test can be called as statistical hypothesis test for determining whether one time series is useful in forecasting another. The test of Granger causality is done in the following manner:

Let *y* and *x* be stationary time series.

The null hypothesis is H_0: *x* does not Granger-cause *y*,

The proper value of *y* is to be found out by running the following regression:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \ldots + a_m y_{t-m} + residual_t.$$

This model is called the restricted model. Estimation of this model yields restricted residual sum of square (RSS_R).

Next, the autoregression is augmented by including lagged values of *x* like the following equation:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \ldots a_m y_{t-m} + b_p x_{t-p} + \ldots + b_q x_{t-q} + residual_t.$$

This model is called the unrestricted model. After estimating this model one can obtain unrestricted residual sum of square (RSS_{UR}).

The test statistic is as follows:

$F = ((RSS_R - RSS_{UR})/l) / RSS_{UR}/(n-k)$

Where *l* is the number of lagged term taken, n is the sample size and k is the number of parameters estimated in the unrestricted equation. The null hypothesis that *x* does not Granger-cause *y* is accepted if and only if no lagged values of *x* are retained in the regression.

The paper uses monthly data on whole sale price and after finding out the monthly volatility, we average them to get the yearly volatility.

2.4 Data Sources:

All the data has been collected from the different issues of the Statistical abstract, Agriculture at a Glance, Agriculture in Brief, Handbook of Statistics of Indian Economics, Cost of Cultivation

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data and Agricultural prices in India published by the Government of India.

3. RESULTS OF ANALYSIS

3.1 Production risk

The results of Engle (1982) test using output series are presented in the Table-1. The estimated values of F statistics are highly significant in all the four states implying that there are ARCH effects in the growth of rice production.

Table 1: Heteroskedasticity test for detection of ARCH effect in case of growth of rice production

States	F-Statistic	Prob.
Andhra Pradesh	52.58498	0.000
Punjab	2854.025	0.000
Uttar Pradesh	5.245804	0.0271
West Bengal	49.72933	0.000

The results of the estimation of the GARCH (1, 1) model are presented in the Table-2. The coefficient of the squared error is significant at 1% level for all states. The coefficient of the conditional variance is statistically significant at 1% level in case of Andhra Pradesh and Punjab. This implies that the shocks to the conditional variance are persistent. The value of the coefficient of the conditional variance in case of Andhra Pradesh and Punjab is large implies that large (Small) changes in it will be followed by other large (Small) changes. From these results one can conclude that the growth series of the rice production is highly volatile in nature in case of all four states.

Table 2: Results of ARCH/GARCH estimation in case of growth of rice production

States	Constant	RESID(-1)^2	GARCH(-1)^2
Andhra Pradesh	0.006457 (0.758444)	0.297878* (3.313715)	0.6102754* (3.645488)
Punjab	0.001316* (2.312656)	0.112081* (2.471399)	0.873917* (14.70634)
Uttar Pradesh	0.002879* (2.594286)	0.703085* (2.995748)	0.115744 (1.031708)
West Bengal	0.000702 (1.865901)	0.976874* (3.158443)	0.075873 (1.158666)

*** Significant at 1% level**

Z values are given in the parenthesis.

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Now before going to the step further we had to verify whether the squared error of the GARCH (1, 1) model presents the ARCH effects. For this purpose the heteroskedasticity test is used again and the results are presented in the Table-3. The results show that there are no additional ARCH effects in the squared errors series in case of all states and hence the use of GARCH(1,1) is justified.

Table 3: Heteroskedasticity test after the estimation of ARCH/GARCH in case of growth of rice production

States	F-Statistic	Prob.
Andhra Pradesh	0.667778	0.4186
Punjab	0.189891	0.6653
Uttar Pradesh	0.253484	0.6173
West Bengal	0.540380	0.4665

3.2 Price risk

Table-4 represents the results of Engle (1982) test for detection of ARCH effect in case of growth of price for all the four states. The estimated values of F statistics are highly significant in all cases suggesting the existence of ARCH effect for all four.

Table 4: Heteroskedasticity test for detection of ARCH effect in case of growth of price of rice

States	F-Statistic	Prob.
Andhra Pradesh	6499.090	0.000
Punjab	10062.09	0.000
Uttar Pradesh	5.216694	0.0228
West Bengal	10812.57	0.000

Table-5 represents the results of the estimation of the GARCH (1, 1) model. The coefficient of the squared error is significant at 1% level for all states. In case of Punjab the coefficient of squared error is high implies that the variance of the present year is highly correlated with its lag. The coefficient of the conditional variance is statistically significant at 1% level in case of all states. This implies that the shocks to the conditional variance are persistent. The value of the coefficient of the conditional variance in case of Andhra Pradesh, Uttar Pradesh and West Bengal are large implies that large (Small) changes in the conditional variance are followed by other large (Small) changes. Thus, from the results one can conclude that the growth of price series of rice production is highly volatile in nature in case of all four states.

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Table 5: Results of ARCH/GARCH estimation in case of growth of price of rice

States	Constant	RESID(-1)^2	GARCH(-1)^2
Andhra Pradesh	0.001940 (1.799178)	0.000736* (5.198889)	0.963600* (43.40847)
Punjab	0.003991* (34.82813)	0.874662* (20.73044)	0.007985* (16.04039)
Uttar Pradesh	0.144637* (55.01335)	0.222283* (4.474522)	0.600210* (4.197395)
West Bengal	0.001152* (6.748331)	0.248640* (6.979118)	0.559626* (9.984588)

*** Significant at 1% level**

Z values are given in the parenthesis.

Now, one has to verify whether the squared error of the GARCH (1, 1) model presents the ARCH effects or not. This is done by using the heteroskedasticity test and the results are presented in the Table-6. According to the results there are no additional ARCH effects in the squared errors series in case of all four states, as the F statistics are insignificant for each.

Table 6: Heteroskedasticity test after the estimation of ARCH/GARCH in case of growth of price of rice

States	F-Statistic	Prob.
Andhra Pradesh	0.860383	0.3540
Punjab	0.050835	0.8217
Uttar Pradesh	0.001451	0.9696
West Bengal	1.502438	0.2208

3.3 Test for Causality

Table-7 represents the results of the Granger Causality test between the risk of growth of output production and the risk of growth of price for rice in case of all four states. By analyzing the results one can conclude that there exist no relation between the production risk and price risk in case of Andhra Pradesh, Uttar Pradesh and West Bengal. In case of Punjab there exist both way relation between the price risk and production risk. Since the share of rice production going to Punjab is not too large with respect to the other three states one can conclude that the price risk of rice in India in general is determined by the factors other than production risk. The reverse is also true in case of rice.

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Table 7: Results of Granger Causality between production risk and price risk

States	Production risk does not Granger Causes Price risk		Price risk does not Granger Causes Production risk	
	F-Statistic	Prob.	F-Statistic	Prob.
Andhra Pradesh	0.68818	0.5088	0.67005	0.5178
Punjab	6.89253	0.0029	9.40674	0.0005
Uttar Pradesh	0.13759	0.8719	0.15872	0.8538
West Bengal	0.07188	0.9308	0.06006	0.9418

4. CONCLUSION

This paper estimates the extent of the growth of price volatility, the growth of output volatility and also analyses the relation between these two in case of rice for the four major rice producing states in India, namely Andhra Pradesh, Punjab, Uttar Pradesh and West Bengal, by using modern time series approach, for the period from 1963-64 to 2012-13. While the existing studies relating to the volatility analysis of Indian agriculture use conventional analysis of taking variance or coefficient of variation as the measures of volatility, the present study is based on the technique of measurement of volatility by using modern time series analysis. The distinguishing feature of the method is that the volatility or the volatility of the series is determined by the ARCH or GARCH method and the method of finding out the relation between the price volatility and the production volatility is much more dependent on time series econometric technique. The main findings of the paper is that one cannot find any relation between price volatility and production volatility for rice in case of three major rice producing states out of four. Only in case of Punjab there exists a both way relation between price and production volatility. So in general one may conclude that the price volatility of rice is more affected by the factors other than the production volatility. Thus one can suggests that in India the volatility in rice production may originate from the input side and hence may be minimized by controlling input usage, like improving irrigation facilities or by using much more modern technique in ploughing or using HYV seeds in production etc. similarly the price volatility may be generated by the cost side and thus needs control of input price for minimizing price volatility. At the same more control of the Government on the price is needed in order to curbing the amount of volatility.

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