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# Long Run Relations and Short Run Dynamics between Agricultural Determinants and Yield Rate of Rice Production: A Study in India

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## Abstract

*The present study examines both SR and LR effects of various agricultural determinants on the yield rate of rice in India during 1996 -2021. The study uses ADF unit root test, Johansen and Juselius cointegration test and causality test in a VECM set up to find the LR association and SR dynamics among the variables. The analysis indicates the presence of cointegrating relationships among the variables, signifying a LR equilibrium relationship among the variables. The VECM demonstrates that LR causation exists from FERT, CI, and IRR to rice yield, indicating that all factors significantly impact rice production over the LR. The same outcome is observed in the SR; specifically, all factors significantly influence the yield rate of rice in this period. This report advocates for the government to enhance infrastructure to support LR agricultural growth. The government needs to proactively enhance spending on essential inputs like fertiliser and irrigation, while also promoting private investment in the agricultural sector to successfully elevate the LR yield rate of rice.*

**KEYWORDS:** Cropping Intensity, Rice, Long run, irrigation.

## INTRODUCTION

Agriculture is crucial to India's economy. India attained self-sufficiency in food grains, namely rice and wheat, as a result of the Green Revolution. However, it soon became evident that we must progress beyond the green revolution, as it has neglected rainfed regions, nutritional crops such as millets, non-cereal crops, and resource-constrained farmers. The sector employs approximately 49 percent of the nation's total workforce (Periodic Labour Force Survey, 2020), while agriculture and related activities contribute 18.4% to the country's GVA at current prices for the period 2022–2023 (MoA and Farmers Welfare, GOI, 2022-23). The proportion of agriculture in the nation's GDP has consistently declined, from an average of 55.12 percent in 1950-51 to 18.2 percent in 2023-24 (Economic Survey, GOI, 2023-24). Notwithstanding this swift fall, agriculture remains a crucial sector of the Indian economy due to its strategic importance for food security, employment creation, exports, and poverty alleviation. Agriculture is fundamentally linked to food and nutritional security (IFPRI, 2015) and has considerably influenced poverty alleviation (Ravallion and Datta 1998). Poverty has a significant impact on food and nutritional security due to poor access to productivity-enhancing agricultural inputs. An improvement in agricultural productivity may improve the nutritional security of the poor by supplying an adequate amount and quality of food which reduces malnutrition and boosts individual's health thereby boosting longevity. According to provisional estimates for 2023-24, the agriculture sector's growth rate stood at 1.4 percent, which is below 4.7 percent in 2022-23 (Economic Survey, GOI, 2023-24), mainly due to a decline in foodgrain production. Despite being a significant agricultural producer, ranking as the second largest in rice, wheat, and cotton, and the first in milk, pulses, and spices, the country's crop yields are much inferior to those of other leading producers. Factors contributing to diminished yields encompass insufficient farm mechanization, fragmented land holdings, poor availability to quality inputs, minimal farm investment, and deficient marketing infrastructure leading to postharvest losses, reliance on rainfall, and abbreviated growing seasons. The Government of India is implementing various measures to improve agricultural productivity in line with the Doubling Farmers Income Report (DFI) 2016, which outlined strategies to boost crop productivity, increase cropping intensity, diversify into high-value agriculture, and ensure profitable prices for farmers' produce. Indicators of Cropping intensity and irrigation intensity are critical metrics for assessing a region's agricultural advancement. Cropping intensity, a vital metric of food security, significantly affects a region's net production (Jain et al. 2013). Implementing activities to augment cropping intensity is a recognized strategy to improve agricultural productivity and rural employment. The accessibility of water for agricultural irrigation, whether by precipitation or alternative irrigation methods, is a critical determinant of CI. In India, CI has progressively increased from 123.1% in 1980–81 to 152.7% in 2020–21 (DES, 2021).

There exists a sizable literature that deals with the determinants of agricultural productivity and which factors have greater influence on productivity. The study of Dayal (1984) measured and mapped India's productivity patterns using three agricultural productivity indexes. Regression analysis evidence demonstrates that the regional heterogeneity in agricultural production correlates favourably with fertilizer and irrigation usage, while exhibiting a negative correlation with population density. In another study Dholakia and Dholakia (1992) examined the sources of growth in Indian agriculture throughout three sub-periods, from 1950–1951 to 1988–1989. They conducted a total factor productivity (TFP) analysis using the growth accounting approach. The study showed that contemporary agricultural inputs such as fertilizer, high-yielding variety seeds, and irrigation influenced Total Factor Productivity (TFP). Rosegrant and Evenson (1995) assessed the rates of return on public investment in agriculture and investigated the sources of productivity growth. The study reveals that allocating investments towards irrigation, extension, and market activities yields a favourable effect on total factor productivity. The study of Hussain and Ishfaq (1997) assess the influence of several factors on agricultural productivity. The independent factors included cropped area, fertilizer, irrigation, labour force, total number of tractors supplied, and total amount of credit disbursed. They found that cropped area and fertilizer were the only major factors influencing agricultural economic growth. The study conducted by Roy and Pal (2002) demonstrates that the enhancement of agricultural productivity significantly contributes to the reduction of rural poverty in India. A major contributing element to this decrease in poverty was identified as rural literacy. In another study Ghosh and Kuri (2007) identified yield growth as the primary factor contributing to significant growth in output in the state of WB throughout the 1980s. Authors have asserted that the significant increase in crop production and economic output during the 1980s was mainly due to the combined impact of institutional reforms, such as land reforms, and technological elements, including high-yielding variety (HYV) seeds, irrigation, and fertilizer. Prabha et al. (2009) studied the relationship between the composite infrastructure index (CII) and technical variables, such as fertilizer and high-yielding varieties on agricultural production in UP. The analysis indicates that agricultural production in UP had substantial growth during the Green Revolution. The research demonstrated a positive and significant influence of the CII, fertilizers, and high-yielding varieties on agricultural production. According to Dhingra, I. C. (2010) improvements in seed varieties are crucial for enhancing agricultural output. In the absence of high-quality seeds of appropriate varieties, the farmer is unable to fully utilise other resources, like irrigation, fertilisers, pesticides, and machinery. High yields and good economic returns from HYV seed use enable farmers to adopt intensive agriculture. The study of Anjani Kumar and Rajni Jain (2013) conducted an analysis of the expansion and instability in the agricultural sector of India. Agricultural productivity exhibits significant variability both at the state and national levels. The study further demonstrated that modern inputs, including fertilizers, rainfall, irrigation, human resources, and transportation, significantly enhance the yield of the crop sector.

In another study of Falguni Pattanaik, F. P., & Sarbeswar Mohanty, S. M. (2016) have investigated the influence of macroeconomic factors on the growth of area, production and yield in Odisha agriculture by using OLS estimation. The coefficients of macroeconomic factors, i.e., fertilizer consumption, cropping intensity, rainfall, GIA, gross cropped area and literacy rate on growth of yield of major crops are positive and significant. In another study Das, A., & Kumar, S. (2018) have examined the impact of various factors on growth in area, production and yield of rice in WB. Regarding yield, they found that the coefficients of cropping intensity, fertilizer consumption and literacy were both positive and significant. Kundu & Goswamy (2019) examined the trends of yield rate of major crops (both food and cash crops) of West Bengal along with the identification of major factors influencing the average yield rate. They found that the yield rate is significantly and positively influenced by agricultural credit, IRR and cropping intensity. Ghosh, B. C., & Kuri, P. K. (2024) investigate the growth and instability of yield of the major principal crops across different districts of WB during 1995-2019 and identify the possible factors that can affect the average yield rate in West Bengal over the study period by using panel data fixed effect regression model. Their findings indicate that cropping intensity, rainfall, agricultural wages, fertilizer consumption and IRR play a positive role in raising the average yield rate in agricultural production.

## RATIONALE OF THE STUDY

The aforementioned literature indicates that most of the studies have focused on state level without having the study at national levels. From the survey of literature, it was also found that the study has only been conducted for a short period of time. This study examines the SR and LR relationships in India over a longer time and aims to address a gap in the literature.

## OBJECTIVE OF THE STUDY

The main objective of this study is to examine both SR and LR effects of various agricultural determinants on the yield rate of total rice in India during 1996 -2021.

## DATA AND METHODOLOGY

To investigate the impact of several factors on the overall rice yield rate in India, we utilized data from the RBI for the period 1996-2021. Several editions released by theMoa and Farmers Welfare (GoI), DES, and Agriculture Census are other data sources. The descriptions of all the determinants are as follows:

### A. Yield of Rice

Yield is nothing but the production of per unit of area. The growth rates in yield generally determine the overall performance of an agrarian economy (Bhattacharya and Bhattacharya, 2007). Now the question may arise what are the possible factors that can affect the enhancement of yield rate in Indian agriculture.

### B. Cropping Intensity

Cropping intensity is conventionally defined as the ratio of gross cropped to net cropped area in a given crop year, multiplied by 100.

### C. Irrigation

Irrigation is another vital agricultural determinant in developing countries like India. Rainfall provides the natural water supply for agriculture. Rainfall, however, is the most irregular, with significant regional changes as well as annual variations in its quantity and duration. As a result, the only solution to the water scarcity problem is artificial water supply through irrigation. In our study, irrigation measure as a percentage of GIA to Total Cropped Area (IRR).

**D. Fertiliser consumption**

The use of fertiliser has an important role for increasing agricultural output. Application of fertilizer significantly enhances the levels of natural soil nutrients, leading to an increase in per acre productivity. Excessive usage of fertilizers can lead to decreased crop yield. Proper use of fertilizer results in highest output per acre. In our study fertiliser consumption per hectare of GCA is the composition of three chemical fertilisers i.e., nitrogen (N), phosphate (P) and potash (K).

There is a strong relationship between yield rate and agricultural determinants. Increasing the area under cultivation and introducing improved technology can enhance agricultural production. Technology plays a crucial role in determining the availability of water and fertilizer. Sufficient use of fertilizer could provide the necessary nutrients for crop growth and directly enhance agricultural yields. Irrigation significantly contributes to agricultural production. If a significant portion of the cultivable land in a region is irrigated, it typically opens up the possibility for multiple cropping in that area. This is because it encourages firms to engage in cultivation during the post-rainy season. This may increase the agricultural yield rate.

## METHODOLOGY

**A. Augmented Dicky-Fuller (ADF) Test**

While performing a time series analysis, the concepts of stationarity and unit root are very important because spurious regression occurs mainly due to the non-stationary in the time series data. Therefore, to avoid the problem of spurious regression, the stationary of the time series data is assessed by a unit root test. Given that we possess 26 data points, the examination of both LR and SR impacts of various factors on the yield rate of total rice must be preceded by evaluating the stationarity of all variables (dependent and independent). For a data set ($y_t$ = 1, 2, ..., T), where t represents time, we will examine the following linear regression framework for the unit root test of the ADF (p) (1979) regression.

$$\Delta y_t = \mu + \varsigma_t + \gamma y_{t-1} + \sum_{i=1}^{p} \zeta_i \Delta y_{t-1} + \varepsilon_t \quad \text{...... (1)}$$

The null hypothesis is that

$H_0 : \gamma = 0$ i.e., there is unit root and the time series data is non-stationary. Against the alternative hypothesis is

$H_1 : \gamma < 0$ i.e., the time series data is stationary

**B. Cointegration and Vector Error Correction Mechanism (VECM)**

We have examined the LR connection among variables using the Johansen and Juselius (1990) cointegration approach and the SR dynamics using the Vector Error Correction Mechanism (VECM). The prerequisite for ascertaining the number of cointegrating relationships is that all variables must be I(1). The multivariate cointegration model proposed by Johansen and Juselius (1990) is expressed as follows:

$$\Delta y_t = \beta_0 + \prod y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + \varepsilon_t \quad \text{............ (2)}$$

Where $\prod$ and $\Gamma_i$ are coefficient matrices and p is the lag order. The Johansen cointegration test comprises two distinct statistical tests: namely the Trace test and the Maximum Eigenvalue test. These tests ascertain the rank of the cointegration vector, which subsequently reveals the number of existing cointegrating relationships. These tests may be calculated as follows:

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \quad \text{............... (3)}$$

$$J_{\max} = -T \ln(1 - \hat{\lambda}_{r+1}) \quad \text{................. (4)}$$

Where $\hat{\lambda}$ is the expected eigenvalue of the characteristic roots and T is the sample size.

If one or more cointegration relationships exist among variables, then we use the VECM. The regression equation for the VECM can be expressed as follows:

$$\Delta y_t = \mu_1 + \theta_1 ECT_{t-1} + \sum_{i=1}^{n} \beta_i \Delta y_{t-i} + \sum_{i=1}^{n} \delta_i \Delta FERT_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta CI_{t-i} + \sum_{i=1}^{n} \lambda_i \Delta IRR_{t-i} + \varepsilon_{1t}$$

*...... (5)*

Where $\beta_i$, $\delta_i$, $\gamma_i$ & $\lambda_i$ are the short run coefficients. The dependant variable $y$ determine the yield rate of total rice and FERT, CI & IRR represents fertilizer consumption, cropping intensity and percentage of GIA to total cropped area respectively. $ECT_{t-1}$ is the error correction term (ECT). The coefficient of ECT ($\theta_1$) gives the speed of adjustment of the variables to its LR equilibrium. A negative and significant coefficient of ECT indicates the presence of LR causality among the variables.

## ANALYSIS OF RESULTS

The yield rate of total rice in India can be affected by the following factors (1) Fertilizer consumption (FERT) (Per hectare of GCA) (2) Cropping Intensity (CI) (3) Percentage of GIA to Total Cropped Area (IRR).

The following model can be specified to examine the impact of various factors on the yield rate of total Rice in Indian agriculture. We transform all the variables into Logarithmic.

LogYield = $f$ (LogFERT, LogCI and LogIRR)

Prior to conducting the quantitative evaluation of our hypothesis on the SR and LR impacts of numerous agricultural factors on the overall rice yield rate in India, we will first present a graphical representation of the logarithmic values of all variables. Figures 1 to 4 respectively display the charts for LogYield, LogFert, LogCI and LogIRR in India for the study period. Figure 1 indicates that the LogYield series exhibits an upward trend over time. From 1996 to 2021 logarithmic values of yield increased from 7.5 to 7.9. The highest logarithmic value of yield was found in 2020. In the case of fertilizer consumption, the logarithmic values of fertilizer (Figure 2) have shown an increasing trend up to 2011. Compared to 2011, the logarithmic value of fertilizer has decreased slightly in 2021 Figure 3 illustrates that the LogCI series has an increase trend over time. The highest LogCI found in 2020 and the lowest in 2001. From Figure 4, we have observed that the logarithmic values of IRR are of increasing trend.

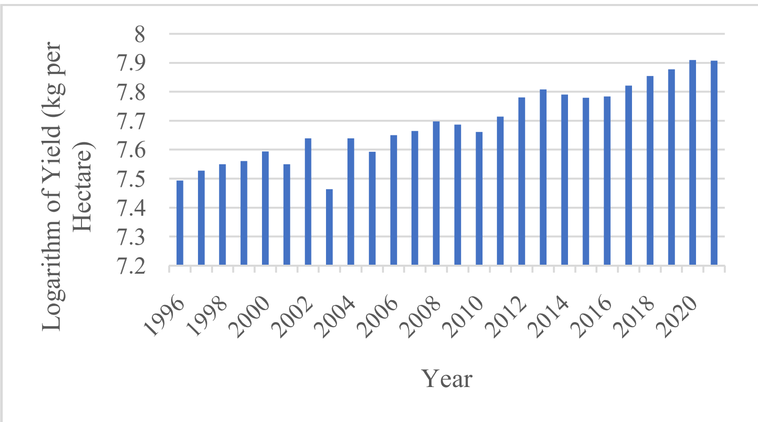


**Figure 1: Series for LogYield**

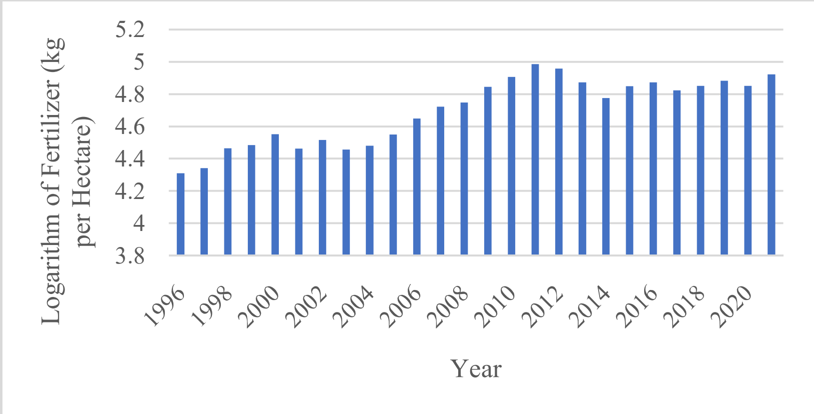


**Figure 2: Series for LogFertilizer**

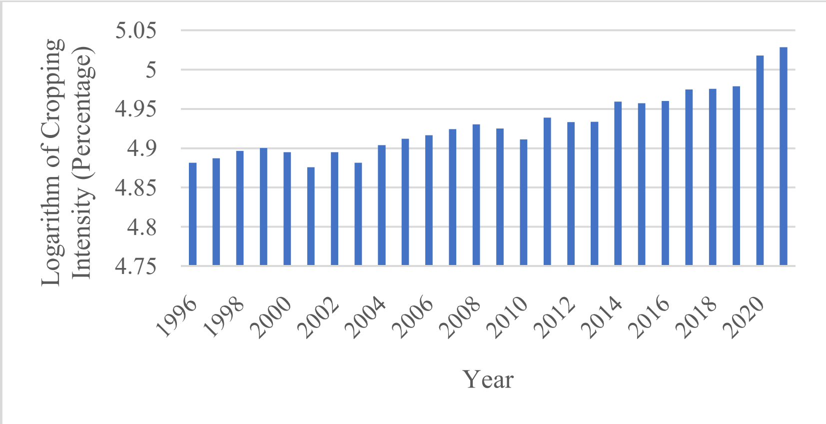


**Figure 3: Series for LogCI**

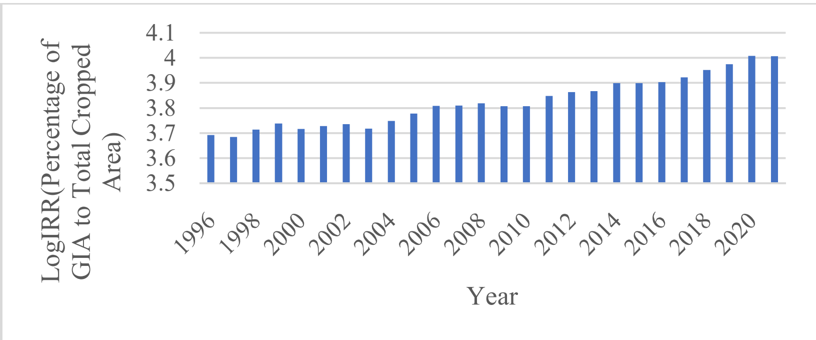


**Figure 4: Series for LogIRR**

## UNIT ROOT TEST RESULTS

We have calculated ADF test statistics for the logyield, logfertilizer, logci, and logirr series by estimating equation (1). The findings are shown in Table 1. All variables have been shown to be non-stationary at level and exhibit unit root issues. All the series are stationary at first difference.

**Table 1: Unit root test result for logyield, logfertilizer logci, and logirr**

| Variables | ADF | | ADF | | Remarks |
|---|---|---|---|---|---|
| | Level | Prob | First Difference | Prob | |
| LOGYIELD | -0.045 | 0.945 | -10.972 | 0.000 | S |
| LOGFERT | -1.614 | 0.460 | -4.229 | 0.003 | S |
| LOGCI | 1.496 | 0.998 | -6.184 | 0.000 | S |
| LOGIRR | 2.539 | 0.999 | -5.139 | 0.000 | S |

Source: Computed by the authors

From the results of unit root tests for logyield, logfert logci, and logirr series we find that all the series are stationary at first differences and the variables are integrated of the same order i.e., I(1) . We have, therefore, run the Johansen and Juselius (1990) cointegration test by estimating equation (2), (3) and (4) as there are the possibilities of LR equilibrium relations among the variables. Before conducting the Johansen-Juselius Cointegration test, the lag length has to be determined. Table no. 2 reported the result of the most favourable lag Selection. The finding of this analysis indicates that the most favourable lag order is 1.

**Table 2: VAR Lag Order Selection Criteria**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 172.1897 | NA | 9.62e-12 | -14.01581 | -13.81946 | -13.96372 |
| 1 | 240.1787 | 107.6494* | 1.30e-13 | -18.34823 | -17.36652* | -18.08778* |
| 2 | 257.7163 | 21.92195 | 1.30e-13 | -18.47636* | -16.70928 | -18.00755 |

***** denote lag order selection by the criterion

Source: Computed by the authors

**Table 3: Johansen and Juselius Cointegration Test**

| Hypothesized Number of Cointegrations | Trace statistics | 0.05 critical value | Prob** | Max-Eigan Statistics | 0.05 critical value | Prob** |
|---|---|---|---|---|---|---|
| None | 64.85 | 47.85 | 0.0006 | 45.69 | 27.58 | 0.0001 |
| At most 1 | 19.15 | 29.79 | 0.4819 | 14.07 | 21.13 | 0.3586 |
| At most 2 | 5.07 | 15.49 | 0.8007 | 5.00 | 14.26 | 0.7418 |
| At most 3 | 0.07 | 3.84 | 0.7827 | 0.07 | 3.84 | 0.7827 |

Trace statistics test and Max-eigenvalue test indicates 1 cointegrating equation at the 0.05 level

**Mackinnon-Haug-Michelis (1999) p-values

Source: Computed by the authors

The findings of the Johansen-Juselius Cointegration test are presented in Table 3. Table 3 reveals that both the Trace test and the Max-eigenvalue test suggest the presence of a single cointegration equation. When the variables exhibit cointegration or a LR connection, the VECM can be employed. The outcomes of vector error corrections for both LR and SR analyses are displayed in Tables 4 and 5. Table 4 reveals that the coefficient of the ECT, with logYield as the dependent variable, is negative and statistically significant, showing a convergence from SR dynamics to LR equilibrium.

**Table 4: Error Correction Estimation**

| | D(LYIELD) | D(LFERT) | D(LCI) | D(LIRR) |
|---|---|---|---|---|
| CointEq1 | -1.816551<br>(0.31955)<br>[-5.68471] | -1.226745<br>(0.77664)<br>[-1.57954] | 0.033831<br>(0.16837)<br>[0.20093] | -0.042658<br>(0.23778)<br>[-0.17940] |

Note: Dependent variable is D(LYIELD); Standard errors in ( ) & t-statistics in [ ]

Source: Computed by the authors

**Table 5: VECM Estimation for SR Analysis**

| | D(LYIELD) | D(LFERT) | D(LCI) | D(LIRR) |
|---|---|---|---|---|
| D(LYIELD(-1)) | 0.275900<br>(0.19998)<br>[1.37962] | 0.241559<br>(0.48604)<br>[0.49699] | -0.052801<br>(0.10537)<br>[-0.50109] | 0.000879<br>(0.14881)<br>[0.00591] |
| D(LFERT(-1)) | -0.473175<br>(0.11454)<br>[-4.13108] | -0.089250<br>(0.27838)<br>[-0.32060] | -0.052646<br>(0.06035)<br>[-0.87232] | -0.017203<br>(0.08523)<br>[-0.20184] |
| D(LCI(-1)) | -2.851195<br>(0.58328)<br>[-4.88817] | -0.245676<br>(1.41763)<br>[-0.17330] | -0.373955<br>(0.30734)<br>[-1.21676] | -0.314646<br>(0.43403)<br>[-0.72494] |
| D(LIRR(-1)) | 1.000340<br>(0.40866)<br>[2.44785] | 0.580932<br>(0.99322)<br>[0.58490] | 0.267919<br>(0.21533)<br>[1.24425] | 0.077757<br>(0.30409)<br>[0.25570] |
| Constant | 0.024739<br>(0.00708)<br>[3.49260] | 0.015741<br>(0.01722)<br>[0.91433] | 0.006577<br>(0.00373)<br>[1.76219] | 0.014562<br>(0.00527)<br>[2.76273] |

Note: Standard errors in ( ) & t-statistics in [ ]

Source: Computed by the authors using Eviews

To know the impact of various factors on the yield rate of rice, one must know the probabilities values. So, for probabilities values we generate system equations through Eviews and then estimate equations by applying least square method. The system equation is as follows:

D(LYIELD) = C(1)*(LYIELD(-1) – 0.1166434449637*LFERT(-1) -1.62462729725*LCI(-1) – 0.410028961562*LIRR(-1) +2.43144449176) + C(2)*D(LYIELD(-1)) + C(3)*D(LFERT(-1)) + C(4)*D(LCI(-1)) + C(5)*D(LIRR(-1)) + C(6)

**Table 6: VEC Equation Estimation**

| | Coefficient | Standard Error | t- statistic | Prob. |
|---|---|---|---|---|
| C(1) | -1.816551 | 0.319550 | -5.684709 | 0.0000 |
| C(2) | 0.275900 | 0.199983 | 1.379620 | 0.1846 |
| C(3) | -0.473175 | 0.114540 | -4.131081 | 0.0006 |
| C(4) | -2.851195 | 0.583285 | -4.888169 | 0.0001 |
| C(5) | 1.000340 | 0.408660 | 2.447853 | 0.0249 |
| C(6) | 0.024739 | 0.007083 | 3.492599 | 0.0026 |

Note: Dependent variable is D(LYIELD)

Source: Computed by the authors

Table 6 indicates that C(1) represents the coefficient of the cointegrated model (LR) with logyield as the predictand variable, whereas C(2), C(3), C(4), and C(5) denote the SR coefficients. C(1) is referred to as the error correction term (ECT) or the speed of adjustment towards LR equilibrium. The negative and significant coefficient of C(1) at the 5% level (refer to table 6) indicates that there is LR causality from FERT, CI, and IRR to YIELD, suggesting that these explanatory factors significantly influence the yield rate of total rice.

**Table 7: Result of Wald Test**

| Null Hypothesis | Prob. Chi-square | Decision |
|---|---|---|
| C(3) = 0 | 0.0000* | Rejected |
| C(4) = 0 | 0.0000* | Rejected |
| C(5) = 0 | 0.0144* | Rejected |

Note: C(3), C(4) & C(5) are the coefficients of LFERT, LCI and LIRR respectively.

*Represent significant at 5% level

Source: Computed by the authors

In the subsequent phase, we analysed the SR association among the variables. To achieve this objective, we conducted a Wald test. The outcome of the Wald test is presented in Table 7. The Wald test findings indicate the rejection of the null hypothesis at the 5% significance level for C(3), C(4), and C(5). This indicates that there exists SR causation from FERT, CI, and IRR to YIELD; hence, these factors significantly influence the yield rate of total rice in the SR.

**Table 8: Diagnostic Checking**

| Statistics | F stat. (prob.) |
|---|---|
| Serial Correlation | 0.1895 (0.82) |
| Heteroscedasticity Test | 1.60 (22.65) |
| Normality Test (Jarque-Bera) | 0.20 (0.90) |
| Adjusted $R^2$ | 0.82 |
| F-Statistics | 22.61 (0.000) |

Note: Dependent variable is D(LYIELD); Probability value in parenthesis ( )

Source: Computed by the authors

The outcome of the residual analysis is displayed in Table 8. Table 8 indicates that the residuals exhibit no serial correlation, no heteroscedasticity, and are normally distributed, since all probability values above 0.05, so allowing us to accept the null hypothesis. The $\overline{R}^2$ is 0.82, indicating that 82% of the variation in the predictand variable is accounted for by the variance in the explanatory factors. The F value (22.61) for the overall goodness of fit of the regression model is highly significant.

## CONCLUSION

This study investigates the LR and SR effects of various agricultural factors on the total rice output in India from 1996 to 2021 utilising the Johansen-Juselius cointegration test and the VECM. The ADF test indicated that all series exhibit non-stationarity at levels and stationarity at the first difference. The analysis identified long-term correlations among variables, with a speed of adjustment towards equilibrium of -1.817. The VECM indicates that SR causality running from FERT, CI, and IRR to YIELD, meaning that all factors significantly influence the yield rate of total rice in the SR. The government should take the initiative to increase expenditure on key inputs such as fertilizer and irrigation, as well as encourage private investment in the agricultural sector to effectively improve the long-term yield rate of rice.

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