INTERNATIONAL JOURNAL FOR INNOVATIVE RESEARCH IN MULTIDISCIPLINARY FIELD
ISSN(O): 2455-0620 [Impact Factor: 9.47]
Monthly, Peer-Reviewed, Refereed, Indexed Journal with IC Value : 86.87
Volume - 10, Issue - 10, October - 2024

DOIs:10.2015/IJIRMF/202410018 --:-- Research Paper / Article / Review

Long Run Relations and Short Run Dynamics between Agricultural Determinants and Yield Rate of Rice Production: A Panel Data Analysis across Major States of India

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Abstract: *The main objective of this study is to examine the both SR and LR effects of various agricultural determinants on the yield rate of rice across major states in India over the period 1996 -2021. In order to do this, the study applied the panel unit root test, Pedroni panel cointegration test and VECM. The Pedroni cointegration results confirm the presence of cointegration between all the determinants and yield rate of rice i.e., there is a LR association between the variables. The VECM reveals that there exists a LR causality among the study variables. The present study suggests that the government should take the initiative to increase expenditure on key inputs such as fertilizer and irrigation. The study also suggested ensuring timely supply of adequate quantities of quality inputs and encouraging private investment in the agricultural sector to effectively improve the long-term yield rate of rice.*

Key Words: *Panel Unit Root, Vectorerror correction Model, rice, agricultural crédit etc.*

1. INTRODUCTION:

Agriculture is a pivotal sector of the Indian economy due to its critical role in food security, employment creation, and alleviating poverty. The majority of India's population resides in rural region and derives their income predominantly from agriculture. Approximately 65% of India's population inhabits rural areas, and 45.76% of the overall workforce was employed in agriculture and related sectors during 2022-23 (Periodic Labour Force Survey Reports, 2022-23). Furthermore, the agricultural and related sector accounted for around 18.4% of India's GVA at current prices during the same timeframe (Ministry of agricultural and Farmers' Welfare, GOI, 2022-23). Agriculture is fundamentally linked to food and nutritional security (IFPRI, 2015), and the expansion of this sector 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. Enhancing agricultural productivity or yield is essential for economic growth and development. This can be accomplished through the utilisation of advanced agricultural technology, enhanced quality seed, fertilisers, and irrigation, public investments in agriculture, the establishment of an incentive framework comprising remunerative prices for select crops and subsidies on agricultural inputs, and the augmentation of agricultural credit accessibility for farmers. One of the essential inputs in agriculture is credit. It provides funding for farmers to make new investments or implement new technology. The present policy framework prioritises the increase of agricultural productivity to improve the well-being of farmers (Chand, 2017)

2. REVIEWOF LITERATURE:

There exists a sizable literature that deals with the determinants of agricultural productivity or yield and which factors have greater influence on yield. The study of Hussain and Ishfaq (1997) assess the influence of various factors on yield or agricultural productivity. The independent variables included cropped area, fertilizer, irrigation, labour force, total number of tractors supplied, and total amount of credit disbursed. The study revealed that cropped area and fertilizer were the only major factors influencing agricultural economic growth. Joshi et al. (2006) investigates the factors contributing to the growth in Indian agriculture through the 1980s and 1990s. The research indicates that, at the national level, technological advancements (yield increases) were the primary driver of development in the 1980s, but escalating prices and diversification were the principal sources of agricultural growth in the 1990s. In another study, Dhingra, I. C. (2010) asserts that enhancements in varieties of seeds are essential for augmenting agricultural productivity. Lacking high-quality seeds of appropriate varieties, the farmer is unable to effectively harness other resources such as irrigation, fertilizers, herbicides, and machinery. The high yields and favourable economic returns resulting from HYV seed usage encourage farmers to adopt intensive agriculture. According to Kumar et al. (2010), agricultural credit plays a crucial role in encouraging the growth and development of the agricultural sector in India. The availability of credit and financial services can help farmers make investments in technology, improve productivity, and manage risks associated with farming activities. In another study, Ahmad and Heng (2012) investigated the impact of several variables on the increase of agricultural total factor productivity in Pakistan. The analysis indicates that farmers' educational attainment, fertilizer utilization, and access to agricultural credit significantly and positively impact productivity growth.

The study of Anjani Kumar and Rajni Jain (2013) investigated the growth and instability in the agricultural sector of India. The level of agricultural productivity varies significantly at both the state and national levels. The study also revealed that modern inputs like fertilizers, precipitation, irrigation, human resources, and transportation significantly enhance the crop sector's yield. Birthal et al. (2014) determined that, at the national level, technology, evidenced by increased crop yields and diversity, constitutes the primary drivers of agricultural growth, whereas the contributions from area and pricing are small and inconsistent. Falguni Pattanaik, F. P., &Sarbeswar Mohanty, S. M. (2016) investigated the influence of macroeconomic factors on the growth of area, production, and yield in Odisha agriculture by employing OLS estimation. The coefficients of macroeconomic variables, including fertilizer consumption, cropping intensity, rainfall, GIA, GCA, and LR, had positive and statistically significant effects on major crops' yield growth. In another study of Das, A., & Kumar, S. (2018) investigated the influence of various factors on growth in area, production and yield of rice in WB. Regarding yield, they found that the coefficients of CI, fertilizer consumption and literacy were both positive and statistically significant. Kundu & Goswamy (2019) conducted an analysis of the yield rate trends of major crops in WB, encompassing both food and cash crops. They also identified the major factors influencing the average yield rate. The study revealed that the yield rate is significantly and positively influenced by agricultural credit, IRR and cropping intensity.

3. RATIONAL OF THE STUDY:

The survey of the literature indicates that most of the studies have focused on district level without having the study at state level as well as at the national level. Additionally, the existing studies do not focus on the determinants of yield or agricultural productivity by using panel cointegration test and VECM for the LR relations and SR dynamics. This study seeks to bridge the current knowledge gap in this domain.

4. OBJECTIVE OF THE STUDY:

This study aims to examine the short-run and long-run impacts of various agricultural determinants on the yield rate of rice across major states of India from 1996–2021.

5. DATA AND METHODOLOGY:

To examine the effects of various factors on the yield rate of rice across major states of India, we have used the RBI data for the study period 1996-2021. Various issues published by the MoA and Farmers Welfare (GOI), Directorate of Economics & Statistics and Agriculture Census are other data sources. The following factors are taken into account for analysis in this study.

Yield of Rice
Yield (kg/per hectare) is calculated by the production per unit of area.

Irrigation
Irrigation is another vital agricultural determinant in India. In our study irrigation measure as a Percentage of Gross Irrigated Area (GIA) to Total Cropped Area (IRR).

Fertiliser consumption
The use of fertiliser has a crucial role in enhancing agricultural productivity. In our study, fertiliser usage (per hectare of gross cropped area) comprises three chemical fertilisers: nitrogen (N), phosphate (P), and potash (K).

Agricultural Credit

The other possible factor that can influence yield rate in agriculture is agricultural credit. We measured agricultural credit in rupees per hectare of gross cropped area.

Methodology

Panel Unit root test Approach:

When panel data comprises n cross-sections and m time points, conducting individual unit root tests may encounter power issues, resulting in spurious regression outcomes. To solve this issue and provide more powerful findings, use a panel unit root test.

Levin and Lin (1993) and Levin, Lin, and Chu (2002) proposed methodologies for testing panel unit roots with homogeneous coefficients (β_is) across all panel units, while Im, Pesaran, and Shin (2003), along with the ADF–Fisher Chi-square and PP–Fisher Chi-square methods by Maddala and Wu (1999) and Choi (2001), addressed the scenario of heterogeneous coefficients across individual units. The theories put out by Levin and Lin (1993) and Levin et al. (2002) are encapsulated in equation (1), where β_is = β.

$$\Delta k_{i,t} = \beta k_{i,t-1} + \sum_{l=1}^{p} \varphi_l \Delta k_{i,t-l} + z'_{i,t}\delta + u_{i,t} \quad \ldots\ldots\ldots\ldots (1)$$

According to Fischer's recommendation, the test statistic introduced by Maddala and Wu (1999) is structured as follows.

$$\chi^2 = -2\sum_{i=1}^{N} (\log p_i) \quad \ldots\ldots\ldots\ldots (2)$$

If the panel unit root test reveals that all series are I(1) (i.e., integrated of the same order), we may subsequently test for cointegration among the series to determine LR relationships. If cointegration is identified, we then implement the VECM. If the VECM yields usual sign and statistically significant outcomes, we may conclude that there exists LR causality running from FERT, IRR, and Credit to yield of rice.

Panel Cointegration Test and Vector Error Correction Model (VECM)

Pedroni (1999; 2004) introduced a methodology for assessing the null hypothesis of no cointegration in dynamic panels with multiple regressors. The heterogeneous panel cointegration test developed by Pedroni (1999; 2004) accommodates cross-sectional interdependency with varying individual effects. To estimate the regression residuals from the proposed cointegrating regression, Pedroni (1999) introduced following equation:

$$y_{it} = \mu_i + \zeta_i t + \psi_{1i,} k_{1i,z} + \psi_{2i,} k_{2iz} + \ldots\ldots\ldots + \psi_{qi,} k_{qi,t} + \varepsilon_{i,t} \quad \ldots\ldots\ldots (3)$$

Where $i = 1, 2, \ldots\ldots, N$, $t = 1, 2, \ldots\ldots, T$ and $q = 1, 2, \ldots\ldots, Q$ refers to the number of regression variables. $\varepsilon_{i,t}$ indicates the estimated residual. To examine the cointegration connection within a heterogeneous panel Pedroni (1999; 2004) introduced seven distinct statistics. Among these seven statistics, four are derived from within-dimension statistics, while the other three panel cointegration statistics are based on between-dimension.

Upon confirming that the series are cointegrated according to the Pedroni approach, we will proceed to construct the panel VECM established by Pesaran et al. (1999) to evaluate Granger causality tests, which may assess both SR and LR causality. The VECM is represented by the subsequent equations.

$$\Delta yield_t = \mu_1 + \theta_1 ECT_{t-1} + \sum_{j=1}^{n} \beta_{1j} \Delta yield_{t-j} + \sum_{j=1}^{n} \xi_{1j} \Delta FERT_{t-j} + \sum_{j=1}^{n} \eta_{1j} \Delta IRR_{t-j} + \sum_{j=1}^{n} \tau_{1j} \Delta credit_{t-j} + \varepsilon_{1t} \quad \ldots\ldots\ldots\ldots (4)$$

$$\Delta FERT_t = \mu_2 + \theta_2 ECT_{t-1} + \sum_{j=1}^{n} \beta_{2j} \Delta yield_{t-j} + \sum_{j=1}^{n} \xi_{2j} \Delta FERT_{t-j} + \sum_{j=1}^{n} \eta_{2j} \Delta IRR_{t-j} + \sum_{j=1}^{n} \tau_{2j} \Delta credit_{t-j} + \varepsilon_{2t} \quad \ldots\ldots\ldots\ldots (5)$$

$$\Delta IRR_t = \mu_3 + \theta_3 ECT_{t-1} + \sum_{j=1}^{n} \beta_{3j} \Delta yield_{t-j} + \sum_{j=1}^{n} \xi_{3j} \Delta FERT_{t-j} + \sum_{j=1}^{n} \eta_{3j} \Delta IRR_{t-j} + \sum_{j=1}^{n} \tau_{3j} \Delta credit_{t-j} + \varepsilon_{3t} \quad \ldots\ldots\ldots\ldots (6)$$

$$\Delta credit_t = \mu_4 + \theta_4 ECT_{t-1} + \sum_{j=1}^{n} \beta_{4j} \Delta yield_{t-j} + \sum_{j=1}^{n} \xi_{4j} \Delta FERT_{t-j} + \sum_{j=1}^{n} \eta_{4j} \Delta IRR_{t-j} + \sum_{j=1}^{n} \tau_{4j} \Delta credit_{t-j} + \varepsilon_{4t} \quad \text{.............................. (7)}$$

Where β_i, ξ_i, η_i & τ_i are the short run coefficients. The dependent variable yield determines the yield rate of total rice and FERT, IRR & Credit represents fertilizer consumption, percentage of GIA to total cropped area & agricultural credit respectively. ECT_{t-1} is the error correction term (ECT). The coefficient of ECT (θ) 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.

6. ANALYSIS OF RESULTS:

The yield rate of rice can be affected by the following factors (1) Fertilizer consumption (FERT) (Per hectare of GCA) (2) IRR (3) Agricultural credit (Credit)

The following model can be specified to assess the influence of various factors on the yield rate of rice across major states of Indian agriculture. We transform all the variables into Logarithmic.

LogYield = f (LogFERT, LogIRR and LogCredit)

Before performing the quantitative assessment of our hypothesis on the SR and LR effects of key agricultural factors on rice yield rates across major Indian states, we need first examine a graphical representation of the logarithmic values of all variables. Figures 1 to 4 respectively, display the charts for LogYield, LogFert, LogIRR, and LogCredit across states in India for the study period. Figure 1 reveals an increasing trend in the LogYield series over time. The state of Punjab led the group before 1998. From 1998 to 2007, Kerala led the group. Panjab again leads the group after 2007. In terms of fertilizer consumption, the logarithmic values of fertilizer (Figure 2) have shown an increasing trend over the period. The state of Panjab leads the group for the entire period. In the case of IRR, the logarithmic values of IRR (Figure 3) have shown an increasing trend over the time period. Panjab holds first place for the entire period, and Assam holds last place in terms of irrigation. Figure 4 shows that all the states' logcredit series are trending upward. Before 2011, Uttar Pradesh led the group in agricultural credit. From 2012 to 2016, the state of Tamil Nadu leads the group. From 2017 to 2020, Tamil Nadu and Uttar Pradesh coincide in the state agriculture credit, and in 2021, Tamil Nadu occupy the 1st position and Uttar Pradesh occupy the 2nd position.

Figure 1 Series for LogYield

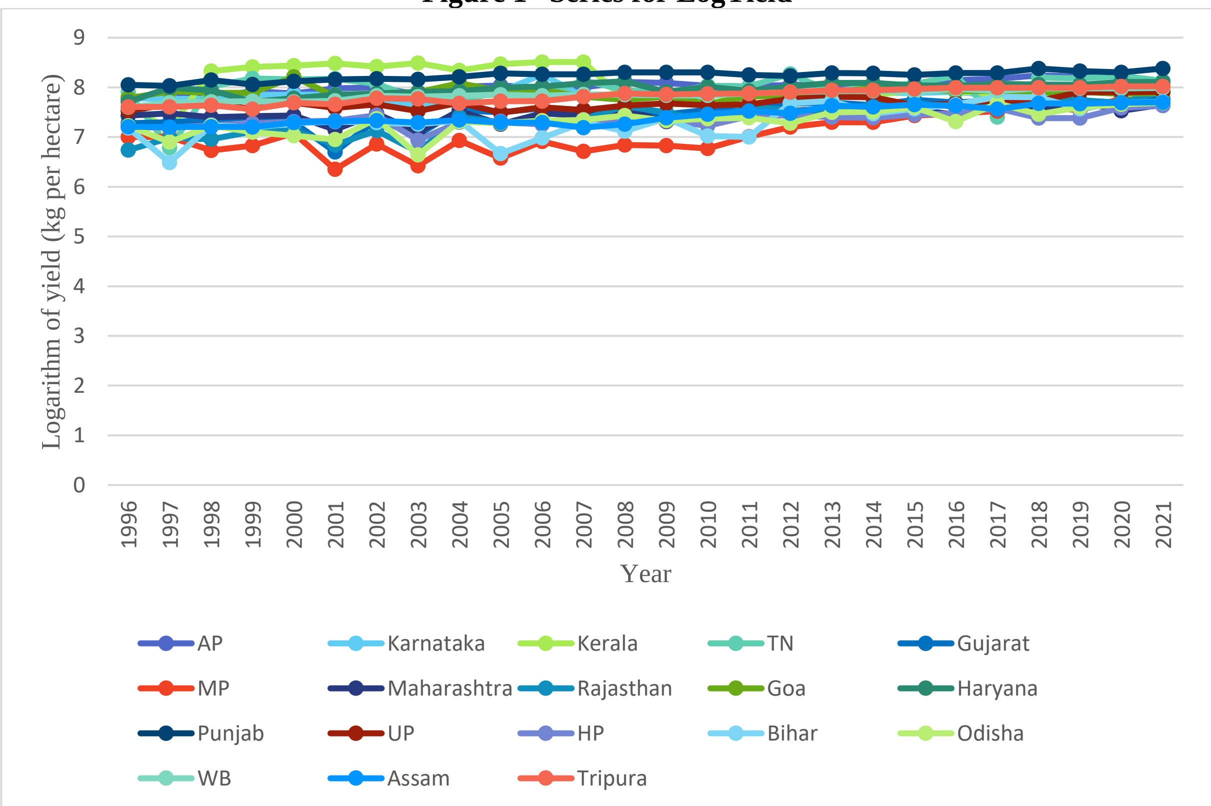


Figure 2 Series for LogFERT

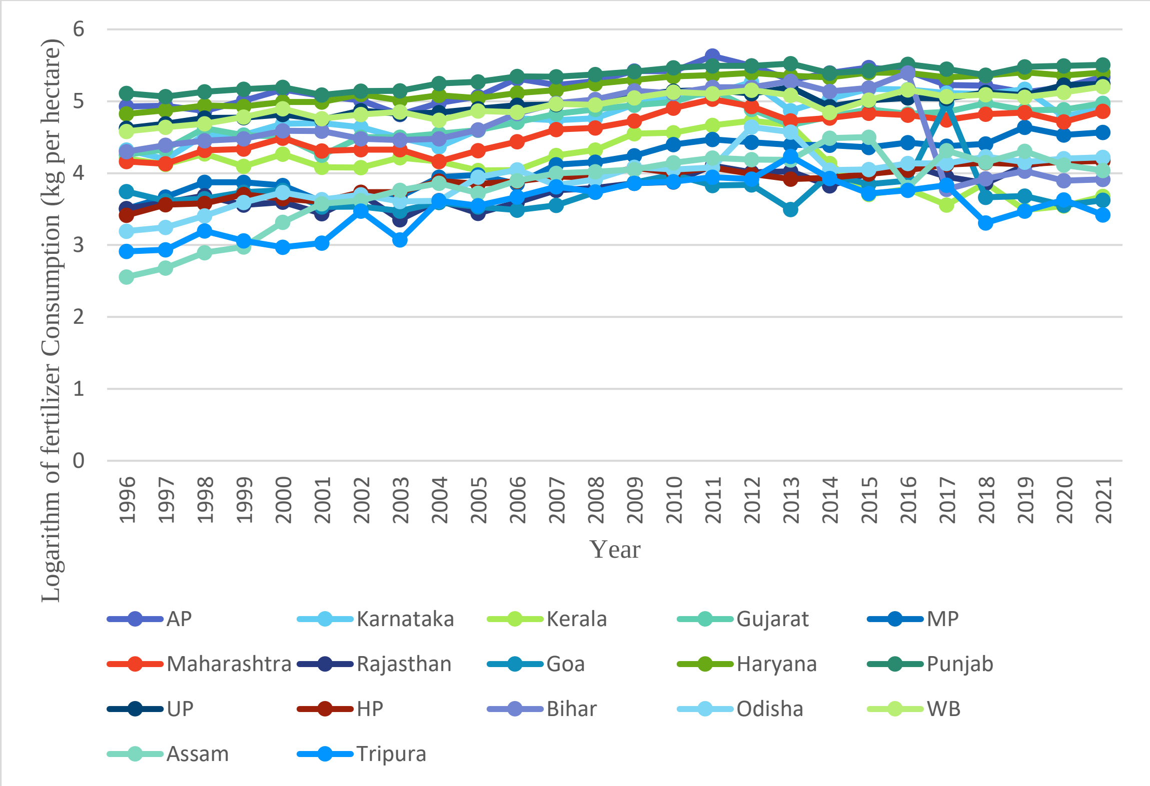


Figure 3 Series for LogIRR

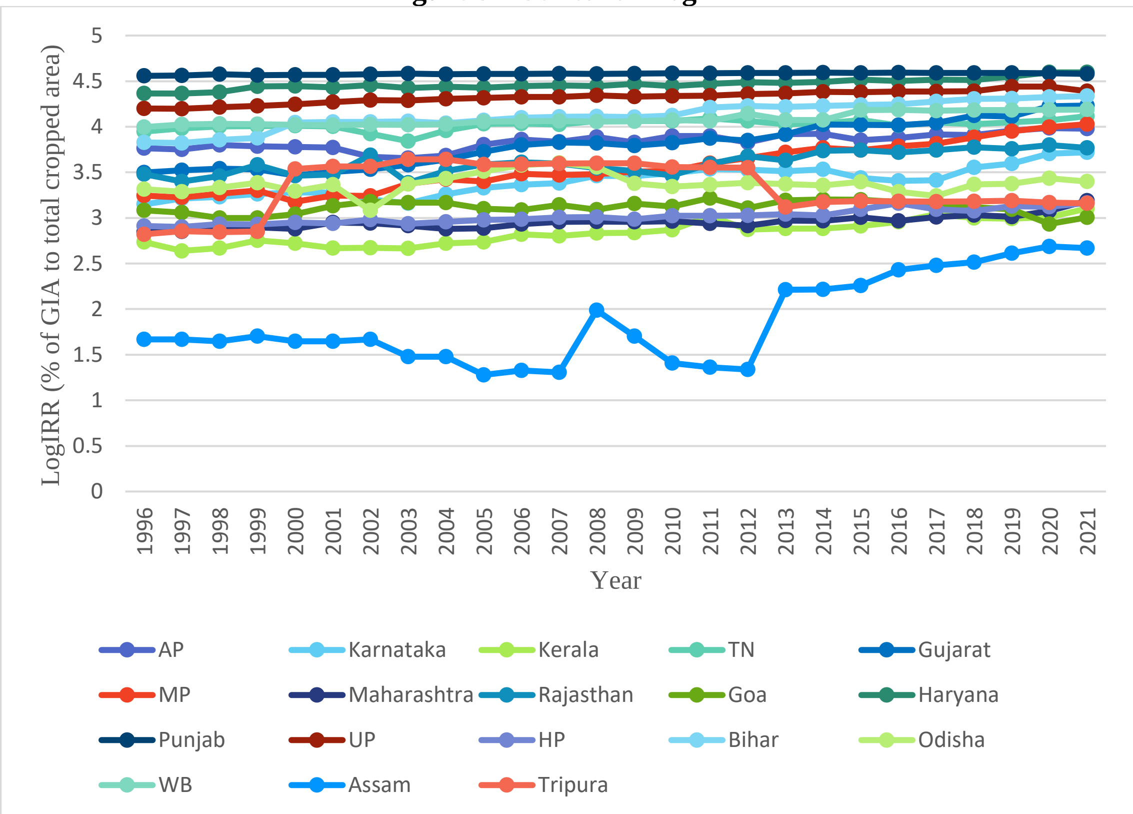
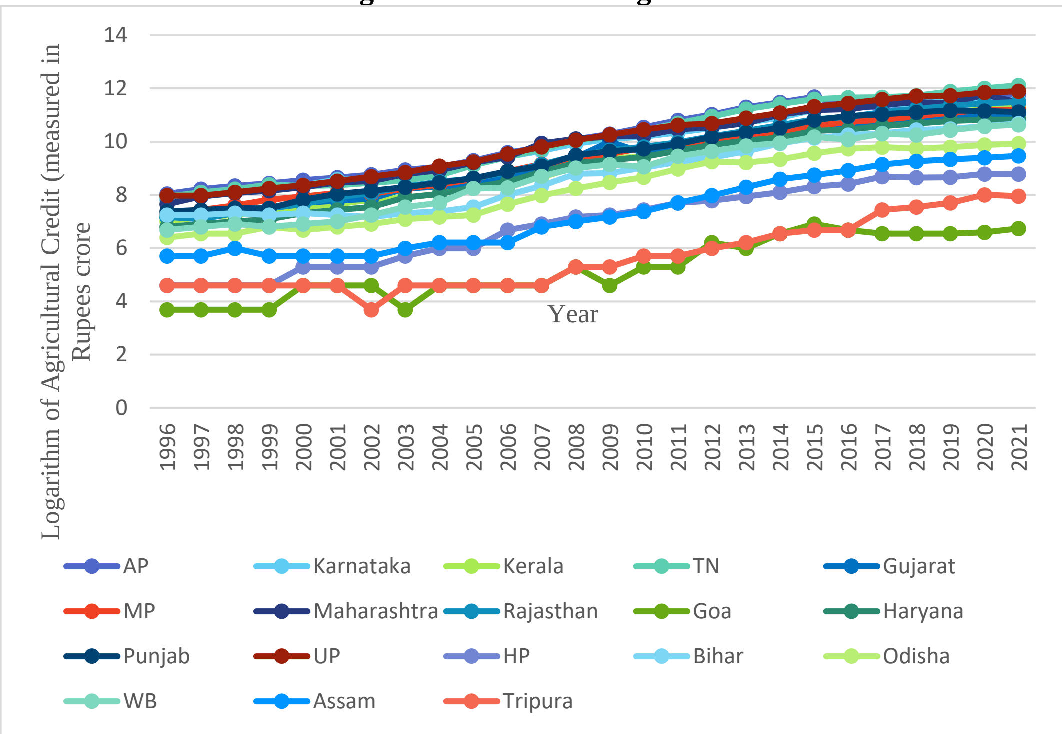


Figure 4 Series for LogCredit



Panel Unit Root Test Results

The findings of the panel unit are displayed in Table 1. All series have been shown to be non-stationary at their levels and exhibit unit root issues. Consequently, we do not provide this in the table. All the series exhibit stationarity at the first difference, indicating they are integrated of order one, I(1). Consequently, we shall proceed to the Pedroni cointegration test. It is essential to ascertain the lag duration prior to performing the cointegration test.

Table 1: Panel Unit Root Test Results

Variables	At First difference			
	Test Statistics with Intercept	Prob.	Test Statistics without Intercept	Prob.
Levin, Lin and Chu	-6.600	0.000	-18.466	0.000
LogYield	-9.035	0.000	-16.039	0.000
LogFERT	-8.143	0.000	-14.239	0.000
LogIRR	-3.842	0.000	-4.561	0.000
LogCredit				
Im, Pesaran and Shin				
LogYield	-15.919	0.000	-	-
LogFERT	-11.530	0.000	-	-
LogIRR	-11.607	0.000	-	-
LogCredit	-4.968	0.000	-	-
			-	-

MW–ADF–Fisher Chi-square	272.106	0.000	359.444	0.000
LogYield	192.421	0.000	275.369	0.000
LogFERT	195.064	0.000	245.842	0.000
LogIRR	87.633	0.000	75.885	0.000
LogCredit				
MW–PP–Fisher Chi-square	494.985	0.000	589.435	0.000
LogYield	385.749	0.000	454.894	0.000
LogFERT	328.171	0.000	389.748	0.000
LogIRR	233.824	0.000	162.138	0.000
LogCredit				

Source:Computed by the author.

Panel Cointegration Test and Error correction Test Results in a VECM set up

The panel unit test results indicate that all the series are stationary and integrate to the same order I (1). Therefore, we run the Pedroni panel cointegration (1999; 2004) test to examine the LR connection among the study variables. Table 2 presents the findings of the panel cointegration tests for both the within and between dimensions. The results of the panel cointegration test indicate that, with an intercept, most test statistics rejected the null hypothesis of no cointegration at both the 1% and 5% significance levels. In the scenario including intercept and trend, we have also observed that the majority of the test statistics rejected the null hypothesis. Thus, Table 2 confirms the presence of cointegration among the examined variables. Consequently, we can ascertain that a LR connection exists among the research variables.

Table 2: Pedroni Panel Cointegration Test Results

	With Intercept		With Intercept and Trend	
	Weighted		Weighted	
Within-dimension	Statistic (prob)	Statistic (prob)	Statistic (prob)	Statistic (prob)
Panel v-statistic	-0.191 (0.57)	-1.186 (0.88)	-2.3036 (0.98)	-3.607 (0.99)
Panel rho-statistic	-5.539 (0.00)	-5.316 (0.00)	-2.128 (0.01)	-1.728 (0.04)
Panel pp-statistic	-11.465 (0.00)	-10.779 (0.00)	-14.993 (0.00)	-13.914 (0.00)
Panel ADF-statistic	-6.718 (0.00)	-4.822 (0.00)	-7.985 (0.00)	-6.127 (0.00)
Between-dimension	Statistic (prob)		Statistic (prob)	
Group rho-statistic	-1.8807 (0.03)		-0.5366 (0.29)	
Group pp-statistic	-14.1649 (0.00)		-16.7021 (0.00)	
Group ADF-statistic	-5.3007 (0.00)		-5.2977 (0.00)	

Source: Computed by the author

If the variables are cointegrated, we can run the VECM. Table 3 displays the outcomes of vector error corrections for both LR and SR studies. The coefficient ECT in equation (4) is negative and statistically significant. It indicates that there exists LR causality from FERT, IRR, and credit to yield of rice, meaning all factors significantly influence of yield of rice, with speed of adjustment towards LR equilibrium of 8%. Besides the LR relationship among the five indicators, there needs to be testing whether there are short-run causal relations present. The SR causality tests indicate that only IRR has the SR causality running from IRR to yield rate of rice. Concerning equation (5) the sign of ECT is negative but insignificant. From the SR causality test in equation (5), we find that only IRR has SR causality running from IRR to FERT. The coefficient of the ECT in equation (6) is significant at the 5% level, indicating LR causality from yield, FERT, and credit to IRR, with a 2% speed of adjustment towards equilibrium. This indicates that all independent factors significantly affect the IRR over the LR. Regarding the SR causality of this equation, we noted that there is no SR causality from yield, FERT, and credit to IRR. Ultimately, regarding equation (7), the sign of the ECT is negative and statistically significant. This indicates a LR relationship among the studied variables, characterised by a 4% speed of adjustment towards equilibrium, whereas SR causality tests reveal a causal relationship from IRR to credit.

Table 3: VECM Results

Dependent Variables	Independent Variables					
	Δy	$\Delta FERT$	ΔIRR	$\Delta Credit$	ECT_{t-1}	Direction of Causality
Δy		3.65(0.16)	6.72(0.03) **	1.10(0.57)	-0.08 (0.00) *	$IRR \rightarrow Y$
$\Delta FERT$	2.19(0.33)		12.26(0.00) *	1.60(0.44)	-0.03(0.19)	$IRR \rightarrow FERT$
ΔIRR	3.01(0.22)	2.15(0.34)		0.73(0.69)	-0.02(0.04)**	No Causality
$\Delta Credit$	2.00(0.36)	1.25(0.53)	10.23(0.00) *		-0.04(0.00) *	$IRR \rightarrow Credit$

Source: Computed by the author.
Note: Wald Chi-square statistics reported with respect to SR changes in the independent variables. Value in () represents p-value. * & ** represent significant at 1% and 5% level respectively.

7. CONCLUSION:

The main aims of this research are to investigate whether there are LR and SR impacts of various agricultural determinants on the yield rate of rice across major states in India over the period 1996–2021. The panel unit root test finding indicate that all the variables are stationary at first difference. The derived results also show the presence of LR associations among five indicators in equation (4) (6) and (7) with speed of adjustment toward equilibrium are 8%, 2% and 4% respectively. The short-run causality test findings indicate that only the IRR exhibits short-run causality originating from yield, FERT, and credit to the IRR. The population of small and marginal farmers exhibits limited risk-taking capacity, technology uptake, and fertiliser application, leading to reduced investment and therefore low yields in agriculture. The present study suggests that the government should provide better infrastructure, such as fertilizer, agricultural credit and irrigation etc. for agricultural development in the long run. The government should take the initiative to increase expenditure on key inputs such as fertilizer and irrigation. The study also suggested improving access to credit for small and marginal farmers by simplifying procedures, ensuring timely supply of adequate quantities of quality inputs, and encouraging private investment in the agricultural sector to effectively improve the long-term yield rate of rice.

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