International Review of Management and Social Sciences (IRMSS)
Volume-1, Issue-1, November 2025
https://doi.org/10.55524/irmss.2025.1.1.7
Article ID IRP-1503, Pages 42-49
https://irmssjournal.irpublications.org/

The Impact of Cultivated Area, Fertilizer Use, and Rainfall on Pulses Production in India: Evidence from an Autoregressive Distributed Lag Model

Santanu Bhattacharya [1], and Souvik Dasgupta [2]

[1]Research Scholar, Department of Economics, Sidho-Kanho-Birsha University, Purulia, West Bengal, India
[2]Assistant Professor, Department of Economics, Sidho-Kanho-Birsha University, Purulia, West Bengal, India

Correspondence should be addressed to Santanu Bhattacharya; Santanueco789@gmail.com

Received 4 November 2025; Accepted 23 November 2025; Published 30 November 2025;

ABSTRACT- The study investigates the relationship among the total production of pulses, total production area under pulses, total use of fertilizer and total annual rainfall in India during 1950-51 to 2016-17. The result establishes the existence of long run relationship in the total production of pulses, total production area under pulses, total use of fertilizer and total annual rainfall. According to the results of the ARDL and ARDL-VECM tests, the total production of pulses from the prior year develops a major long-term influence on the total production of pulses this year. The annual rainfall of the current year significantly enhances the total output of pulses for that same year, both in the short and long term. The findings indicate that the total area of pulse production, total fertilizer usage, and yearly rainfall for the current year significantly influence the total pulse production in the short term.

KEYWORDS: Pulses Production, India, Structural Break, Zivot-Andrews test, ARDL, ARDL-VECM test, ARDL-WALD test

1. INTRODUCTION

Agriculture sector has an important contribution in India’s gross domestic product and it has registered striking growth over last few decades. The third advance projections from the Union Ministry of Agriculture and Farmers Welfare indicate that pulses accounted for around 8.82 percent of India's total food grain production in 2021-22. In India, pulses represent a significant and reasonably priced source of protein for both animal and human nutrition. According to the FAO, India accounts for 25% of the world's production, 27% of its consumption, and 14% of its imports of pulses. In 2020–21, pulses accounted for over 22% of the area under food grains, according to the Ministry of Agriculture and Farmers Welfare's Agricultural Statistics at a Glance-2021 report. However, the per capita net availability of pulses decreased from a higher level of 22.16 kg/year in 1951 to 16.4 kg/year in 2021. This is caused by increase in population and stagnation in production of pulses in India. Indeed, pulses have been in short supply for last two decades. As a result, massive imports of pulses have become a habitual feature in our country to fulfil the demand and supply gap. A peculiar situation had risen because increasing prices of pulses have not been able to encouraged farmers to increased pulses production. In India's agriculture and nutrition ecosystem, pulses have a dominant role. They also account for 11 per cent of the nation's total cropped area and 8 per cent of its total food grain production (Joshi & Saxena, 2002; Kumar et al., 2017). These crops are vital for food security (Singh, 2018) and are also sources of micronutrients such as calcium, iron, zinc, magnesium, and other vitamins (Singh, 2017). Approximately 10 per cent of the daily protein intake in rural areas and 11 per cent in urban areas comes from pulses. Given this high domestic consumption, it renders India a key importer of pulses in large quantities, alongside the imported range of shelf-stable, processed pulse-based products (Singh et al., 2015; Verma et al., 2019). With breaking of monotony of food shortage under rainfed and resource limited environment, pulses have emerged as the crops of choice which grow well under these conditions. Remarkably, around 56 per cent of the area under pulses is rainfed, which accounts for 83 per cent of the total pulses production in India (Suresh et al., 2014). Pulses have an extensive value chain with a number of actors involved namely farmers, researchers, aggregators, commission agents, wholesalers, retailers, processors and millers (Sah et al., 2014).

Against this backdrop it would be an absolute necessity to do an in-depth analysis on pulses production in India using some sophisticated econometrics tools. The present study is motivated to execute such exercise by investigating nexus between production of pulses with some other probable variables. The article's remainder is structured as follows. A brief review of pertinent literature is summarized in the next section. The research gap was emphasized in the third section, which also clarified the goals of the study. Section Four provides descriptions of the variables and data source. The study's econometric methodology and results analysis are described in the next section. Lastly, we present the conclusion.

2. LITERATURE REVIEW

In this section we will briefly review the underlying studies explaining pulses productivity, production trends and stability with focus on India. Bharathi et al. (1992) used the Coppock Instability Index to investigate the causes of Andhra Pradesh's pulse production instability between 1970–71 and 1986–87. Their analysis showed that yield instability was the main cause of production fluctuations, and that growing the cultivated area was more important for raising total output than yield increases. Mundinamani et al. (1998) examined the patterns of growth in Karnataka's pulse production, yield, and area at the district level from 1970–71 to 1984–85. They found three districts that consistently showed positive growth in all three areas, even though the growth at the state level stayed essentially unchanged. Ramaswamy and Selvaraj (2002) analyzed India's pulse, oilseed, and coarse cereal growth rates in terms of area, production, and yield. Their research showed that coarse cereal productivity growth was not statistically significant, in contrast to superior cereals. More specifically, crops like jowar and bajra showed negative growth rates in area cultivated between 1970–71 and 1999–2000, suggesting a decrease in their cultivation during this time. Sharma and Prakash (2002) studied India's major pulse production and productivity from 1950–51 to 1999–2000. The study discovered that during the pre-green revolution era, the area under total pulses stayed essentially unchanged. The growth rate of chickpea and total pulse production, as well as the area under cultivation, decreased during the post-Green Revolution era. All pulses saw an increase in productivity growth rate, with the exception of chickpeas. They also came to the conclusion that both the area and production of pulses were growing slowly and lowly. A study conducted in Punjab state by Elumalai Kannan (2011) examined the growth performance, variability, and instability of food grains and pulses from 1960–1961 to 2009–2010. The study made clear that during this time, the growth rate of pulse production fell off considerably. This study found that while variability and instability were lower in food grains, they were higher in pulses, indicating that the instability of pulse production was excessively high. Sihmar (2014) conducted a study at the district level on the development and instability of farm production in Haryana. The study included three different time periods: 1980-81 to 1989-90, 1990-91 to 1999-2000, and 2000-01 to 2006-07. Employing compound annual growth rates and the Coefficient of Variation of Deviation Index (CVDI), the research indicated that staple crops such as rice and wheat had consistently robust growth and stable production performance throughout all three periods. However, crops such as gram, lentil (massar), maize, sesamum, and groundnut had poor performance, with large negative growth rates in production. In addition, the research observed a general downward trend in pulse production, with gram witnessing the sharpest decline in both area under cultivation and production. Volatility in rice and wheat production was found to be comparatively low and followed a declining trend over time. Mech et al. (2017) had researched to study growth trends, instability, and driving factors in Assam's rice production during 1972-73 to 2014-15. The variables included were yield, area under cultivation, application of fertilizers, adoption of high-yielding varieties (HYVs), temperature, and rainfall. The results showed that the effect of all the factors, with the exception of rainfall, on rice production in the area was positive. Bisht and Kumar (2018) applied exponential growth function and Cuddy Della Valle index to calculate the growth rates and instability of five major pulses of India during 1996-97 to 2015-16. They divided the total time period into two sub-periods that were before and after NFSM. The study suggested that the growth rate of sub period-II was significantly higher than the sub period-I. The yield and area under pulses had also shown a marginal but significant growth rate of 1.19 and 0.44 percent respectively. Devegowda et al. (2018) utilized a semi-log linear model to study the growth patterns of the major pulses crops in India in the time span of 1990-2015. They analyzed changes in production and its related factors over a decade in a cyclical approach. The research pointed out that there was growth in most of the pulse crops, especially in case of total pulses which had slight growth in area, yield and production over the years. Jeevitha (2020) performed an in-depth analysis of the growth trends and the volatility of wheat cultivation in the state of Uttar Pradesh from the year 1950-51 to 2015-16. The study’s examination of area, production, and yield changes benchmarked area under wheat cultivation using the Compound Annual Growth Rate (CAGR) and instability with Coefficient of Variation (CV). It has been observed that the level of instability in the production of wheat was the highest at 73.7 per cent, followed by yield instability of 43 per cent and area instability of 32 per cent. Such findings reveal that indeed the greater fluctuations over the study period were in production rather than area or productivity. Nasim Ahmad et al. (2018) studied the growth and volatility in the cultivation of sugarcane for major producing states in India during the period from 2000-01 to 2015-16. By employing compound growth rates along with the Cuddy Della Valle index, they noted an increase at the national level in area, production, and productivity and observed a positivity trend on statewide stability in growth Gujarat, yielded equilibrium across Uttarakhand and Tamil Nadu to mark regionally stable sub-national scale dynamics respectively. Hashmi et al. (2021) examined the relationship concerning the area and yield of food grain crops in India from 1950-2018. The study verified a considerable long-term relationship which suggests that increases in the cultivated area have a strong relationship with the higher levels of production

3. RESEARCH GAP AND OBJECTIVE OF THE STUDY

As mentioned in the previous section, lots of studies have been done in this area but hardly focus on the issue of structural breaks in pulses production in India. Moreover, the existing literatures hardly analysed the long run relationship and short run causality among pulses production and other possible important factors. This study aims to put light on such research gaps with more in-depth empirical narratives. The specific research objectives that the study will address are as follows:

- To check the presence of structural breaks in the total production of Pulses in India during 1950-51 to 2016-17.
- To analyse the influence of the total production area under pulses, total use of fertilizer and total annual rainfall on total production of pulses in India during 1950-51 to 2016-17.
- To analyse the long run relationship and short run causality among the total production of pulses, total production area under pulses, total use of fertilizer and total annual rainfall in India during 1950-51 to 2016-17.

4. DATA SOURCE AND VARIABLE DESCRIPTION

The study uses time-series data of 67 years on total area under pulses production, total production of pulses, total use of fertilizer and total annual rainfall in India from secondary sources for the time period 1950-51 to 2016-17. Table 1 gives the descriptions of the variables and their data sources.

Table 1: Data Sources and Variable Descriptions

Variable	Description	Unit	Data Source	Natural Logarithm
P	Current year total pulses production	Million-Tonnes	ICAR-IIPR	LOGP
A	Current year total area of pulses production	Million Hectare	ICAR-IIPR	LOGA
F	Current year total use of fertilizer	KG/Hectare	ICAR-IIPR	LOGF
ARF	Current year total annual rainfall	in 10th of mm	Kothawale & Rajeevan (2017)	LOGARF

5. EMPIRICAL INVESTIGATION, FINDINGS AND DISCUSSION

The summary statistics of the variables is presented in Table 2. It shows that LOGP and LOGA are positively skewed with leptokurtic distribution, on the other hand LOGF and LOGARF is negative skewed with platykurtic distribution. None of the variables have satisfied the normal distribution criteria $(\gamma_1 = 0)$and $(\beta_2 = 3)$ which itself indicates that the four variables exhibit fluctuation during 1950-51 to 2016-17

Table 2: Summary statistics of variables

	LOGP	**LOGA**	**LOGF**	**LOGARF**
Mean	2.51	3.13	8.23	9.28
Median	2.49	3.13	8.95	9.28
Maximum	3.13	3.38	10.24	9.49
Minimum	2.12	2.93	4.18	9.04
Std. Dev.	0.19	0.06	1.85	0.09
Skewness	0.44	0.04	-0.83	-0.14
Kurtosis	3.65	5.59	2.42	2.90
Jarque-Bera	3.42	18.7	8.75	0.26
Probability	0.18	0.000	0.01	0.87
Sum	169	210	552	622
Sum Sq. Dev.	2.63	0.31	226	0.60
Observations	67	67	67	67

Source: Authors' own calculations

5.1. Analysis of Structural Breaks

Figure 1 depicts the trends in area, production of Pulses, total use of fertilizer and total annual rain fall in India in India during 1950-51 to 2016-2017. The trends of total production, total area of production, total use of fertilizer and total annual rainfall in India suggest slight positive uneven growth during the entire period. From the Figure 1 we have found that there are jerks and fluctuations in total production, total area of production, total use of fertilizer and total annual rainfall throughout the entire period in India which increases the possibilities of having structural breaks in data.

Plotted graphs of total area, total production of pulses, total use of fertilizer and total annual rainfall showed clear jerks and fluctuations over the time 1950-51 to 2016-17 in India. So, we have fitted the Bai-Perron multiple breakpoint test separately for each variable series to the check existence of significant structural breaks. Results are given in the Table 3.

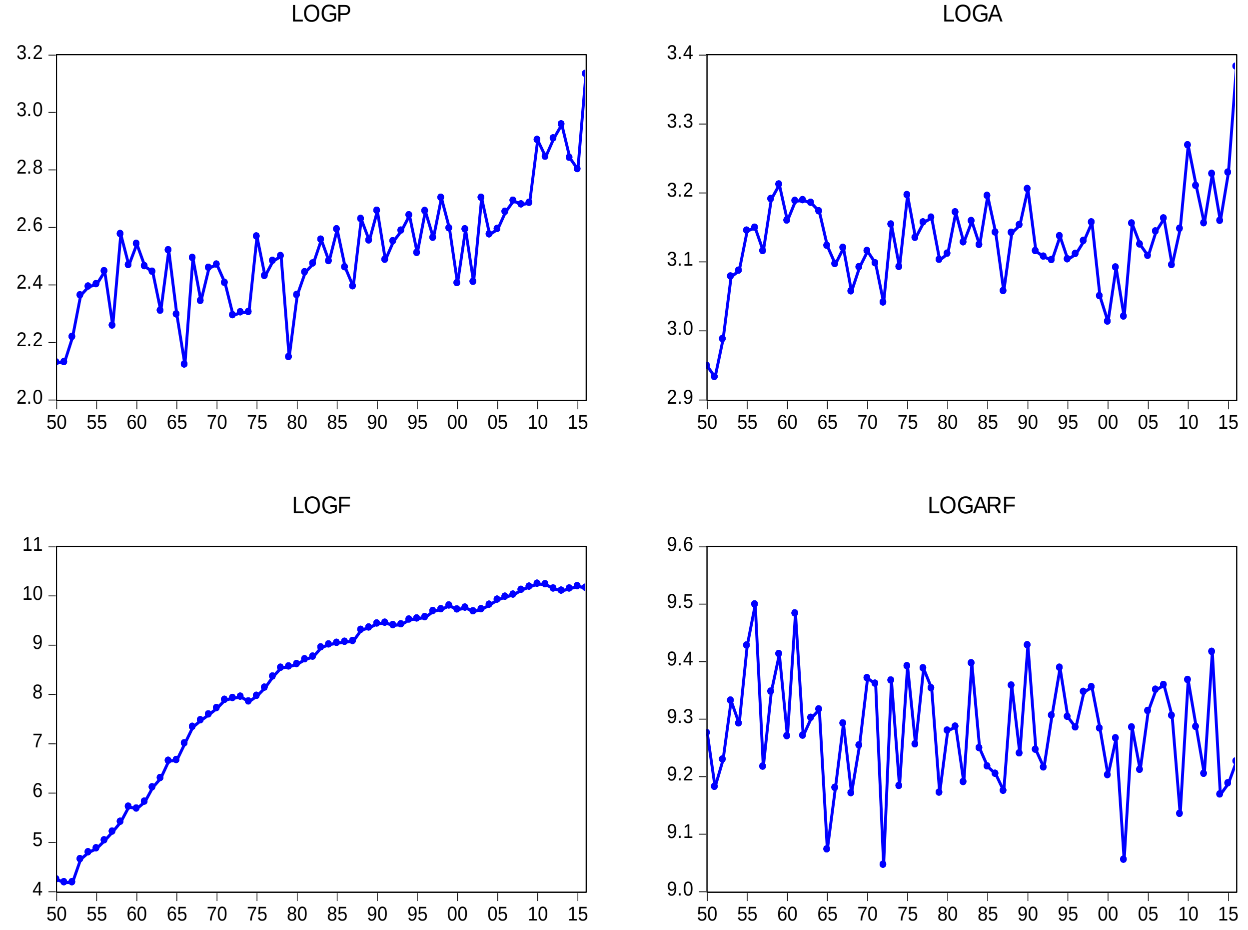

Figure 1: Total area, production of pulses, use of total fertilizers and rainfall in India (1950-51 to 2016-17)

Table 3: Analysis of structural breaks in total area, production of pulses, use of fertilizer and rainfall in India (1950-51 to 2016-17)

Bai-Perron multiple breakpoint tests (Sample: 1950- 2016)						
Variable	Break Test	F-statistic	Critical values	Break dates:	Sequential	Repartition
LOGP	0 vs. 1 *	61.07061	8.58	1	2006	1982
	1 vs. 2 *	30.72358	10.13	2	1982	2007
	2 vs. 3	1.590077	11.14			
LOGA	0 vs. 1 *	15.86289	8.58	1	2007	2007
	1 vs. 2	3.636778	10.13			
LOGF	0 vs. 1 *	233.4699	8.58	1	1968	1964
	1 vs. 2 *	66.85191	10.13	2	1983	1978
	2 vs. 3 *	11.56382	11.14	3	1997	1997
	3 vs. 4	2.183792	11.83			
LOGARF	0 vs. 1	4.174394	8.58	…		

* Significant at the 0.05 level

Source: Authors' own calculations

The Table 3 suggests that the total production of pulses has two significant structural breaks in the years 1982 and 2006 over the period of 1950-51 to 2016-17. Total production area of pulses has also one significant structural break in year 2007. Total use of fertilizer in India has three significant structural breaks in the years 1968, 1983 and 1997. However, total annual rainfall has not any significant structural break during 1950-51 to 2016-2017.

5.2. Analysis of Stationarity

As mentioned in the last sub-section, we have found the presence of structural breaks in case of three variables; we have fitted the Zivot-Andrews unit root test to check the stationary of the variables. This is because in this case (presence of structural breaks) conventional unit root tests like Dickey-Fuller and Augmented Dickey Fuller fail to give reliable results (Zivot and Andrews, 1992) whereas, Zivot-Andrews unit root test gives more reliable results by considering the presence of structural breaks in the series. Results of Zivot-Andrews unit root test for the data are given in the Table 4.

Table 4: Stationary analysis of the total area, production of pulses and total use of fertilizers in India (1950-51 to 2016-17)

Zivot-Andrews Unit Root Test				Sample: 1950 -2016 (Included obs.: 67)			
Variables	Test statistic	At Level	Break	test statistic	1st difference	Break	Order
LOGP	-5.4***	Stationary	2000				I(0)
LOGA	-5.41***	Stationary	1999				I(0)
LOGF	-3.65	Non-Stationary	1966	-8.82***	Stationary	1968	I(1)
LOGARF	-9.22*	Non-Stationary	1962	-6.32***	Stationary	1967	I(1)
Critical Value: ***1% (-5.57) **5% (-5.08) *10% (-4.82)							

Source: Authors' own calculations

From the Table 4 we have found that LOGP and LOGA are stationary at their level. On the other hand, LOGF and LOGARF are non-stationary at their level, but both are found to be stationary at their first differences.

5.3. Determination of long run relationship

LOGF and LOGARF were integrated at level I (1), while LOGP and LOGA were integrated at order I (0), as shown in Table 4. Because the variables in this study are integrated in different orders, the presence of a long-term link between the variables is tested using the ARDL-Bound test. Table 5 displays the cointegration test results (using the bound technique).

Table 5: Result of ARDL-Bound test

ARDL Model	AIC	SC	Log likelihood	F Wald Test	P
ARDL(1,1,1,1)	-1.269966	-0.968897	50.27389	3.503085	0.0127

Source: Authors' own calculations

Table 5 shows a statistically significant p value, indicating the existence of a long-term association between the variables. Since the Bound test revealed that the variables were co-integrating, the long- and short-term coefficients of the variables under consideration are determined by fitting an auto regressive distributed lag model (ARDL). This is how the ARDL model is defined:

Long Run Relationship:

$$LOGP_t = \alpha + \sum_{i=1}^{2} \beta_{1i} LOGP_{t-i} + \sum_{i=0}^{2} \beta_{2i} LOGA_{t-i} + \sum_{i=0}^{3} \beta_{3i} LOGF_{t-i} + \sum_{i=0}^{3} \beta_{3i} LOGARF_{t-i} + \mu_t \quad \dots\dots \ (1)$$

Short Run Relationship with VECM:

$$\Delta LOGP_t = \alpha + \sum_{i=1}^{2} \beta_{1i} \Delta LOGP_{t-i} + \sum_{i=0}^{2} \beta_{2i} \Delta LOGA_{t-i} + \sum_{i=0}^{3} \beta_{3i} \Delta LOGF_{t-i} + \sum_{i=0}^{3} \beta_{3i} \Delta LOGARF_{t-i} + \gamma ECT_{t-1} + \mu_t \quad \dots\dots \ (2)$$

where,

μ_t : White noise error term

ECT_{t-1}: The one period lag of residual which treated as error correction term.

Δz: First difference of variable z

The estimated ARDL model result is presented in Table 6.

Table 6: Long run and short run coefficients respect to total production of pulses in India (1950-51 to 2020-21)-ARDL estimation result

Variable	**Coefficient**	**Variable**	**Coefficient**
Dependent Variable: LOGP		Dependent Variable: ΔLOGP	
C	-0.099556	C	-0.004992
LOGP(-1)	0.266708**	ΔLOGP(-1)	0.841269
LOGP(-2)	0.430936***	ΔLOGP(-2)	0.699915*
LOGA	1.532997***	ΔLOGA	1.204507***
LOGA(-1)	0.775162*	ΔLOGA(-1)	-1.57438*
LOGA(-2)	-0.043281	ΔLOGA(-2)	0.01797
LOGF	-0.037027	ΔLOGF	-0.035127
LOGF(-1)	0.118176	ΔLOGF(-1)	0.213964
LOGF(-2)	-0.217323	ΔLOGF(-2)	-0.311619*
LOGF(-3)	0.152067	ΔLOGF(-3)	0.151977
LOGARF	0.285054*	Δ(LOGARF)	0.419332***

LOGARF(-1)	0.043501	ΔLOGARF(-1)	-0.135839
LOGARF(-2)	-0.373016**	ΔLOGARF(-2)	-0.597477**
LOGARF(-3)	-0.115986	Δ(LOGARF(-3)	-0.083564
		ECT(-1)	-1.597509*
R-squared		0.834262	0.741083
Adjusted R^2		0.79117	0.663958
Standard Error		0.086018	0.087292
Sum squared residual		0.369951	0.358134
Log likelihood		74.09251	71.7993
F-statistic		19.36002	9.608935
Prob(F-statistic)		0.000	0.000
Durbin-Watson stat		2.097421	2.026306

Note: *, ** and *** are significance at 10%, 5% and 1% levels respectively. Numbers in parentheses are p-values
Source: Authors' own calculations

In the Table 6 significant F-statistic for both the models implies that the models are fitted significantly. The value of Durbin - Watson test statistic implies the absence of autocorrelation problem in both the models. Table 6 reveals that during 1950-51 to 2016-17, in short run previous year's total production of pulses has no significant impact on the current year's production whereas; it has a positive significant impact on current year's total production of pulses in long run. The two years lag of current year's total production has a positive significant impact on current year's total production of pulses in short run, as well as in the long run. Current year's total area of pulses production and previous year's total area of pulses production has a positive influenced on current year's total pulses production in short run, as well as in the long run. On the other side, total use of fertilizer has no significant impact on the current year's production of pulses in both short run and long run. Current year's annual rainfall positively impacts the current the year's total production of pulses in both short run as well as in long run. But two years lag of the current year's annual rainfall negatively influence the current the year's total production of pulses in both short and long run. In the short run coefficient model one period lag of residual term which was treated as error correction term which has significantly influenced current year's total pulses production. A significant error correction term with negative coefficient indicates that the speed of adjustment towards long run equilibrium is at the speed of 159 per cent.

5.4. Determination of short run causality

Now, to determine the short run causality or joint significance of the coefficients we have fitted ARDL-Wald test. The Wald test demonstrated whether or not the dependent variable is significantly impacted by the combined effect of the independent factors. Table 7 presents the results.

Table 7: Result of ARDL- WALD test

Wald Test			
Null Hypothesis: ΔLOGA=ΔLOGF=ΔLOGARF = 0			
Test Stat	Value	df	Prob
F-stat	20.28	(3, 47)	0.00
Chi-square	60.86	3	0.00
Null Hypothesis: ΔLOGARF =ΔLOGARF(-1)= ΔLOGARF(-2) = ΔLOGARF(-3) =0			
F-stat	3.88	(4, 47)	0.00
Chi-square	15.53	4	0.00

Source: Authors' own calculations

Table 7 shows that this year's total number of pulses produced is greatly influenced by the total area used for pulse farming, the total amount of fertilizer used, and the annual rainfall. The total annual rainfall for the current year and the preceding three years has a major influence on the total quantity of pulses produced this year.

5.5. Stability Testing and Diagnostic Checking

The model's compliance with the diagnostic tests is confirmed by the findings shown in Table 8. Up to lag 1, the errors term's variance remains constant across time, and there is no indication of serial correlation. At the 5% level, the functional form is validated by the Ramsey reset test for model stability. Thus, the model appears to have the expected econometric features based on the results of all experiments.

Table 8: Result of diagnostic test of the model

Diagnostic Test	Test Statistics	Prob
Serial Correlation LM Test: Breusch-Godfrey	0.65	0.52
Heteroskedasticity Test: Breusch-Pagan-Godfrey	1.79	0.07
RESET Test: Ramsey	0.52	0.46

Source: Authors' own calculations

The graph represented in both part of the Figure 2 highlights the result of CUSUM and CUSUMSQ test which indicates the stability of all the parameters. So, the fitted model is stable and properly specified.

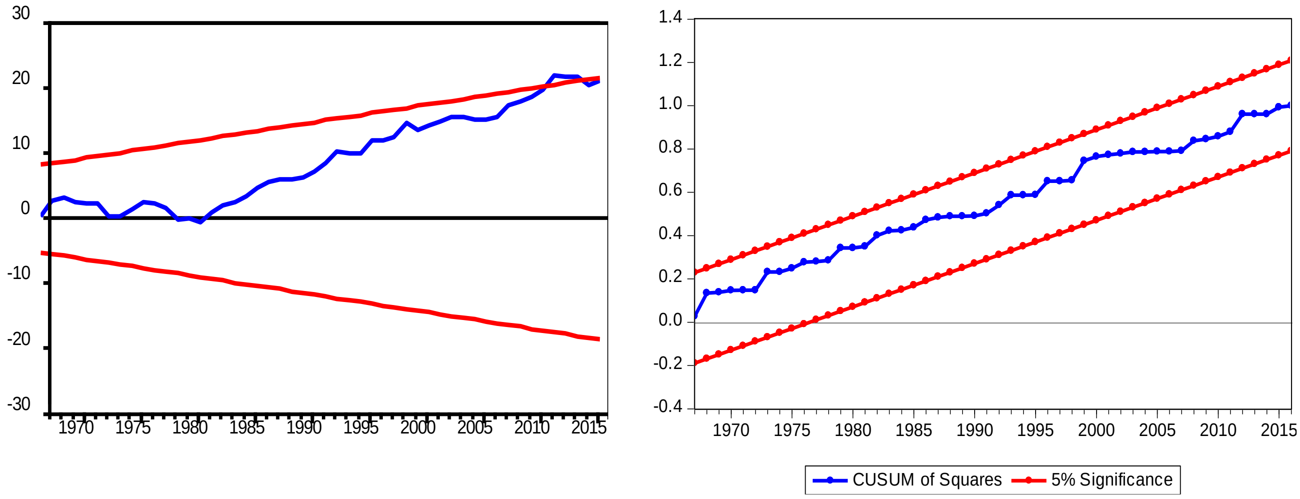

Figure 2: CUSUM Test & CUSUM SQUARE Test

6. CONCLUSION

The present study is based on specific objective to examine the relationship among the total production of pulses, total production area under pulses, total use of fertilizer and total annual rainfall in India during 1950-51 to 2016-17 using data from different secondary sources. The present study finds the existence of significant structural breaks in the pulses production. Analysis of the study has shown that there is a long-term relationship between total yearly rainfall, total fertilizer use, total production area under pulses, and total production of pulses. Additionally, this analysis indicates that while the total production of pulses from the previous year has no discernible effect on the total production of pulses this year, it has a positive and significant influence on the current year's total production of pulses over the long term. Current year's total area of pulses production and previous year's total area of pulses production have a positive influence on current year's total pulses production in short run, in addition to in the long run. One important finding this that total use of fertilizer do not have any significant impact on the current year's production of pulses in short run as well as in the long run. Current year's annual rainfall positively influences the current the year's total production of pulses in both short and long run. The present study has also found that current year's total area of pulses production, current year's use of total fertilizer and current year's annual rain fall have significant joint impact on current year's total production of pulses. Joint combinations of total annual rainfall from current to 3 years lag have a significant impact on current year's total production of pulses.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

FUNDING INFORMATION

This work was carried out without any financing.

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