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Food Grain Production in India: An Assessment of long-term Stability and Growth

Dr. Rahul K[1] and Dr. Prajisha P[2]

[1]Associate Professor of Economics, NMSM Government College Kalpetta, Kerala, Affiliated to University of Calicut, Kerala, India

[2]Assistant Professor of Economics, NMSM Government College Kalpetta, Kerala, Affiliated to University of Calicut, Kerala, India

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ABSTRACT

This paper examines the long-term stability of food grain production with special focus on cereals and pulses in India over the period 1967 to 2024, a timeframe marked by significant agricultural revolutions and policy changes. With the use of wide-ranging time-series data, the analysis studies growth trends, fluctuations, and structural stability to evaluate how consistent the food grain production has been across six decades. The paper employs estimation of growth rate including log-linear trend analysis, and also structural break tests to investigate the nature of food grain production over the years. The findings disclose significant but decelerating growth in the production cereal and modest growth in pulses over the years. Both Cereals and Pulses show key structural break detected in the year 2003 and 2001 respectively. But the break in cereals is not significant in dummy variable regression. The pulses show a downward shift in intercept in 2001, but late a significant positive trend can be seen after 2001.

Key words: Food grain production, Cereal output, Pulse production, Structural break, Agricultural growth trends.

Introduction

Production of food grains is essential for a country's food security, which is directly influencing the availability, and stability of staple food items such as rice, wheat etc. India occupies second position in the world food grain production which is accounting for about one fifth share in country's total agricultural GDP. And playing an important role in national food security and stability in the economy [1]. India's food grain production has experienced an important transformation after green revolution in late 1960s, mostly driven by agricultural policy changes,

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technological improvement, and institutional backing. Although much attention has been given to the Green-Revolution and successive technical improvements, questions persist about the long-term stability and reliability of output trends. This study focuses on the long-term trend and structural stability of two major food grain components: cereals and pulses. The main objectives of the study are to identify trends, compare their growth, and examine the presence of structural changes.

Numerous studies have investigated trends in Indian agriculture. Bhalla and Singh [2] studied the impact of policy reforms and government investment on food crop production. Gulati and Fan [3] noted the regional disparities and inefficiencies in agricultural policy. In their study, Radhakrishna, and Murty [4] emphasized stagnation in the production of pulses as a reason for concern. Recently, Chand et al., [5] points out the crop shifting patterns and challenges in productivity of food crops. In their study, Dev and Rao [6] examined the effect of subsidies and Minimum Support Prices on cereal production, whereas Birthal and others [7] explored crop diversification and its effect on food grain production. Swaminathan [8] argued for wide-ranging agricultural policies to improve the production of pulses and ensure food security and nutrition intake. However, few studies have combined trend analysis with structural break testing over an extended period, which this study addresses. Despite extensive research on food grain production in India, several important gaps remain that this study seeks to address:

While many studies examine short-term trends or decade-wise changes [12,13,14], few offer a comprehensive structural analysis of long-term structural stability in food grain production over multiple decades (1967–2024). There is a lack of time-series econometric studies that incorporate structural break tests and trend stability analysis for such a broad time frame. inadequate focus on pulses and coarse cereals Research has disproportionately focused on rice and wheat due to their dominance in procurement and food security policies [22,23,24]. However, there is insufficient attention to pulses and coarse cereals, which are critical for nutrition and are often cultivated in marginal areas. Their production trends and stability patterns remain under-explored.

Considering the above gaps, this study proposes a comprehensive time-series investigation into the structural stability and trend behaviour of food grain production in India from 1967 to 2024. By applying rigorous statistical tools and incorporating commodity-level, and regional disaggregation, this research aims to provide new insights into the sustainability, and policy relevance of India’s food grain economy.

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Materials and Methods

The study uses annual time series production data of cereals and pulses which obtained from the Ministry of Agriculture and farmers welfare, Government of India. The study takes the period after green revolution. That is the time span of the study covers almost five decades from 1967 to 2024. For the study we use CAGR, trend analysis and structural break tests. The important methods used in the study are summarized below.

In order to capture the average annual growth rate, the **Compound Annual Growth Rate (CAGR)** formula has been used. The CAGR is a useful indicator as it represents **the smoothed average annual growth rate** over a period of time, assuming that it is compounding. Contrasting arithmetic averages, CAGR reflects the geometric progression of growth and is especially appropriate for long-term time series data that may include fluctuations or volatility.

$$CAGR = \left(\frac{Vf}{Vi}\right)^{\frac{1}{n}} - 1$$

Where Vf is denoting final value, Vi denoting initial value and n is number of years.

For time-series analysis Eviews software has been used. The data are transformed in to log format and then checked unit root using Augmented Dickey Fuller test. The functional form of ADF is that;

$$\Delta y_t = \beta_1 + \delta y_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta y_{t-i} + u_t$$

To estimate trends using natural logarithm transformations of production both for cereals and pulses.

$$\ln Y_t = \alpha + \beta_t + u_t$$

$\ln Y_t =$ Natural logarithm of the dependent variable,

α Intercept term,

β_t Slope coefficient, representing the **constant** *growth* **rate,** t Time

To identify possible structural breaks in the production trend, the Bai-Perron multiple breakpoint test and the Quandt-Andrews breakpoint test has been employed.

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Further, a dummy variable interaction model is used to assess the intensity and significance of the identified structural breaks.

Results and Discussions

Growth rate of Food Grain Production

Before analyzing the long-term trends in food grain production, it is essential to first examine the average annual growth performance of cereals and pulses over the study period. To achieve this, the **Compound Annual Growth Rate (CAGR)** has been calculated separately for both cereals and pulses for the entire period from 1967 to 2024. The result of this analysis gives,

The **CAGR for cereal production** calculated over the entire period is **2.67%,** indicating that on average, cereal production increased by 2.67% per annum, compounded annually. The **CAGR for pulse production** is **1.87%,** which reflects a relatively lower but still positive annual growth rate in the pulse sector.

These results suggest that while both cereal and pulse production experienced positive long-term growth since the Green Revolution, the pace of growth has been notably higher in the case of cereals than pulses. This disparity may be attributed to a variety of factors such as greater policy focus on cereals, better irrigation support, higher MSP coverage, and more widespread adoption of high-yielding varieties (HYVs) in the case of cereals compared to pulses.

Trend Estimation Using Log-Linear Regression

To study the long-term trend in cereal production in India, a log-linear regression model was estimated with the natural logarithm of cereal production as the dependent variable and time as the independent variable.

Production trend of Cereals: The estimated model demonstrates a significant upward trend in the double-logarithm of cereal production over the period 1967–2024. The trend equation is which is derived from the result is

$$\log(\text{ln\_Cereals}) = -4.1954+0.003*\text{Year}$$

The coefficient on the time variable is positive and also statistically significant at the 1% level since the value of $\beta = 0.003$ and p value is less than 0.05. The result is suggesting a steady increase in the cereal production, by approximately 0.31% annually. The model explains a considerable share of the variation in the dependent variable, with an R-squared value of 0.958. To address concerns regarding autocorrelation and heteroskedasticity, robust standard errors were calculated using the Newey-West (HAC) method, which slightly increased the standard

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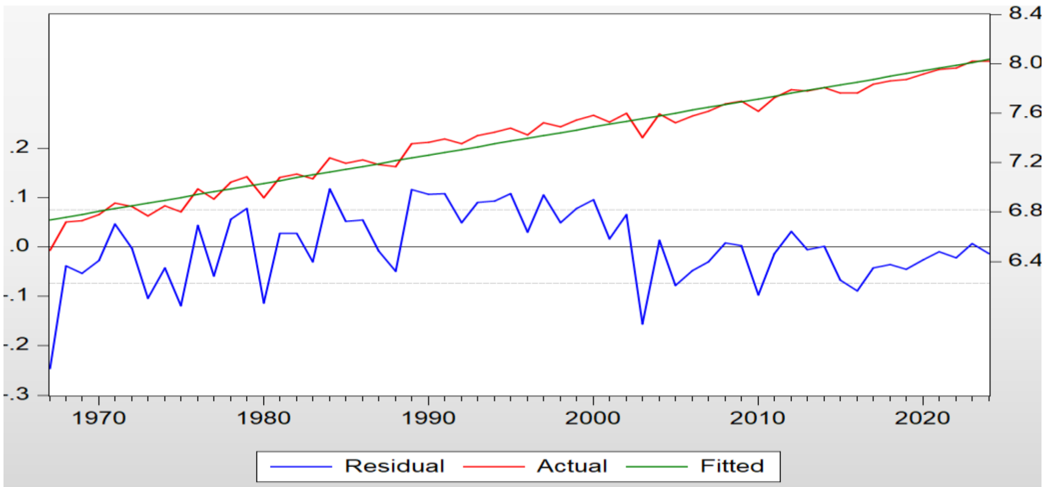
errors but did not affect the significance of the estimates. Although the Durbin-Watson statistic indicates the presence of positive autocorrelation (DW = 1.11), the use of HAC robust standard errors ensures that the inference drawn from the model remains valid. Overall, the results confirm a persistent and statistically robust growth trend in cereal production throughout the study period.

Figure 1: Trend in cereal production



Source: Authors' calculation

The analysis reveals a statistically significant positive trend in the double-logarithm of cereal production from 1967 to 2024, with an estimated annual increase of approximately 0.31%. The model explains 95.8% of the variation in production and remains robust after correcting for autocorrelation and heteroskedasticity using Newey-West standard errors. Despite evidence of positive autocorrelation in the residuals, the corrected inference confirms a steady and reliable growth trend in cereal production over the study period.

Production trend of Pulses: The regression results reveal a statistically significant positive trend in the double-logarithm of pulses production between 1967 and 2024. The estimated trend equation is:

$$\ln(\text{Pulses}) = -23.6923 + 0.01435 * \text{Year}$$

The coefficient for the Year variable is 0.01435, which is positive and statistically significant since t = 7.10 and p value < 0.01). The result indicating an average annual growth rate of around 1.44% in production of pulses over the sample period. The constant term (-23.69) is also significant. The R-squared value is 0.737, suggesting that about 74% of the variation in log-transformed pulses production is explained by the linear time trend. This shows a moderate to

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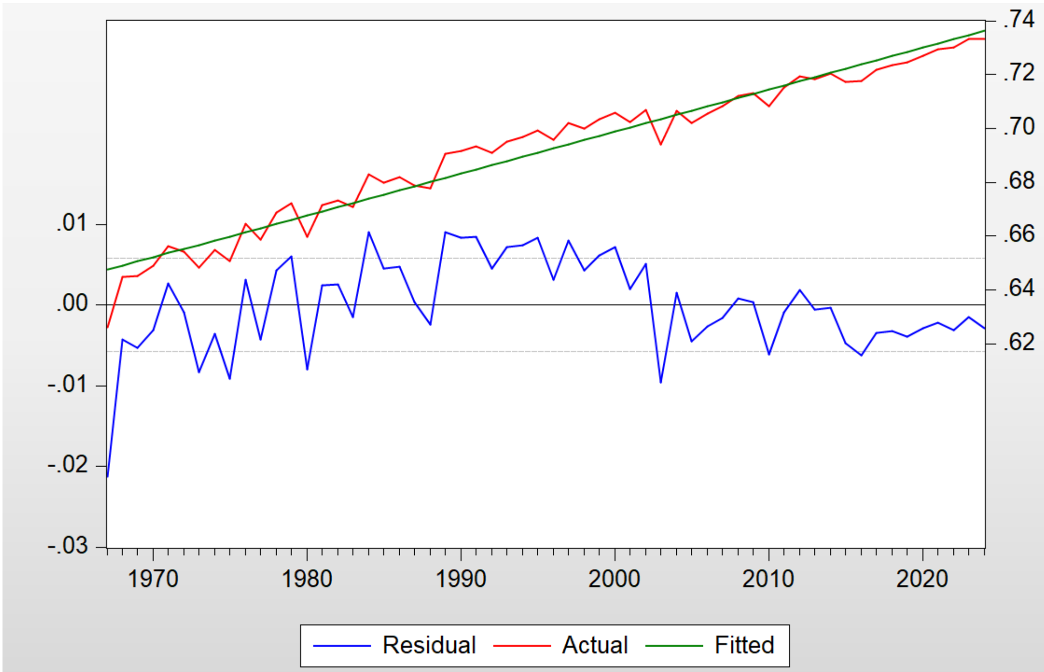
strong model fit. The Wald F-statistic is 50.46, $p < 0.01$ confirms that the trend is jointly statistically significant even after accounting for serial correlation and heteroskedasticity.

Figure 2. Trend in pulse production



Source: Authors' calculation

Overall, the results confirm a steady and statistically sound and positive trend in pulses production when measured using the double-log transformation, capturing nuanced growth patterns over the nearly six decades under study.

Structural Break in Cereal Production

To assess the stability of cereal production trends in India, two complementary structural break tests were employed: the Quandt-Andrews unknown breakpoint test and the Bai-Perron multiple breakpoint test. These tests are well-suited for time series models where breakpoints are not known a priori and can detect both isolated and multiple shifts in regression coefficients over time.

The Quandt-Andrews test was applied to cereal production data for the period 1976–2016, with the regression model estimated using year as an explanatory variable. The test results are summarized below:

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Table 1: Quandt Andrews Breakpoint test for cereals

Test Statistic	Value	p-Value	Interpretation
Maximum LR F-statistic (at 2003)	20.79	0.0000	Strong evidence of a structural break in 2003
Maximum Wald F-statistic (at 2003)	41.59	0.0000	Significant parameter instability at 2003
Exp. LR / Wald F-statistics	7.76 / 17.54	0.0000	Break exists, averaged over time
Average LR / Wald F-statistics	10.96 / 21.91	0.0001	Persistent deviation from a stable trend

Source: Authors' Calculations

All test statistics are statistically significant at the 1% level, leading to rejection of the null hypothesis of structural stability. The most probable breakpoint is in the year 2003, which corresponds to a significant change in the trend or dynamics of cereal production.

To complement the Quandt-Andrews findings and explore the possibility of multiple breaks, the Bai-Perron test was applied using the same dataset. The results are as follows:

Table 2: Bai-Perron Multiple Breakpoint for cereals

Comparison	F-statistic	Scaled F-stat	Critical Value (5%)	Conclusion
0 vs 1	20.79	41.59	11.47	One significant break
1 vs 2	3.23	6.45	12.95	No second break

Source: Authors' Calculations

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The Bai-Perron test confirms a single statistically significant structural break in 2003, based on both sequential and repartition algorithms. No evidence supports additional breaks beyond this point, reinforcing the robustness of the 2003 regime shift.

To complement the Quandt-Andrews and Bai-Perron structural break tests, a dummy-interaction regression was estimated to explicitly capture changes in both the level and growth trend of cereal production around the identified breakpoint year, 2003. The regression included a time trend (YEAR), a dummy variable (D2003) representing the post-2003 period, and an interaction term (YEAR_D2003) to test for changes in the slope of the trend.

$$\ln\_cereal_t = \beta_0 + \beta_1 YEAR_t + \beta_2 D_{2003} + \beta_3 (YEAR_t * D_{2003}) + \varepsilon_t$$

The coefficient on YEAR was positive and statistically significant at the 1% level, suggesting that prior to 2003, cereal production grew at an average annual rate of approximately 2.77%. This confirms the robustness of the upward trend during the pre-2003 period.

However, both the post-2003 level shift (D2003) and the interaction term (YEAR_D2003) were statistically insignificant at conventional levels. Although the sign of the coefficients suggests a modest increase in production levels and a marginal decline in the growth rate after 2003, the high p-values (0.1599 and 0.1481, respectively) indicate that these changes are not statistically distinguishable from zero.

Table 3: Regression Results with Dummy Interaction (Breakpoint at 2003)

Variable	Coefficient	p-value	Interpretation
C	-47.81	0	Intercept (baseline cereal production level before 2003)
YEAR	0.0277	0	Significant positive growth trend before 2003 (2.77% annually)
D2003	6.07	0.1599	Increase in level after 2003 (not statistically significant)
YEAR_D2003	-0.0031	0.1481	Slight decline in growth rate post-2003 (not statistically significant)

Source: Authors' Calculations

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This suggests that, although the earlier breakpoint tests detected a statistically significant structural break in 2003, the dummy-interaction model does not find strong evidence of a sharp or immediate shift in the level or slope of production. The observed moderation in growth may therefore reflect a gradual structural transformation, possibly due to policy reorientation, environmental constraints, or diminishing technological returns, rather than an abrupt change.

Structural Break in Pulse Production

To examine the stability of pulse production trends in India, two complementary structural break tests were employed: the Quandt-Andrews unknown breakpoint test and the Bai-Perron multiple breakpoint test. Both tests are suitable for time series data where breakpoints are unknown in advance, enabling detection of isolated as well as multiple shifts in regression coefficients over time.

The Quandt-Andrews test was applied to pulse production data covering the period 1976–2016, with year as the explanatory variable in the regression model. The key results are summarized below:

Table 4: Quandt-Andrews test Result of Pulse production

Test Statistic	Value	p-Value	Interpretation
Maximum LR F-statistic (at 2001)	36.23	0	Strong evidence of a structural break in 2001
Maximum Wald F-statistic (at 2001)	72.47	0	Significant parameter instability at 2001
Exp. LR / Wald F-statistics	14.92 / 32.58	0.0001 / 0.0009	Break exists, averaged over time
Average LR / Wald F-statistics	17.60 / 35.20	0.0038	Persistent deviation from a stable trend

Source: Authors' Calculations

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All test statistics are statistically significant at the 1% level, leading to rejection of the null hypothesis of structural stability. The most probable breakpoint is identified in 2001, indicating a marked shift in the growth dynamics of pulse production.

To validate the Quandt-Andrews findings and check for multiple structural breaks, the Bai-Perron multiple breakpoint test was performed on the same dataset. The results are as follows:

Table 5: Bai-Perron Multiple Breakpoint Test Results

Comparison	F-statistic	Scaled F	Critical Value (5%)	Conclusion
0 vs 1	36.23	72.47	12.25	One significant break
1 vs 2	3.03	6.05	13.83	No second break

Source: Authors' Calculations

The Bai-Perron test confirms a single statistically significant structural break in **2001**, based on both sequential and repartition tests. There is no evidence to support additional breakpoints beyond this date, reinforcing the robustness of the identified regime shift.

This analysis indicates that pulse production in India experienced a significant change in trend or regime around **2001**, possibly reflecting policy reforms, shifting agricultural priorities, or other socio-economic and environmental factors affecting pulse cultivation.

The regression model investigates the impact of a structural break in 2001 on the trend of pulse production in India, measured by the natural logarithm of pulses (LN_PULSES) as the dependent variable, with YEAR, a dummy variable for 2001 (D2001), and their interaction term (YEAR_D2001) as regressors.

$$\ln\_pulses_t = \beta_0 + \beta_1 YEAR_t + \beta_2 D_{2001} + \beta_3 (YEAR_t * D_{2001}) + \varepsilon_t$$

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Table 6: Regression Results with Dummy Interaction (Breakpoint at 2001)

Variable	Coefficient	Std. Error	t-Statistic	p-Value	Interpretation
C	-14.37	3.37	-4.27	0.0001	Baseline intercept representing the log level of pulses in 1967.
YEAR	0.0097	0.0017	5.68	0.0000	Positive and statistically significant growth trend before 2001 (approx. 0.97% annual increase).
D2001	-55.38	6.68	-8.29	0.0000	Significant negative level shift in pulse production starting 2001, indicating a sudden drop.
YEAR_D2001	0.0276	0.0033	8.28	0.0000	Significant positive change in the growth rate after 2001, increasing annual growth by approx. 2.76%.

Source: Authors' Calculations

The model explains about 88.8% of the variation in LN_PULSES, reflecting a strong fit (Adjusted $R^2 = 0.882$). The Durbin-Watson statistic (2.08) indicates no serious autocorrelation concerns. The overall F-statistic (142.35, $p < 0.0001$) confirms the model's statistical significance.

Before 2001, pulse production exhibited a modest but statistically significant positive growth trend of roughly 0.97% per year. However, the negative and highly significant coefficient on the dummy variable D2001 indicates a sharp drop in the level of pulse production starting in 2001, suggesting a structural break that caused an immediate decline.

Following this drop, the interaction term YEAR_D2001 is both positive and highly significant, implying a substantial acceleration in the growth rate after 2001. Specifically, the annual growth rate in pulse production increased by about 2.76% post-2001, offsetting the initial decline and suggesting a new, faster growth trajectory.

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In sum, the dummy-interaction regression provides strong evidence that pulse production in India experienced a significant structural break in 2001, marked by an immediate decline followed by a faster growth trend, possibly reflecting shifts in agricultural policy, technological adoption, or market conditions post-2000.

This study analyzes the long-term trends and structural stability of food grain production in India, focusing on cereals and pulses from 1967 to 2024. Using time-series econometric methods, including CAGR, log-linear trend models, and structural break tests, the research finds consistent and significant growth in cereal production, with a CAGR of 2.67%. A structural break is detected in 2003; however, regression analysis shows no significant shift in either growth rate or production level, suggesting a gradual rather than abrupt transformation, possibly due to policy shifts or diminishing returns to earlier technologies. Cereal output has largely benefitted from favorable government policies, widespread use of high-yielding varieties, and better irrigation support.

Pulse production, in contrast, exhibits a lower CAGR of 1.87% and more unstable growth. A clear structural break is identified in 2001, with an immediate drop in production level followed by a significantly stronger positive growth trend post-2001. This shift reflects recent efforts to boost pulse output through targeted policy support and rising demand. The findings highlight the differing dynamics of cereal and pulse production, pointing to the need for tailored strategies: sustaining momentum in cereals while reinforcing and scaling recent gains in pulses. The study underscores the importance of long-term, commodity-specific policies to ensure agricultural sustainability and food security in India.

Conclusion

The observed patterns in food grain production trends in India, particularly the divergence between cereals and pulses, can be attributed to a combination of policy orientation, technological interventions, and market incentives. The Green Revolution, which began in the late 1960s, focused heavily on cereal crops—especially wheat and rice—through the promotion of high-yielding varieties (HYVs), expansion of irrigation infrastructure, and input subsidies (Gulati & Dixon, 2008). These efforts translated into sustained growth in cereal production, as reflected in the consistent CAGR of 2.67% in this study. The structural break in 2003 does not reflect a drastic policy change but rather the plateauing of earlier gains, possibly indicating diminishing returns from first-generation technologies, as noted by Fan, Gulati, and Thorat (2008). The stability in growth despite this break underscores the entrenched policy and institutional support systems favoring cereal production, such as minimum support prices (MSPs), procurement systems, and public distribution mechanisms.

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In contrast, pulses have historically been neglected in both policy and investment terms, leading to lower productivity and fluctuating output (Reddy, 2004). The structural break in 2001, accompanied by a significant rise in the growth rate of pulse production post-break, aligns with renewed policy attention following growing domestic demand and widening supply gaps. Recent policy efforts—such as the National Food Security Mission (NFSM) and price incentives for pulses—have begun to reverse the stagnation in this segment. The volatility and initially sluggish growth of pulse output reflect both the biological and agronomic complexity of pulse crops and the lag in research and extension support compared to cereals. These findings highlight the need for differentiated agricultural strategies—while cereal production systems may require diversification and sustainability focus, pulses demand intensified support in R&D, market access, and farmer incentives to secure India's food and nutritional security.

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