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Ashis Kr Mukherjee
Department of Economics, Nistarini College, Purulia, West Bengal, India

Gargi Sarkar
Student, Department of Economics, SKBU, Purulia, West Bengal, India

Corresponding Author:
Ashis Kr Mukherjee
Department of Economics, Nistarini College, Purulia, West Bengal, India

Impact of crop production on economic development in West Bengal: An econometric analysis

Ashis Kr Mukherjee and Gargi Sarkar

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Abstract
This study investigates the impact of agricultural production on the economic development of West Bengal by analysing the relationship between rice, wheat, cereals, pulses and oilseeds production with GDP. Using thirty years annual time series data from 1993 to 2022, we employ descriptive statistics to summarize the key characteristics of each agricultural production variable before conducting further econometric analysis. The unit root tests confirm the stationary properties of the variables, while the Johansen test of co-integration establishes a long run equilibrium relationship among the variables. The results indicate that oilseed and cereal production positively contribute to GDP growth, whereas pulses production has a negative effect on it. The CUSUM test reveals structural instability in the estimated relationship, suggesting shifts in agricultural policy or external economic factors. Additionally, residual diagnostic tests validate the model's reliability. These findings highlight the significance of crop production in West Bengal's economic growth and emphasize the need for stable agricultural policies.

Keywords: Agricultural production in West Bengal, economic growth, time series analysis

Introduction

Agriculture has been the backbone of the Indian economy for decades, serving as the primary source of livelihood for a significant portion of the population. According to the recent report, around 42.3 percent of India's population is engaged in the agricultural sector and contributing around 18.2 percent in the India's GDP (current prices). In India, West Bengal is known for its agrarian base, has a diverse and productive agricultural sector that plays an important role in its economic development, contributing approximately 20 percent to the state's gross domestic product (GSDP) in 2022-23 (PRS India). However, in recent years, there has been a notable shift in the state's economic structure. We have noticed that the contribution of agriculture to West Bengal's gross domestic product (GDP) has declined over the years, primarily due to structural shifts towards industry and service sectors, as well as challenges such as land fragmentation, climate variation and declining investment in the sector. Despite of this decline, the agricultural sector continues to play an important role to influence the state's economy by generating employment especially in rural areas, ensuring food security, and supplying raw materials to agriculture-based industries. The favourable climate of West Bengal, characterized by ample rainfall, fertile soil, provides a strong foundation for both food grain (i.e., rice, wheat, pulses etc) and non-food grain (i.e., oilseeds, sugarcane, jute etc) production. However, recent years have seen challenges such as erratic weather patterns, declining land productivity and shifts in labour away from agriculture. Despite these challenges, agriculture remains a key driver of the state's GDP, supporting rural livelihoods, exports, and the agriculture-based industries that contribute to economic resilience. A well performing agricultural sector not only boosts rural income and employment but also strengthens the economic foundation. The interdependence between agriculture and economic growth suggests that higher crop production can contribute to GDP expansion, fostering a more robust and resilient economy. However, the precise nature and extent of this relationship require empirical analysis.

In West Bengal, where agriculture plays a dominant role in the state economy, the extent of its contribution to GDP remains an important area of study.

The agricultural output has fluctuated over the years due to some external factors such as changes in climatic conditions, policy implementation etc. For analysing this, our study seeks to examine the relationship between agricultural production and GDP growth in West Bengal by analysing past 30 years (1993 to 2022) time series data using various econometrics techniques.

Objective of the study

The key objectives of this study are as follows:

- To investigate the role of agricultural production in shaping the economic growth of West Bengal.
- To analyse the relationship between agricultural production and economic growth in West Bengal.
- To study the progress of Agricultural Sector in terms of production and productivity of West Bengal Economy.
- To examine how fluctuations in agricultural production impact the overall economic stability and growth trajectory of West Bengal.

Sources of Data

This study primarily relies on secondary data obtained from the 'Handbook of Statistics on Indian States', published by Reserve Bank of India (RBI). The dataset includes annual time series data on the gross domestic product (GDP) of West Bengal and the production of major crops, namely rice, wheat, pulses, cereals, oilseeds, sugarcane and jute for the period of 1993 to 2022.

Methodology

This study analyses the relationship between agricultural production and economic growth in West Bengal using different steps. These steps are mentioned below:

- In section I, we conduct descriptive statistical analysis to summarize the characteristics of each agricultural production variable.
- In section II, before conducting the unit root test or further econometric analysis, all variables are transformed into their natural logarithmic form to stabilize variance and improve the interpretability of the results. After that, we test whether the study variables contain unit roots or not. The stationary of each series is checked through Augmented Dickey Fuller method and Phillips Perron method.
- In section III, we use the Johansen test of co-integration, for checking whether a long run equilibrium relationship exists among the variables or not.
- In section IV, to ensure the reliability of the estimated model over time, we conduct the cusum (cumulative sum) test.
- Finally in section V, we explain residual diagnostic tests. There are several types of residual diagnostic tests, including tests for autocorrelation and heteroscedasticity.

Model Specification

In this study, GDP is taken as the dependent variable, while the production of rice (R), wheat (W), cereals (C), pulses (P) and oil seeds (O) are the independent variables. For our present study, the functional form can be written as follows:

gdp = f (r, w, c, p, o)

In the log-linear form, the model can be written as;

$lngdp = \beta_0 + \beta_1 lnr + \beta_2 lnw + \beta_3 lnc + \beta_4 lnp + \beta_5 lno + €_t$

Where,

lngdp is the Logarithmic value of gross domestic product (GDP)

lnr is the Logarithmic value of rice production

lnw is the Logarithmic value of wheat production

lnc is the Logarithmic value of cereals production

lnp is the Logarithmic value of pulses production

lno is the Logarithmic value of oilseeds production

β_0, β_1, β_2, β_3, β_4 and β_5 are the estimated parameters

β_0 represents the Autonomous part or constant term and β_1, β_2, β_3, β_4 and β_5 are Partial slope coefficients

$€_t$ is the Random error term

Results and Discussion

Section I

In this section, we summarize the characteristics of the agricultural production variables, including rice (r), wheat (w), cereals (c), pulses (p), oilseeds (o), sugarcane (s) and jute (j). The descriptive statistics provide insights into the average production, distribution, variability and overall trends in agricultural output. Unlike the econometrics analysis, where log-transformed values are used, here we analyse the data in its original form to maintain the interpretability in absolute terms. The result of the descriptive statistics of different crop productions is shown in the following table:

Table 1: Descriptive Statistics

	R	W	C	P	O	S	J
Mean	14469.97	783.4567	648.8133	240.2267	759.49	1474.63	7906.233
Median	14698.35	840.25	320.05	211.6	680.6	1470.9	8016.45
Maximum	16728.7	1058.6	2667	443.8	1277.5	2105.5	9400.1
Minimum	11887	312	77.9	126.1	491.9	542.4	5639.3
Std. Dev.	1334.471	179.8433	793.897	101.7798	239.0047	385.363	858.4134
Skewness	-0.40012	-1.11674	1.591632	0.852304	0.72383	-0.42062	-1.23174
Kurtosis	2.293292	3.787285	4.093668	2.410559	2.265586	2.996623	4.589286
Jarque-Bera	1.424779	7.010298	14.1616	4.066415	3.293857	0.884638	10.74323
Probability	0.490471	0.030042	0.000841	0.130915	0.192641	0.642544	0.004647

Source: Author's computation using E Views 7 Econometric software

The above table represent the descriptive statistics of agricultural production in west Bengal. To calculate average production during period 1993 to 2022 we calculate mean and median values. The mean is the average value of the series. A higher mean suggests a greater tendency towards higher values. On the other hand, the median is the middle most value in a dataset when the number are arranged in ascending or descending orders. It divides the data into two equal parts with 50 percent of the values below it and 50 percent above it. A higher median means that the overall trend or typical value in the dataset is larger. From the above table we see that, the production of cereal, pulses, oil seeds and sugarcane indicate that the data distribution is positively skewed (mean>median) means that there are some outliers pulling the mean higher than the median. Most values are clustered towards the lower end but some high value extend the tail on the right. On the other side, the production of rice, wheat and jute indicates the data is negatively skewed (mean<median) because they have frequent high production levels with occasional drops due to some external shocks. The standard deviation reveals significant differences in production stability across different crops. Rice and jute production exhibit the highest degree of variation (1334.47 and 858.41 respectively), indicating substantial fluctuations in production levels, while the pulses production (101.77) shows the least variability. This indicates that pulses production is more stable compared to other crops, whereas rice and jute production exhibits significant fluctuations, may be due to some external factors. For checking the given dataset follows normally distributed or not, we use Jarque Bera statistics. From the above table the Jarque-Bera test results indicates that the rice, pulses, oil seeds and sugarcane production follow a normal distribution while wheat, cereals and jute production deviates significantly from normality, highlighting irregular trends. These findings suggest that factors affecting wheat, cereals and jute production may be more unpredictable. Now for better understanding the contribution of different crop types, we classify them into two broad segments: (1) Food grains (FG) and (2) Non-food grains (NFG) to examine production trends. The Food grains category includes the production of rice (r), wheat (w), cereals (c) and pulses (p) and the Non-food grains category consists of the production of oilseeds (o), sugarcane (s) and jute(j). To visualize the contribution of food grain and non-food grain production to West Bengal's agricultural output, a bar graph is shown below:

The above figure illustrates the production trends of food grains (FG) and non-food grains (NFG) in west Bengal from 1993 to 2022. The graph highlights that food grain production has consistently been higher than non-food grain production throughout the study period. While both categories display an overall increasing trend, food grain production shows a relatively steadier and more significant rise, especially after the mid-2000s. The increase could be attributed to improved agricultural practices, and higher demand for staple crops. On the other hand, non-food grain production exhibits fluctuations, indicating variability in factors such as market conditions, climate impact, and policy interventions. Despite this variability, there is a general upward trend, reflecting the importance of non-food grains in Went Bengal's agricultural economy.

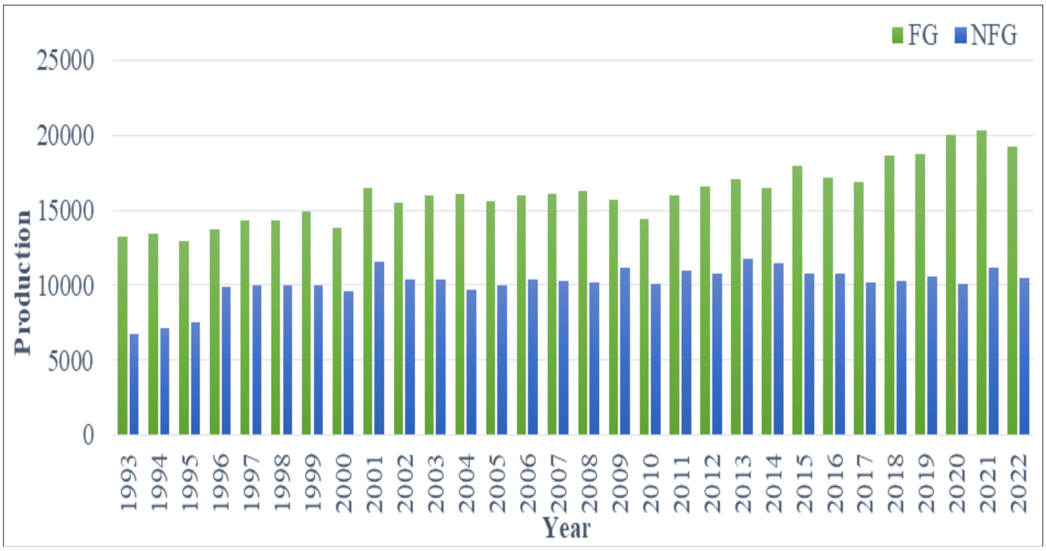

Fig 1: Production trends of Food grains and Non-food grains

Section II

Results of Unit Roots Tests

In time series analysis, the presence of a unit root indicates that the variable is non stationary, which means its statistical properties (i.e., mean, variance and covariance) changes over time. Non-stationary time series can lead to unreliable and misleading regression results, often referred to as spurious regression. So, for ensuring a valid econometric analysis, it is very crucial to check for stationarity before proceeding with further modelling. There are several tests to check whether a time series data is stationary or not. For our present study, we conduct the Augmented Dickey-Fuller test. To ensure accuracy, we also conduct the Phillips-Perron test as a double-check. In both tests, the null hypothesis is

H_0: Presence of unit root or the series is non-stationary.

Against the alternative hypothesis

H_1: Absence of unit root or the series is stationary.

If the value of the test statistic is less than 5% critical value or if the p-value is greater than 5% we accept the null hypothesis that there is a unit root and the series is non-stationary, otherwise the series is stationary.

Let our model be written as

$$y_t = \rho y_{t-1} + u_t \;\dots\dots(i)$$

Where, ρ = Autocorrelation coefficient $(-1 \leq \rho \leq 1)$

U_t = white noise error term satisfies the following assumptions.

i.e. $E(u_t) = 0$, $E(u_t^2) = \sigma^2$, $E(u_t u_s) = 0$ for all $t \neq s$

If ρ=1, then we have

$y_t = y_{t-1} + u_t$
or, $y_t - y_{t-1} = u_t$

or, $\Delta y_t = u_t$

This means that the first difference of the series is stationary, The result of the unit root test is shown below:

Table 2: ADF Test

Variables	Level		First Difference	
	Test statistic	P-Value	Test statistic	P-Value
Lngdp	-1.565	0.5009	-5.057	0.000
lnr	-2.313	0.1677	-8.672	0.000
lnw	-2.175	0.2153	-4.886	0.000
lnc	0.711	0.9900	-5.642	0.000
lnp	-1.312	0.6235	-7.342	0.000
lno	-0.204	0.9381	-7.245	0.000

Source: Author's computation using STATA 14 Econometric software.

Table 3: Phillips Perron Test

Variables	Level		First Difference	
	Test statistic	P-Value	Test statistic	p-Value
lngdp	Z(rho) = -0.495 z(t) =-2.019	0.2782	Z(rho) = -25.341 z(t) = -5.054	0.000
lnr	Z(rho) = -5.681 z(t) = -2.132	0.2317	Z(rho) = -37.165 z(t) = -10.397	0.000
lnw	Z(rho) = -9.376 z(t) = -2.203	0.2050	Z(rho) = -21.604 z(t) = -4.925	0.000
lnc	Z(rho) = 1.113 z(t) = 0.904	0.9931	Z(rho) = -30.775 z(t) = -5.636	0.000
lnp	Z(rho) = -4.274 z(t) = -1.277	0.6394	Z(rho) = -37.280 z(t) = -7.331	0.000
lno	Z(rho) = 0.652 z(t) = 0.521	0.9855	Z(rho) = -32.028 z(t) = -8.208	0.000

Source: Author's computation using STATA 14 Econometric software.

From the above two tables, we observe that at levels, the test statistics is less than 5% critical value. Also, we see from these tables that the p values are more than 5% at I (0), which indicates that all variables are non-stationary at level. However, after taking the first difference they become stationary and rejecting the null hypothesis of a unit root. Therefore, from this result we can conclude that all variables are integrated of order one, i.e., I (1).

Section III

Results of Cointegration Test

In time series analysis, variables often exhibit non-stationary, indicates that their statistical properties change over time. This non-stationary time series data can lead to misleading inferences when analysed through standard regression techniques. In such cases, the presence of a long run relationship between non stationary variables can be checked through cointegration analysis. Cointegration implies that although individual time series data may be non-stationary, but a linear combination of these series can be stationary and suggesting a stable long run relationship between these series. There are several types of cointegration tests namely Engle Granger Cointegration test, Phillips-Ouliaris test and Johansen-Juselius cointegration test. In our study, to check the long-run association among agricultural production (i.e., rice, wheat, cereals, pulses and oil seeds) and GDP we conduct the Johansen-Juselius test of cointegration.

The test statistic has two forms.

1. Trace statistic
2. Maximum eigenvalue statistic

From the trace statistic we can evaluate the number of linear combinations (k) in time series data. In this test the null hypothesis is $H_{0:}$ (k=0), against the alternative hypothesis $H_{1:}$ (k>0). The rejection of the null hypothesis confirms the existence of a cointegration relationship among the variables,

On the other hand, the Maximum eigenvalue statistic defines a non-zero vector which, when a linear transformation is applied to it, in this test $H_{0:}$ (k=0), against the alternative hypothesis $H_{1:}$ (k=k_0+1). If the null hypothesis is rejected it means that there is only one possible outcome of the variable to produce a stationary process.

The result of the Johansen-Juselius cointegration test is shown in the following table:

Table 4: Johansen-Juselius cointegration test

Max. Rank	Trace Statistic		Max Statistic	
	Value	5% critical value	Value	5% critical value
0	132.1200	94.15	64.3086	39.37
1	67.8115*	68.52	27.5013	33.46

Source: Author's computation using STATA 14 Econometric soft ware

From the above table, we see that at rank 0 both the trace statistic (132.12) and max statistic (64.30) exceeds their 5% critical values (94.15 and 39.37 respectively), which leads to the rejection of the null hypothesis and indicating at least one cointegrating vector. On the other side, at rank 1 we observe that the trace statistic (67.81) is slightly below from its critical value (68.52), and max statistic (27.50) is also lower than its critical value (33.46). This implies that among the variables one cointegrating relationship exists in our model. Now we are regressing growth rate of GDP (lngdp) on growth rate of rice (lnr), wheat (lnw), cereals (lnc), pulses (lnp) and oil seeds (lno) production.

Source	SS	df	MS			
				Number of obs	=	30
				F(5, 24)	=	107.24
Model	1.2553356	5	.25106712	Prob > F	=	0.0000
Residual	.056186295	24	.002341096	R-squared	=	0.9572
				Adj R-squared	=	0.9482
Total	1.31152189	29	.045224893	Root MSE	=	.04838

lngdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnr	.5805345	.4196067	1.38	0.179	-.2854912	1.44656
lnw	.0553789	.1000599	0.55	0.585	-.1511346	.2618924
lnc	.1542065	.0561312	2.75	0.011	.0383574	.2700557
lnp	-.4219167	.0958432	-4.40	0.000	-.6197273	-.2241061
lno	1.291698	.2562357	5.04	0.000	.7628539	1.820543
_cons	1.934299	1.484203	1.30	0.205	-1.128946	4.997543

Source: Author's computation using STATA 14 Econometric soft ware

From the above results the estimated regression equation can be written as:

lngdp = 1.934299 + 0.585345lnr + 0.0553789lnw +0.1542065lnc+ 0.4219167lnp + 1.291698lno + $€_t$

T-Value = (1.30) (1.38) (0.55) (2.75) (-4.40) (5.04)

P-Value = (0.205) (0.179) (0.585) (0.011) (0.000) (0.000)

R^2= 0.9572; Adjusted R^2=0.9482

The above showing regression results indicate that the model is well fitted to the data which means highly significant (p<0.01) and explains most of the variation (95.72 percent) in the growth of GDP. This result highlights varying impact of different crops production on GDP growth of west Bengal. We see from the above result that the cereals and oilseeds production have a significant positive impact on GDP growth and pulses production exhibits a significant negative relationship with GDP. On the other side, rice and wheat production have no such significant relationship with GDP growth.

Section IV

CUSUM (Cumulative Sum) test

In time series analysis, it is important to check whether the relationship between dependent and independent variables remains stable over time or not. Stability in regression relationships is a crucial assumption when modelling economic phenomena. Structural changes in economic data, whether due to some external shocks or policy implementation, can significantly impact the reliability of regression estimates. To check for stability or structural changes in time series data, there are several tests available, cusum or cumulative sum test is one of them. In our study, the cusum test is applied to examine the stability of the estimated coefficients in the context of the relationship between growth of the GDP and various crops production in west Bengal. Now the result of the cusum test is shown in the following figure:

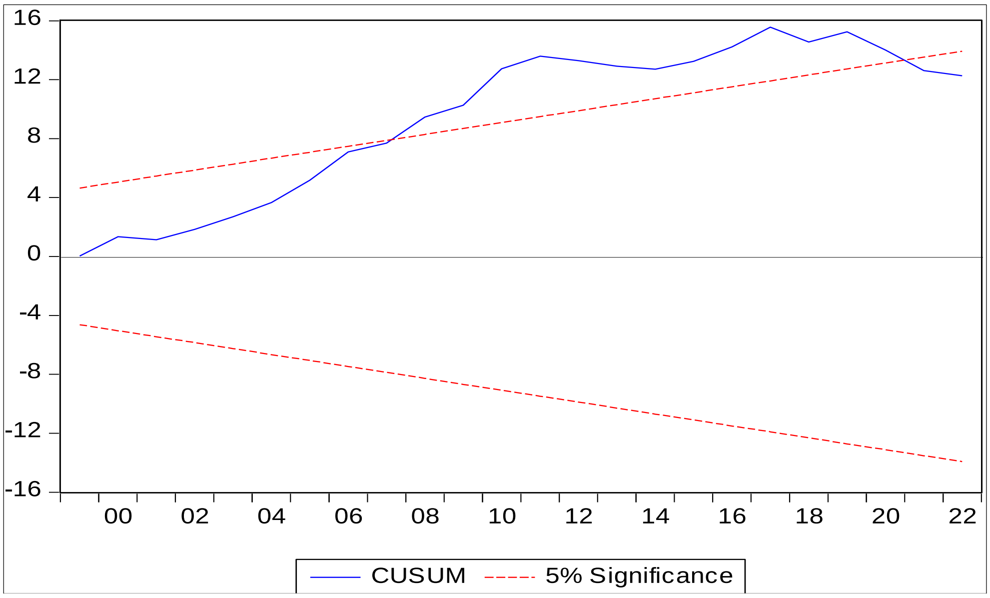

Fig 2: CUSUM Test

In the above figure, the blue line represents the cumulative sum of recursive residuals and the dashed red lines signifies the 5 percent significance bound. According to the test methodology, if the blue line remains within the critical bounds (i.e., between the dashed red lines) the regression coefficients are considered stable. However, if this line crosses the significance boundary, it highlights the structural instability in the model. As we observed from the above figure, the blue line or cumulative sum crosses the upper 5 percent significance bound around period 06 and continues to deviate beyond the threshold. This implies the presence of structural instability in the estimated relationship between agricultural production and GDP over time.

Section V

Residual Diagnostics Test

To ensure the robustness and validity of the estimated regression model, a series of residual diagnostic tests are used. These tests verifying that whether the fundamental assumptions of the ordinary least square (OLS) estimation method are satisfied or not. Residual diagnostic test indicates that the overall specification adopted is satisfactory. Some common residual diagnostic test includes

1. Test for autocorrelation
2. Test for heteroskedasticity

Test for Autocorrelation

Autocorrelation refers to the correlation of error terms across observations, which can lead to inefficient parameter estimates and biased standard errors, affecting statistical inference. In our study, for checking the presence of autocorrelation, we perform Breusch Godfrey Lagrange Multiplier test. In this test the null hypothesis is

H0: No auto correlation in the model

Against the alternative hypothesis

H1: there is a problem of auto correlation

The result of Breusch Godfrey multiplier test is shown in the following table:

Table 5: Breusch-Godfrey LM test for autocorrelation

Lag	Chi2	DF	Prob>chi2
1	0.004	1	0.9515

Source: Author's computation using STATA 14 Econometric soft ware

From the above result we see that the value of chi square is 0.004 with one degree of freedom, and the corresponding p value is 0.9515. Given that the p value is substantially greater than the significance level of 5 percent ($p>0.05$), so we fail to reject the null hypothesis and conclude that there is no autocorrelation problem in our present model.

Test for Heteroskedasticity

Heteroskedasticity arises when the variance of the error term is not constant across observations, violating the OLS assumption of homoskedasticity. This problem can lead to inefficient estimates of parameter and unreliable hypothesis testing due to incorrect standard errors. To detect the presence of heteroskedasticity, we applied Breusch-pagan Godfrey Heteroskedasticity test. In this test, the null hypothesis is

H_0: The variance of the residual is constant (homoskedasticity)

Against the alternative hypothesis is

H_1: The variance of the residual is not constant (heteroskedasticity).

The result of Bruesch Pagan Godfrey test of heteroskedasticity is shown below:

Table 6: Breusch-Pagan/Cook-Weisberg test for heteroskedasticity

chi2	DF	Prob>chi2
1.35	1	0.2449

Source: Author's computation using STATA 14 Econometric soft ware

From the above table we see that the value of Chi square at 1 D.F. is 1.35 with a p value of 0.2449. Since the p value exceeds the conventional significance thresholds of 0.05, so we can accept the null hypothesis and conclude that variance of the residual is constant and there is no heteroskedasticity in the model.

Conclusion

This study analyses past 30 years (1993 to 2022) of time series data to assess the impact of some key crop production on economic development in West Bengal and we found some important findings regarding this. We found from our study that the production of cereals and oilseeds has a significant positive impact on GDP, indicating their crucial role in driving economic growth in West Bengal. However, pulses production exhibits a negative relationship with GDP, implying that some external factors such as market inefficiency or shifting consumer preferences may limit its economic contribution. These results highlight the importance of promoting cereals and oilseeds production while addressing challenges in pulse production to enhance agricultural productivity and overall economic growth.

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