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ARTICLE

Macroeconomic Shifts and Structural Transformation in Indian Agriculture: A Policy-Oriented Perspective

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Abstract

Agriculture remains a vital source of livelihood and an enduring pillar of India's socio-economic and cultural foundation. This study investigates the macroeconomic determinants of agricultural productivity in India using annual time series secondary data for the period 2000–2024. Employing advanced econometric techniques, including the Auto Regressive Distributed Lag (ARDL) model and the bounds testing approach to co-integration, the study examines both the short-run dynamics and long-run equilibrium relationships between agricultural productivity and key macroeconomic variables.

Empirical findings indicate that the inflation rate and interest rate are positively associated with agricultural productivity, suggesting that moderate inflation and credit expansion may incentivize agricultural investment. Conversely, GDP growth, exchange rate depreciation, population growth, gross capital formation, gross domestic savings, public expenditure, export value, and foreign direct investment (FDI) exhibit a negative relationship with the agricultural productivity ratio during the study period.

The study recommends a comprehensive policy framework focusing on: (i) strengthening rural infrastructure and agricultural technology adoption; (ii) enhancing social sector spending, particularly in education and health; (iii) implementing population control measures; (iv) promoting agricultural exports through a competitive exchange rate regime; (v) improving access to affordable credit for farmers; (vi) incentivizing domestic savings and productive investment through tax and subsidy reforms; and (vii) fostering greater public-private partnerships and attracting targeted FDI in the agricultural sector. These measures are critical to unlocking productivity gains and ensuring the long-term sustainability of Indian agriculture within a transforming macroeconomic environment.

Keywords: Agriculture Productivity, Exchange Rate, Inflation, Interest Rate, Breusch-Godfrey Test, Augmented Dickey-Fuller Test

1. INTRODUCTION

Agriculture is one of the oldest and most foundational economic systems globally, and in India, it has remained a vital pillar of livelihood, food security, and cultural identity for millennia. As of 2024, India, with a population exceeding 1.4 billion, stands as the world's most populous country. Its agricultural sector is vast, diverse, and characterized by a multitude of agro-climatic zones, cropping patterns, and farming systems. Despite significant structural changes in the economy, agriculture continues to employ approximately 49.6% of India's workforce, contributing around 17% to the nation's Gross Domestic Product (GDP) (MoSPI, 2023). This discrepancy between employment and income share highlights persistent productivity gaps and structural challenges within the sector.

Since independence, Indian agriculture has witnessed multiple phases of transformation — each shaped by technological innovations, policy shifts, and socio-economic dynamics. In the pre-Green Revolution period (1950 – 1965), Indian agriculture was marked by subsistence farming, low productivity, and vulnerability to food shortages. The Green Revolution (1966 – 1985) introduced high-yielding variety (HYV) seeds, chemical fertilizers, and irrigation expansion, leading to dramatic

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increases in cereal production, especially in wheat and rice. This period laid the foundation for food self-sufficiency, but it was also regionally concentrated and resource-intensive.

The post-Green Revolution era (1986–2000) was characterized by stagnating yield growth, rising input costs, soil fertility depletion, and uneven regional benefits. Despite efforts by the government to modernize agriculture through institutional credit, input subsidies, and rural development programs, systemic challenges such as fragmented landholdings, poverty, low education levels among farmers, and inefficient markets persisted.

Between 2001 and 2015, Indian agriculture entered a phase of gradual reform and modernization. This period saw increasing public and private investments in rural infrastructure, irrigation, mechanization, and agri-extension services. Government initiatives such as the National Horticulture Mission (2005) and Rashtriya Krishi Vikas Yojana (2007) aimed to diversify agriculture beyond cereals to high-value crops, horticulture, and livestock. Furthermore, income augmentation for farmers became a key policy objective, supported by digital outreach and targeted subsidies.

The period from 2016 onward has seen an intensified focus on sustainability, climate-resilient agriculture, and agricultural diversification. Flagship programs such as the Pradhan Mantri Fasal Bima Yojana (PMFBY), Soil Health Card Scheme, Paramparagat Krishi Vikas Yojana, and e-NAM (electronic National Agriculture Market) were launched to improve risk mitigation, soil health, organic farming, and market integration. Simultaneously, digital technologies, precision farming, and climate-smart practices are increasingly promoted to address environmental concerns and resource efficiency.

India's crop production increased from 82 million tonnes in 1965 to approximately 296 million tonnes in 2020, underlining the long-term output growth. The primary drivers of this growth include the expansion of irrigation coverage (which now supports over 50% of gross cropped area), intensified use of fertilizers and agrochemicals, adoption of mechanization, and public investment in agricultural research and technology dissemination (ICAR, 2023). However, these gains are increasingly challenged by climate variability, land degradation, water scarcity, and a growing mismatch between input use and ecological sustainability.

Moreover, globalization and market liberalization have exposed Indian farmers to international price volatility, while integration into global value chains remains limited due to weak post-harvest infrastructure and fragmented supply chains. Despite these obstacles, emerging domains such as organic farming, digital agriculture, agri-tech startups, and precision agriculture offer transformative opportunities for enhancing productivity, sustainability, and farmer incomes.

Against this backdrop, there is a critical need to examine the macroeconomic linkages of Indian agriculture, particularly how variables such as GDP growth, inflation, interest rates, public expenditure, savings, capital formation, and exchange rate movements influence agricultural productivity. Current literature reveals gaps in understanding the systemic macroeconomic drivers of agricultural performance in India, especially in the context of recent technological, climatic, and policy transitions [1-6].

This study aims to bridge these gaps through a comprehensive macroeconomic analysis of trends, patterns, and policy frameworks affecting Indian agriculture from 2000 to 2024. It investigates the short-run and long-run relationships between agricultural productivity and selected macroeconomic indicators, using advanced time series econometric tools. The findings are intended to inform evidence-based policymaking and provide actionable insights to a broad spectrum of stakeholders, including policymakers, researchers, agribusinesses, and farming communities. Given the centrality of agriculture to India's inclusive and sustainable development goals, understanding these interrelationships is essential for designing effective interventions that enhance rural livelihoods, ensure food and nutritional security, and strengthen economic resilience in a globalized world .

2. LITERATURE REVIEW

The relationship between macroeconomic variables and agricultural productivity has been the subject of extensive empirical inquiry, both within India and globally. This review synthesizes contemporary research to elucidate the multidimensional interactions between macroeconomic indicators and agricultural performance.

2.1. Agricultural Growth and Economic Development

Gupta et al. (2022) [7] empirically established a positive correlation between agricultural output and India's overall economic growth, identifying agriculture as a vital contributor to macroeconomic expansion. Trentinaglia et al. (2023) [8] extended this analysis to low-income economies, emphasizing that sustained agricultural growth—fueled by investments in research, infrastructure, and human capital—catalyzes broader economic development. During the COVID-19 pandemic, Kumar et al. (2021) [9] found that agriculture demonstrated remarkable resilience, stabilizing rural economies and underscoring its countercyclical role in macroeconomic stabilization.

2.2. Government Expenditure and Infrastructure

Public spending on infrastructure and social development has been identified as a key driver of agricultural productivity. Rao et al. (2020) and Mukhopadhyay (2022) [10,11] reported a significant rise in government expenditure in India, reaching 12% of GDP by 2018, with notable allocations toward rural infrastructure and welfare programs. These investments are linked to poverty alleviation and improved rural livelihoods. The Reserve Bank of India (2021) affirmed the critical role of infrastructure — particularly in transportation, irrigation, and education — in sustaining long-term economic growth. Furthermore, World Bank (2023) findings highlight that flagship schemes such as PM-KUSUM and the Agriculture Infrastructure Fund (AIF) have stimulated farm-level investments, enhanced rural employment, and contributed to agricultural output expansion, demonstrating a strong linkage between capital expenditure and agrarian performance.

2.3. Monetary Policy, Inflation, and Agricultural Output

Monetary dynamics exert complex influences on agricultural performance. Ogundari (2021) and Sinha (2024) [12,13] observed that GDP growth and access to finance positively impact agricultural output, while inflation and interest rates have adverse effects due to increased input costs and credit constraints. The RBI's study on "Inflation Dynamics in India" (2020) identified food inflation as a principal driver of headline inflation, indicating the necessity for targeted monetary policies to stabilize food prices. Sharma et al. (2021) [14] revealed that global inflation shocks escalate the cost of key agricultural inputs such as fertilizers, reinforcing the urgency of inflation buffering mechanisms and enhanced rural credit availability.

2.4. Exchange Rates and Agricultural Performance

Exchange rate fluctuations significantly influence agricultural trade. Chaudhary (2018) [15] noted that trade liberalization increased productivity and reduced poverty, but also exposed Indian agriculture to exchange rate volatility. Mishra (2021) [16] demonstrated that post-pandemic currency fluctuations affected export competitiveness in key agri-commodities like basmati rice and spices. These findings underscore the importance of effective exchange rate management and hedging mechanisms in sustaining agricultural trade competitiveness.

2.5. Irrigation and Climate Resilience

Water management plays a pivotal role in enhancing climate resilience and productivity. Zaveri and Lobell (2019) [17] quantified the positive impact of irrigation on wheat yield and reduced heat stress, especially under warming climate conditions. G. Kumar (2025) [18] found that micro-irrigation adoption led to an 18–25% improvement in yield resilience against heatwaves and erratic monsoons. Bhatnagar et al. (2024) [19] linked climate-smart agricultural practices such as zero tillage and precision nutrient application to yield stabilization under extreme weather. The IPCC's AR6 (2022) report identified Indian agriculture as highly vulnerable to climate risks and advocated for scalable adaptive strategies, including resilient seed varieties, rainwater harvesting, and agroecological approaches.

2.6. Agricultural Diversification and Productivity

Agricultural diversification has emerged as a strategy to enhance income stability and reduce climatic risks. Singh et al. (2018) [20] documented a structural shift in Indian agriculture from 1991 to 2016, characterized by increased irrigation and a move toward high-value crops, which corresponded with a 10% annual growth in agri-exports. Basantaray, Acharya, and Patra (2024) [21] observed that diversification into horticulture and aquaculture improved household income resilience and reduced income volatility caused by climate shocks. The FAO (2022) further emphasized diversification as a core strategy for agricultural resilience and nutritional security in South Asia, facilitating deeper integration into global value chains.

2.7. Macroeconomic Variables in Global Context

Comparative studies from developing economies reinforce the broader patterns observed in India. Enilolobo et al. (2019) [22] highlighted that inflation volatility adversely impacts agricultural productivity in Nigeria, while the effects of exchange and interest rates remain inconsistent. Eje et al. (2023) and Bhide et al. (2005) [23,24] reported that monetary aggregates such as money supply had statistically insignificant effects, suggesting that structural factors may override monetary influences. The World Bank (2021) noted that post-pandemic macroeconomic shocks in sub-Saharan Africa disrupted food security via inflation and supply chain fragmentation. UNCTAD (2022) emphasized that macroeconomic stabilization must be complemented by climate resilience and digital inclusion policies for effective transformation in agriculture.

2.8. Structural Transformation and Agricultural Intensification

Post-1991 economic liberalization triggered significant structural shifts in Indian agriculture. The sector transitioned from traditional subsistence to more capital-intensive and knowledge-driven systems. Despite increased mechanization, agriculture's share in GDP declined from 30% in 1981 to 16.5% in 2019 (Sinha, 2017; Bustos et al., 2019) [25-27], reflecting a shift toward services and manufacturing. Mani (2025) [28] documented rapid digitalization and mechanization, with a threefold rise in Agri Tech investments post-2020. However, Opala et al. (2025) [29] identified persistent regional disparities in access to digital technologies, calling for inclusive and region-specific digital transformation strategies. The OECD-FAO Outlook (2023 – 2032) projected that sustainable intensification via precision agriculture, AI-based forecasting, and traceable value chains will be critical for future productivity gains.

2.9. Digital Agriculture and Technological Innovation

Digital innovations are redefining the agricultural landscape. The World Bank (2022) introduced "Agri Tech 2.0," which integrates digital platforms for market access, real-time advisories, and logistics optimization. Singh et al. (2022) [30] evaluated India's Digital Agriculture Mission, identifying benefits such as reduced transaction costs, enhanced input use efficiency, and early pest detection. Lahiri et al. (2024) [31] showed that smartphone-based advisories improved decision-making and profitability by 10–15% among farmers in Uttar Pradesh and Maharashtra. The Indian Council of Agricultural Research (ICAR) (2023) launched e-Krishi Pathshala, an initiative with significant potential to bridge the rural-urban knowledge divide, particularly in tribal and semi-urban areas.

The reviewed literature reveals that agricultural productivity is intricately linked to a range of macroeconomic variables, including public expenditure, inflation, monetary policy, and trade dynamics. Concurrently, adaptive strategies—particularly those rooted in digital innovation and climate-smart practices—are essential to safeguard productivity under increasing macroeconomic and climate-related uncertainties. Recent findings point toward a structural evolution of Indian agriculture, wherein technological diffusion, financial inclusion, and policy targeting have become central to productivity and resilience. However, regional disparities in infrastructure, climate vulnerability, and digital access highlight the need for decentralized, context-sensitive policy frameworks.

3. RESEARCH GAPS IN THE MACROECONOMIC DETERMINANTS OF AGRICULTURAL PRODUCTIVITY IN INDIA

Despite a substantial body of literature examining the drivers of agricultural productivity in India, critical gaps remain in the empirical understanding of how macroeconomic variables influence sectoral performance. A more integrative and methodologically robust approach is required to address these gaps and inform targeted policy interventions for sustainable agricultural development and macroeconomic stability [32–38].

3.1. Limited Integration of Comprehensive Macroeconomic Variables

While prior studies have extensively examined micro-level factors such as irrigation coverage, input usage, and credit access [39–48], there is a notable dearth of research integrating macroeconomic variables into holistic analytical frameworks. Key indicators — such as inflation, exchange rate volatility, interest rates, fiscal spending composition, and public debt—are often examined in isolation or omitted altogether. This fragmented approach limits the capacity to assess the systemic influence of macroeconomic fluctuations on agricultural productivity. A unified macroeconomic model that captures these interdependencies remains largely underdeveloped in the Indian context.

3.2. Underexplored Role of Financial Development

The expanding financial ecosystem in India, spurred by banking reforms, digital payments, and microfinance, has potential implications for agricultural investment and productivity. Yadav and Goyari (2024) [49] empirically demonstrated a positive correlation between financial development and crop productivity; however, broader investigation into the channels through which financial deepening (e.g., credit access, insurance penetration, interest rate dynamics) influences farm-level outcomes remains limited. The lack of longitudinal and disaggregated studies on the impacts of financial sector reforms on agriculture constitutes a significant research omission.

3.3. Neglect of Climate and Environmental Macroeconomic Interactions

Climate change-induced variables such as rising CO_2 emissions, temperature variability, and extreme weather frequency have macroeconomic implications for agriculture, particularly in rain-fed regions. Yet, empirical studies quantifying these environmental shocks within macroeconomic modeling frameworks are scarce. Most existing literature treats climate risks as externalities rather than endogenous variables within agricultural productivity models. This omission weakens predictive capacity and hinders the design of climate-resilient agricultural strategies tailored to India's vulnerability profile.

3.4. Underrepresentation of Technological and Infrastructure Determinants

Despite evidence linking technology adoption and infrastructure development to productivity gains, these variables are often treated as auxiliary rather than central determinants in macroeconomic-agricultural models. Parameters such as mechanization intensity, rural road density, ICT penetration, and access to digital agronomic advisories remain underrepresented in empirical work. Including these factors in econometric analyses would improve the explanatory power of models and better reflect structural transformation trends in Indian agriculture.

3.5. Lack of Region-Specific Econometric Analyses

India's agro-economic heterogeneity, spanning varied climatic zones, soil types, cropping patterns, and governance structures, necessitates regionally nuanced analysis. However, most macroeconomic studies rely on national-level or pooled panel data, which often mask intra-state disparities and policy effectiveness. The absence of disaggregated, state- or district-level econometric modeling restricts the granularity of insights needed for targeted policymaking and adaptive interventions under federal decentralization.

3.6. Methodological Limitations and Underutilization of Advanced Econometrics

Many extant studies employ static or linear regression models that fail to capture dynamic feedback loops and long-run equilibrium relationships between macroeconomic and agricultural variables. Sophisticated econometric techniques—such as Vector Error Correction Models (VECM), Autoregressive Distributed Lag (ARDL) frameworks, panel cointegration methods, and nonlinear causality tests—remain underused. The application of these tools can significantly improve the rigor and robustness of causal inference in macro-agricultural studies.

Bridging these research gaps is imperative for generating nuanced insights into the interplay between macroeconomic conditions and agricultural productivity in India. Future research agendas should adopt integrative frameworks that synthesize economic, technological, environmental, and spatial dimensions. Emphasis should be placed on employing advanced econometric methodologies and generating region-specific evidence to support the design of differentiated and adaptive policy measures. Such an approach is essential not only for enhancing agricultural output but also for promoting inclusive and resilient economic development.

4. OBJECTIVE OF THE STUDY

This study aims to systematically examine the intricate relationship between agricultural productivity and macroeconomic variables in India. The specific objectives are:

i.) To investigate the trends, patterns, and drivers of agricultural productivity in India: This involves analyzing the historical and current trajectories of agricultural output, identifying key factors such as technological advancements, irrigation infrastructure, and policy interventions that have influenced productivity levels.

ii.) To analyze the impacts of macroeconomic variables on agricultural productivity in India: This objective focuses on assessing how macroeconomic indicators, such as inflation rates, interest rates, exchange rates, and fiscal policies, affect agricultural productivity. Understanding these impacts will provide insights into the broader economic forces shaping the agricultural sector.

iii.) To determine the relationship between agricultural productivity and macroeconomic elements in India: This entails establishing the nature and strength of the relationships between agricultural productivity and various macroeconomic factors, employing econometric models to quantify these associations and discern causality where applicable.

By achieving these objectives, the study seeks to contribute to a nuanced understanding of the macroeconomic determinants of agricultural productivity in India, thereby informing policy decisions aimed at enhancing the sector's performance and resilience.

5. RESEARCH METHODOLOGY

This study employs a quantitative econometric approach to analyze the relationship between macroeconomic variables and agricultural productivity in India over the period 2000 – 2024. The primary objective is to assess both short-run and long-run dynamics using the Autoregressive Distributed Lag (ARDL) modeling framework, which is well-suited for time series data with variables integrated of order I (0) and I (1).

5.1. Data Sources

The analysis utilizes annual time series data sourced from reputable national and international databases:

i) Ministry of Finance, Government of India
ii) Ministry of Agriculture and Farmers Welfare
iii) Reserve Bank of India (RBI)
iv) National Sample Survey Office (NSSO)
v) Indian Agricultural Statistics Research Institute
vi) International Monetary Fund (IMF)
vii) World Bank.

The study period spans from 2000 to 2024, ensuring a comprehensive temporal coverage to capture the evolving dynamics between the variables.

5.2. Variable Specification

Dependent Variable: Agricultural Productivity (AGDP): Measured as the ratio of agricultural output to Gross Domestic Product (GDP), serving as a proxy for sectoral productivity.

Independent Variables:

GDP Growth Rate (GDPGR): Annual percentage growth rate of GDP at market prices.

Inflation Rate (INF): Measured by the Consumer Price Index (CPI).

Interest Rate (INT): Lending interest rate as a percentage.

Exchange Rate (EXR): Official exchange rate (local currency units per US dollar).

Population (POP): Total population, reflecting labor availability and consumption demand.

Gross Capital Formation (GCF): Gross capital formation as a percentage of GDP.

Gross Domestic Savings (GDS): Gross domestic savings as a percentage of GDP.

Public Expenditure (PEXP): Government expenditure on agriculture and allied sectors.

Value of Exports (XPT): Total value of agricultural exports.

Foreign Direct Investment (FDI): Net inflows of investment to acquire a lasting management interest.

5.3. Econometric Methodology

The ARDL modeling approach is employed due to its flexibility in handling variables with mixed integration orders (I (0) and I (1)) and its effectiveness in small sample sizes. The methodological steps include:

Stationarity Testing: The Augmented Dickey-Fuller (ADF) test is applied to ascertain the order of integration for each variable.

Model Specification: The ARDL model is specified as follows:

$$AGDPt = \alpha_0 + \Sigma\beta_1 i * AGDP\_\{t-i\} + \Sigma\beta_2 i * GDPGR\_\{t-i\} + \Sigma\beta_3 i * INF\_\{t-i\} + \Sigma\beta_4 i * INT\_\{t-i\} + \Sigma\beta_5 i * EXR\_\{t-i\} + \Sigma\beta_6 i * POP\_\{t-i\} + \Sigma\beta_7 i * GCF\_\{t-i\} + \Sigma\beta_8 i * GDS\_\{t-i\} + \Sigma\beta_9 i * PEXP\_\{t-i\} + \Sigma\beta_{10} i * XPT\_\{t-i\} + \Sigma\beta_{11} i * FDI\_\{t-i\} + \varepsilon t$$

Where:

AGDPt: Agricultural productivity at time t

$\beta_1 i...\beta_{11} i$: Coefficients of lagged variables

εt: Error term

Cointegration Testing: The Bounds Testing approach is utilized to determine the existence of a long-run relationship among the variables.

Short-run and Long-run Estimation: Upon establishing cointegration, the Error Correction Model (ECM) is derived to capture short-run dynamics, while long-run coefficients are estimated to understand the equilibrium relationships.

Diagnostic Tests: To ensure the robustness of the model, several diagnostic tests are conducted:

Serial Correlation: Breusch-Godfrey LM test

Heteroskedasticity: Breusch-Pagan-Godfrey test

Normality: Jarque-Bera test

Model Stability: Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests

5.4. Software Utilization

The econometric analyses are performed using EViews software, which offers comprehensive tools for time series analysis, including ARDL modeling and diagnostic testing.

5.5. Justification for Methodology

The choice of the ARDL approach is justified by its advantages in dealing with small sample sizes and mixed integration orders, as well as its ability to provide unbiased long-run estimates and valid t-statistics even when some regressors are endogenous.

By employing this methodological framework, the study aims to provide a nuanced understanding of how macroeconomic variables influence agricultural productivity in India, offering valuable insights for policymakers and stakeholders in the agricultural sector.

6. ANALYSIS OF THE STUDY

6.1. Unit Root Test of Stationarity

Table 1 presents the results of the unit root tests conducted to assess the stationarity of the time series data for both the dependent and explanatory variables. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed to determine the presence of unit roots in the series at levels and first differences.

The results indicate that the GDP growth rate and inflation rate are stationary at the level, with their p-values statistically significant at the 5% level under both ADF and PP tests. In contrast, other variables—including interest rate, exchange rate, population, gross capital formation, gross domestic savings, public expenditure, exports, and foreign direct investment—are found to be non-stationary at level but become stationary after first differencing, implying that they are integrated of order one, I(1).

Lag Length Selection for ARDL Model: To determine the optimal lag structure for the Autoregressive Distributed Lag (ARDL) model, several information criteria were considered: the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the Hannan-Quinn Information Criterion (HQIC). The appropriate lag order is identified based on the minimum values of these criteria.

Following a series of estimations, the optimal ARDL model was selected as ARDL (1, 1, 1, 1, 1, 1, 1, 1, 1), which indicates one lag for each of the variables included in the model. This specification demonstrated the lowest values across AIC, BIC, and HQIC, suggesting it is the most suitable for further econometric analysis.

[H0 = Data are Stationary, (unit root), H1 Data are Non-Stationary, (No Unit root)]

Table 1. ADF and PP unit Root test results for stationarity of data from 2000 -2024.

Variables	Augmented Dickey-Fuller (ADF) Test		Phillip Parron (PP) Test	
	Level	1st Difference	Level	1st Difference
AGDP	-2.0765(0.2184)	-1.0012(0.7003)	-2.3533(0.1366)	-6.2542(0.0000) ***
INF	-3.5179(0.0113)	-8.2410(0.0000)***	-3.5962(0.0094)***	-8.2048(0.0000) ***
INT	-1.8482(0.3069)	-5.6793(0.0000) ***	-2.0944(0.2122)	-6.6937(0.0000) ***
NXR	-0.3046(0.9113)	-5.3200(0.0001) ***	-0.3274(0.9124)	-5.3183(0.0002) ***
GDPGR	-5.3501(0.0001) ***	-7.2620(0.000) ***	-5.4106(0.0001) ***	-10.01048(0.0000) ***
XPT	-1.3761(0.5108)	-5.5308(0.0001) ***	-1.3750(0.5713)	-5.5461(0.0001) ***
PEXP	3.6520(0.121)	-6.4025(0.0000) ***	-3.5146(0.0132) ***	-13.7318(0.0000) ***
POP	1.3379(0.5891)	-5.2026(0.0002)***	-1.4221(0.5484)	-5.2026(0.0002)***
DSAV	-1.2572(0.6268)	-5.0033(0.0003)***	-1.3326(0.5971)	-5.0551(0.0003)***

GCF	-1.5362(0.4968)	-5.1424(0.0002)***	-1.5262(0.4968)	-5.1229(0.0002)***
FDI	-2.2053(0.2019)	-6.0697(0.000)***	-2.1655(0.2153)	-6.6643(0.0000)***

Sources: Author's calculation using EVIEWS. Level of significance- *, **, ***, 10%,5%, 1*% % respectively

6.2. ARDL Model Estimation Results

Table 2 presents the estimated coefficients of the ARDL model, where agricultural productivity serves as the dependent variable, and GDP growth rate, inflation rate, interest rate, exchange rate, population, gross capital formation, gross domestic savings, public expenditure, exports, and foreign direct investment are included as explanatory variables. The analysis covers the period from 2000 to 2024.

The estimated coefficients for the inflation rate (0.1320%), interest rate (0.0522%), and public expenditure (0.0697%) are positive but statistically insignificant at the 5% level. These values reflect elasticities of less than one, indicating that a 1% increase in inflation, interest rates, and public expenditure is associated with an increase in agricultural productivity by 0.1320%, 0.0522%, and 0.0697%, respectively.

The positive association of inflation with agricultural productivity may be attributed to rising input costs, such as seeds, fertilizers, and labor, driven by overall price level increases. Similarly, changes in lending interest rates influence investment decisions in agriculture and other sectors, potentially impacting productivity through shifts in capital availability. Furthermore, the effectiveness of public expenditure is influenced by both the adequacy and distribution of funds; insufficient and uneven allocation of public resources can constrain agricultural development and limit productivity gains.

Table 2. Results of the Auto Regressive Distributive (ARDL) model.

ARDL Cointegration in the short run				
Cointegration Form				
Variables	Coefficient	Std. Error	T-Statistic	Prob.
AGP(-1)	0.3053	0.1370	2.1344	0.0388
INF	0.1320	0.0625	1.9603	0.0701*
INT	0.0522	0.1195	0.0521	0.6106
INT (-1)	0.1451	0.1155	1.2561	0.2283
EXR	-0.1001	0.0689	-1.4519	0.1761
GDPGR	-0.0617	0.0515	-1.1965	0.2501
XPT	-0.0885	0.0850	-1.0349	0.3174
PEXP	0.0697	0.0866	0.9207	0.3718
PEXP (-1)	-0.3261	0.0836	-3.659	0.0023***

POP	-0.0124	0.0036 *	-3.9654	0.0012***
POP (-1)	-0.1514	0.0037	4.0552	0.0010***
DSAV	-0.0703	0.1271	-0.5535	0.5880
GCF	-0.0901	0.0694	-1.2986	0.2137
FDI	-0.09628	0.3186 *	-3.0261	0.0085***
C	24.7389	8.1725	3.0270	0.0085***
R 2:- 0.972492; Adj-R 2 : 0.9624; Log. Like-lihood : - 11.2700; DW: - 2.908524 ; F-Statistics: 117.2335; H Q :- 1.9573; & AIC-1.7326.				

Sources: Author's calculation using EVIEWS, significant at *** 1 %; ** 5%; & * 10% levels.

Interpretation of ARDL Coefficients (Negative Relationships): The estimated coefficients for exchange rate, GDP growth rate, exports, gross domestic savings, and gross capital formation exhibit a negative relationship with agricultural productivity in India over the period 2000–2024. However, these relationships are statistically insignificant at the 5% level, suggesting that variations in these macroeconomic indicators do not exert a strong or consistent influence on agricultural productivity during the study period.

In contrast, the coefficients for public expenditure, population, and foreign direct investment (FDI) demonstrate a negative and statistically significant relationship with agricultural productivity at the 5% significance level. Specifically, a 1% increase in public expenditure, population, and FDI is associated with a decline in agricultural productivity by 0.3261%, 0.0124%, and 0.0085%, respectively. These elasticities are all less than one, indicating inelastic responses.

The negative impact of population growth on agricultural productivity may be attributed to increasing demographic pressure, leading to fragmentation of landholdings, overuse of natural resources, and strain on rural infrastructure. The inverse relationship between FDI and agricultural productivity could reflect structural imbalances, where foreign investment is directed more toward non-agricultural sectors, resulting in limited spillover benefits to agriculture. Similarly, public expenditure—if inadequately targeted or inefficiently allocated—may fail to translate into productivity gains in the agricultural sector.

Overall, the study finds that only FDI, public expenditure, and population exert a statistically significant influence on agricultural productivity, while the effects of other macroeconomic variables remain statistically insignificant. Furthermore, all estimated coefficients are inelastic (less than one), indicating that changes in these explanatory variables induce proportionally smaller changes in agricultural productivity over the study period.

6.3. Bound Test for Co-integration

Table 3 reports the results of the ARDL bounds testing approach to co-integration, assessing the existence of a long-run relationship between agricultural productivity (dependent variable) and the selected macroeconomic indicators — GDP growth rate, inflation rate, interest rate, exchange rate, population, gross capital formation, gross domestic savings, public expenditure, exports, and foreign direct investment (independent variables)—over the period 2000–2024.

The computed F-statistic value of 4.7242 exceeds both the lower bound (1.96) and upper bound (3.24) critical values of the Pesaran test at the 5% significance level, with K = 10 (number of regressors). This result leads to the rejection of the null hypothesis of "no long-run relationship" among the variables.

Hence, the test confirms the existence of a statistically significant long-run equilibrium relationship between agricultural productivity and the set of explanatory macroeconomic variables included in the model. This finding justifies the application of long-run ARDL modeling to further explore the nature and strength of these relationships.

[Null Hypothesis: No long-run Relationship.]
Table 3. Results of the bound test.

Test Statistics	Value	K	Bound Test	
			Lower Bound	Upper Bound
F-Statistics	4.7242	10	1.96	3.24
Result: Null Hypothesis of No Long Run Relationship rejected.				

Source: Computed from E-views software

6.4. Granger Causality Test and Heteroscedasticity Test results

[H0: Homoscedasticity, H1: Heteroscedasticity.]
Table 4. Results of Heteroscedasticity Test: Bruesch Pagon Godfray test.

F-Staststics: 0.8512	Prob.F(17,11): 0.6355
Obs*R-Squared: 16.3265	Prob-Chai-Square (17): 0.5322
Scaled Explained: 2.7084	Prob-Chai-Square (17): 1.0000

Source: Computed from E-views software

Granger Causality Test: The Granger causality test was employed to examine the direction of causality among the selected macroeconomic variables and agricultural productivity, helping to identify predictive relationships between the time series. The results indicate that:

i.) Public expenditure does not Granger-cause agricultural productivity.
ii.) The population does not Granger-cause the interest rate.
iii.) Exchange rate does not Granger-cause inflation.
iv.) Exports do not Granger-cause the interest rate.
v.) These findings are statistically significant at the 5% level, confirming the absence of unidirectional Granger causality in the above pairs. For the remaining variable combinations, the test revealed weak or negligible causal linkages, suggesting limited predictive power between those variables over the study period.
vi.) Overall, the causality analysis implies that while some macroeconomic variables may be associated with agricultural productivity and related indicators, they do not necessarily cause changes in one another in a temporal or predictive sense.

Heteroscedasticity Test (Breusch-Pagan-Godfrey): To test for the presence of heteroscedasticity in the residuals of the regression model, the Breusch-Pagan-Godfrey test was conducted. The null hypothesis (H_0) assumes homoscedasticity (constant variance of residuals), while the alternative hypothesis (H_1) posits the presence of heteroscedasticity.

The test results show that the probability value of Obs*R^2 = 0.5122, which is greater than the 5% significance level ($p > 0.05$). Therefore, the study fails to reject the null hypothesis and concludes that the residuals exhibit homoscedasticity. This implies that the variance of the error terms remains constant over time, satisfying one of the key assumptions of classical linear regression.

The finding supports the reliability of the estimated model, as the homoscedastic nature of the residuals suggests that the variability in the dependent variable (agricultural productivity) is consistently explained by changes in the independent variables across the study period.

6.5. Autocorrelation Test

The study employs annual time-series data from 2000–01 to 2023–24 to examine the evolving trends, patterns, and determinants of agricultural productivity in India. As part of the diagnostic checking of the estimated model, the Breusch-Godfrey Serial Correlation LM Test was utilized to assess the presence of autocorrelation in the residuals.

The test was applied to determine whether there is any serial correlation between the residuals of the regression equation, where agricultural productivity is the dependent variable, and GDP growth rate, inflation rate, lending interest rate, exchange rate, population, gross capital formation, gross domestic savings, public expenditure, exports, and foreign direct investment serve as independent variables.

The test result indicates that the probability value of the Chi-square statistic is 0.0008, which is less than the 5% significance level ($p < 0.05$). This leads to the rejection of the null hypothesis of no serial correlation, suggesting the presence of first-order autocorrelation in the model's residuals.

The existence of autocorrelation implies that the error terms are not independent across periods, potentially violating a key classical assumption of the Ordinary Least Squares (OLS) framework. This may lead to inefficient estimates and underestimated standard errors, affecting the validity of statistical inference.

To address this issue, remedial measures such as model re-specification, the inclusion of additional lags, or the use of robust standard errors may be considered to improve model reliability and inference accuracy.

[Null Hypotheses H0: Serial Correlation
Alternative Hypotheses H1: No Serial Correlation]

Table 5. Serial correlation LM of the selected ARDL model.

F-Staststics: 4.7522	Prob.F(2,9): 0.0371
Obs*Rquare (R2):14.9057	Prob-Chai Square-(2): 0.0008

Sources: Calculation using EVIEWS.

7. CONXLUSION

This study empirically investigates the relationship between agricultural productivity and key macroeconomic variables in India over the period 2000–2024 using annual time-series data. Employing robust econometric techniques—including the Augmented Dickey-Fuller (ADF) test for stationarity, Johansen and ARDL bounds testing for co-integration, and the Breusch-Godfrey test for autocorrelation—the research estimates both short-run and long-run dynamics within an ARDL framework.

The findings reveal that inflation rate, interest rate, and lagged public expenditure exhibit a positive but statistically insignificant association with agricultural productivity, suggesting that these variables may support productivity gains under certain conditions. Conversely, GDP growth rate, exchange rate, population, gross capital formation, domestic savings, public expenditure (in levels), exports, and foreign direct investment show a negative relationship with agricultural productivity. Among these, public expenditure, foreign direct investment, and population growth have a statistically significant negative impact at the 5% level. Notably, the elasticity of all variables remains below unity, indicating inelastic responses of agricultural productivity to macroeconomic fluctuations.

These findings underscore the complex and often nonlinear interaction between macroeconomic policy variables and agricultural outcomes in India. While macroeconomic stability and investment are necessary, the effectiveness of these interventions depends on their structure, sectoral allocation, and policy implementation mechanisms.

8. RECOMMENDATIONS

Based on the empirical results, the following key recommendations are made:

8.1. Invest in Agricultural Infrastructure and Technology

Modernizing irrigation systems, rural roads, cold chains, and post-harvest management can significantly boost agricultural productivity. Public investment should be restructured toward capital-intensive and productivity-enhancing infrastructure.

8.2. Promote Inclusive Public Expenditure

Given the negative impact of poorly targeted public expenditure, the government must prioritize outcome-based spending in agriculture, especially in research, extension services, and climate-resilient practices, rather than generalized subsidies.

8.3. Stabilize Population Growth

The adverse effect of population pressure necessitates effective demographic policies, including investments in education, health, and family planning programs in rural areas.

8.4. Redirect and Optimize FDI in Agriculture

Although FDI currently shows a negative relationship, this can be transformed through policy incentives that channel foreign investments into agri-tech startups, rural logistics, sustainable farming, and value-chain development.

8.5. Control Inflation and Manage Interest Rates Prudently

While inflation and borrowing rates show a positive (though insignificant) impact, policies should aim to maintain moderate inflation and ensure access to affordable credit, particularly through targeted agricultural lending programs.

8.6. Enhance Export Competitiveness and Manage Exchange Rate Volatility

Strategic exchange rate management is essential to preserve the competitiveness of Indian agricultural exports. Trade policies should also support value-added agri-products and reduce non-tariff barriers.

8.7. Encourage Domestic Savings and Capital Formation

Through fiscal instruments such as tax rebates, subsidies, and targeted investment schemes, the government can stimulate rural savings and channel them into productive agricultural ventures.

9. POLICY IMPLEMENTATIONS

To translate the above recommendations into actionable policies, the following strategies should be adopted:

9.1 National Agricultural Infrastructure Modernization Program (NAIMP)

Launch a centrally coordinated scheme with state-level implementation to build and upgrade agri-infrastructure, especially in underserved regions. Leverage PPP (Public-Private Partnerships) and multilateral funding mechanisms.

9.2 Outcome-Oriented Budgeting in Agriculture

Redesign agricultural public expenditure within the Union and State budgets to align with measurable productivity outcomes. Introduce a Performance-Based Grant System (PBGS) to incentivize efficient states.

9.3 Agri-FDI Facilitation Cells

Establish dedicated units within Invest India to screen, support, and monitor agriculture-specific FDI projects, ensuring alignment with rural employment, sustainability, and technology transfer goals.

9.4 Inflation Monitoring and Credit Access Reforms

Set up an Agricultural Credit MonitoringDashboard at the RBI to ensure effective transmission of interest rate changes to the farm sector and avoid credit rationing to smallholders.

9.5 Exchange Rate Stabilization Fund for Agri-Exports

Provide hedging support to exporters and create a stabilization fund to absorb short-term exchange rate shocks affecting agri-exporters.

9.6 Rural Savings and Investment Promotion Scheme (RSIPS)

Launch a targeted campaign to boost rural household savings through agri-savings bonds and link them with local cooperatives and farmer-producer organizations for reinvestment in productive assets.

9.7 Population Management Task Force (PMTF)

Integrate demographic control within rural development frameworks, linking fertility reduction targets with incentives in education and employment schemes.

These integrated policy efforts, if well-executed, can significantly improve the structural conditions of Indian agriculture, enhance productivity, and contribute to inclusive rural economic growth.

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