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Impact of Agricultural Marketing and CO_2 Emissions on Agricultural Productivity in India: Evidence from Time-Series Data

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ABSTRACT
This study analyses the impact of agricultural marketing and CO_2 emissions on agricultural productivity in India using time-series data. Employing the Dynamic Ordinary Least Squares (DOLS) approach, the study examines long-run relationships while controlling for fertilizer consumption, irrigation, and economic growth. The results indicate that CO_2 emissions have a significant negative effect on agricultural productivity, reflecting the adverse influence of climate-related environmental stress. Fertilizer consumption shows a weakly negative relationship, suggesting diminishing returns from inefficient input use. In contrast, agricultural marketing development and irrigation positively and significantly enhance productivity, while economic growth also contributes favourably. The findings highlight the importance of strengthening agricultural marketing systems, promoting climate-resilient practices, encouraging balanced input use, and expanding sustainable irrigation to achieve long-term productivity growth in Indian agriculture.
Keywords: ARDL, DOLS, CO2 emissions, Agriculture, Economic Growth.

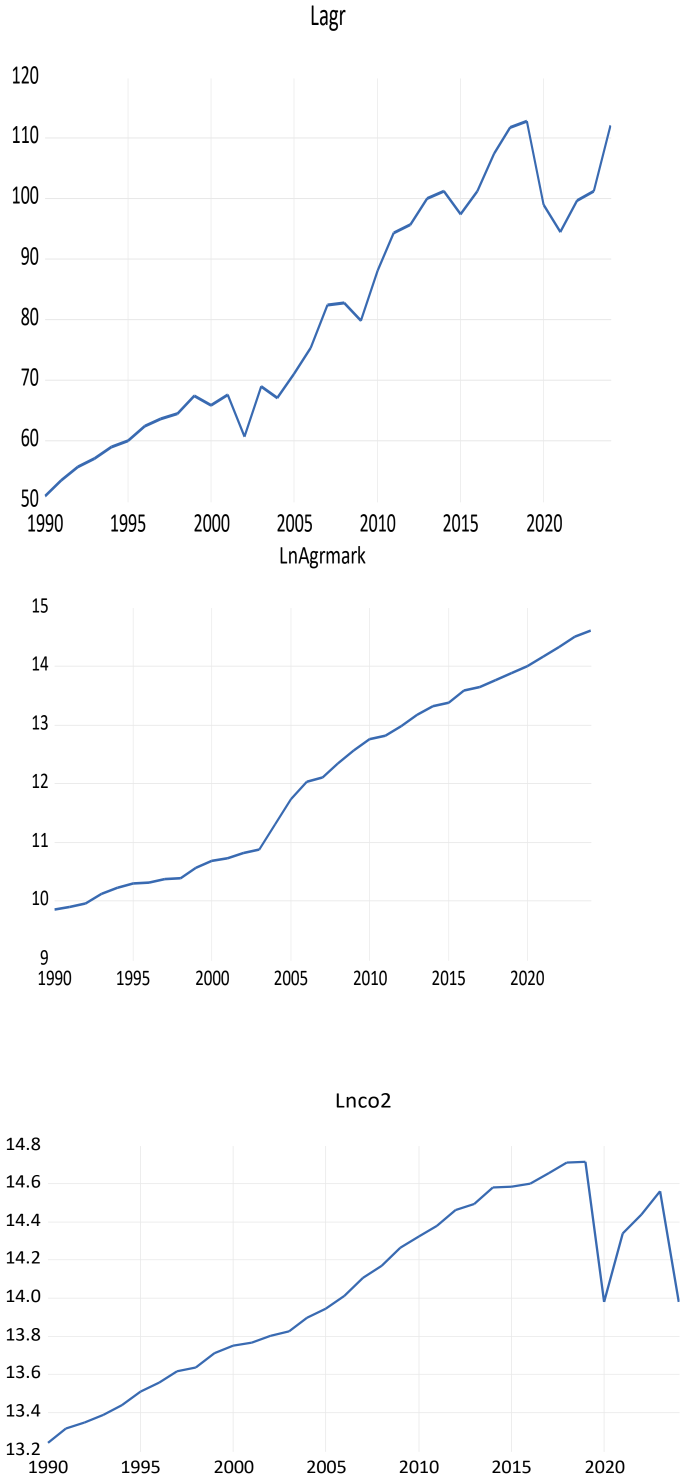
INTRODUCTION:

Agriculture remains a critical sector of the Indian economy, making a substantial contribution to rural subsistence, food security, and employment (Sahu & Choudhary, 2025). Despite the fact that agriculture's proportion of the Gross Domestic Product (GDP) has decreased over time, it continues to provide support for a significant portion of the population. Consequently, the enhancement of agricultural productivity is a critical policy issue. In the face of declining landholdings, increasing uncertainty due to environmental and climatic changes, and increasing population pressure, sustained productivity growth is imperative (Panagariya, 2025). As a result, it is imperative to comprehend the economic and environmental determinants of agricultural productivity in order to guarantee the long-term sustainability of the agricultural sector in India. Agricultural production is impacted by a variety of structural and institutional variables, including agricultural marketing. Efficient agricultural marketing systems promote price discovery, lower transaction and post-harvest losses, and increase access to input and product markets. Improved marketing efficiency motivates farmers to embrace new technology and engage in productivity-enhancing techniques by increasing farm incomes and lowering market risks (Acharya & Agarwal, 2016). In contrast, insufficient marketing infrastructure, knowledge asymmetry, and high intermediation costs can reduce incentives for production and technological adoption, limiting productivity development. Since the early 1990s, India's agricultural marketing sector has experienced significant transformations due to economic liberalization and market-oriented reforms. Policy measures designed to fortify regulated markets, augment storage and warehousing capabilities, promote rural road connections, and advocate for digital marketing platforms aim to improve market efficiency and farmer engagement. Empirical research indicates that enhanced market access and superior marketing infrastructure correlate favourably with agriculture commercialization and productivity growth (Birthal et al., 2015). The productivity enhancements resulting from marketing changes are not consistent across areas and may be affected by overarching structural and environmental factors. Simultaneously, Indian agriculture encounters escalating environmental pressures attributed to climate change and heightened carbon dioxide (CO_2) emissions. The rapid industrialization, urbanization, and increasing energy requirements have resulted in a significant escalation of CO_2 emissions in India during recent decades. These emissions exacerbate climate change by elevating temperatures, modifying precipitation patterns, and increasing the incidence of extreme weather events. India's significant reliance on monsoon precipitation renders agricultural production especially susceptible to climate fluctuations (IPCC, 2022).

Despite substantial study on agricultural marketing and climate change, the two topics are frequently discussed separately in the literature. Agricultural productivity studies often emphasize market access, pricing incentives, and institutional changes, whereas climate studies focus on factors such as emissions, temperature, and rainfall. This division makes it difficult to have a thorough knowledge of how market efficiency and environmental deterioration interact to impact agricultural productivity. From a sustainable development standpoint, productivity gains resulting from improved marketing mechanisms may be undercut by increased environmental stress, raising worries about agricultural growth's long-term sustainability. The relationship between agricultural marketing and CO_2 emissions may be interpreted in the context of sustainable and endogenous growth theories. Efficient marketing systems boost productivity by better allocating resources and enabling technology diffusion, but growing emissions raise production risk and diminish factor productivity over time. The total influence on agricultural output is determined by how these conflicting pressures balance out. An comprehensive empirical study is thus required to determine if improvements in agricultural marketing can sustain productivity gains in the face of rising environmental concerns. This study studies the influence of agricultural marketing and CO_2 emissions on agricultural production in India using a time-series approach. By capturing both long-run linkages and short-run dynamics, the study adds to the literature by combining economic and environmental variables in a single empirical model. The findings are intended to give useful insights for developing policies that encourage efficient agricultural markets while reducing the negative consequences of environmental degradation, hence promoting sustainable agricultural growth in India.

The trend of agricultural productivity, CO2 emissions and agricultural marketing is shown in figure 1.

Figure 1: Trend Graphs



Source: Author's Estimation

LITERATURE REVIEW

Agricultural Productivity and CO_2 Emissions

Research indicates that agricultural productivity is substantially impacted by increasing CO_2 emissions, which have a significant impact on temperature and precipitation patterns, particularly in climate-sensitive economies (Hordofa, 2025; Singh et al., 2025). Although certain experimental studies suggest that CO_2 fertilization may improve crop yields, empirical evidence from developing countries suggests that the adverse effects of climate variability including increased pest incidence, water scarcity, and heat stress are more prevalent (Lobell et al., 2011). The vulnerability of agriculture to environmental degradation is underscored by time-series and panel studies that concentrate on India and other emerging economies, which reveal a negative long-term relationship between CO_2 emissions and agricultural productivity (Guntukula, 2020). These results emphasize the significance of incorporating environmental indicators into the analysis of agricultural productivity dynamics.

Agricultural Productivity and Economic Growth

Development economics literature has extensively examined the correlation between economic growth and agricultural productivity (Osman, 2025; Sahoo et al., 2025; Yadav & Goyari, 2025). Classical and structural transformation theories underscore that productivity development in agriculture contributes to economic growth by releasing labor to non-agricultural sectors, generating marketable surplus, and increasing rural incomes (Johnston & Mellor, 1961). Empirical studies offer compelling evidence that enhancements in agricultural productivity have a substantial and advantageous influence on economic expansion, particularly in agrarian economies (Tiffin & Irz, 2006).

Agricultural Productivity and Agricultural Marketing

A robust marketing infrastructure enhances price discovery, lowers transaction costs, and mitigates post-harvest losses, thereby incentivizing farmers to engage in productivity-boosting technology (Acharya & Agarwal, 2016). Empirical research indicates that enhanced market access and integration correlate with increased agricultural production due to greater input use and output commercialization (Birthal et al., 2015). Conversely, market defects like inadequate infrastructure, information asymmetry, and excessive intermediation have been identified as impediments to productivity development, especially for small and marginal farmers. These findings emphasize the significance of marketing reforms in maintaining agricultural output.

Agricultural Productivity and Fertilizer Consumption

Fertilizer consumption is widely acknowledged as a critical factor in the determination of agricultural productivity, particularly in intensively cultivated systems. The literature on the Green Revolution underscores the importance of chemical fertilizers in increasing crop yields by improving the availability of nutrients in the soil (Evenson & Gollin, 2003). Empirical research conducted in developing countries has shown a positive correlation between the use of fertilizer and agricultural productivity, particularly in the short term. Nevertheless, recent research has warned that the application of fertilizer in an excessive or imbalanced manner can result in environmental degradation and a decrease in marginal returns, which could have a detrimental impact on long-term productivity (Pingali, 2012). In the Indian context, research underscores the necessity of a balanced and efficient fertilizer use to maintain productivity growth without compromising soil health.

Agricultural Productivity and Irrigation

Irrigation has long been recognized as an essential factor for improving agricultural output, especially in areas marked by unpredictable rainfall. The research repeatedly demonstrates that availability to dependable irrigation enhances cropping intensity, stabilizes yields, and promotes the adoption of high-yielding cultivars (Fan et al., 2000). Empirical research from India demonstrates that irrigated areas display markedly greater output than rainfed regions, highlighting the importance of irrigation in alleviating climate hazards (Narayanamoorthy, 2007).

Data and Methodology

The time series annual data for the period 1990 to 2024 of different variables are acquired from various sources shown in first table.

Table 1: Data Sources

Variables	Description	Logarithmic Forms	Units	Sources
AGR	Agricultural Productivity	LAGR	Agriculture, forestry, and fishing, value added (% of GDP)	WDI World Bank Indicator
CO2	CO2 Emissions	LNCO2	Kilotons (kt)	WDI World Bank Indicator
FERT	Fertiliser Consumption	LNFERT	Consumption of Fertilisers (N+P+K) (lakh tonnes)	RBI DBIE
AMRK	Agricultural Marketing	LNAMRK	annual credit disbursement by Scheduled Commercial Banks for agriculture	RBI DBIE

IRRI	Irrigation	LNIRRI	Net Irrigated Area	RBI DBIE
GDP	Economic Growth	GDP	Per capita GDP at current US$	WDI World Bank Indicator

The empirical model is shown in the equation below.

$$LAGRt = \alpha + \beta 1LNAMRKt + \beta 2LNCO2t + \beta 3FLNERTt + \beta 4LNIRRIt + \beta 5GDPt + \varepsilon t \ (1)$$

Cointegration tests

The study employed the ARDL bound test, which was created by Pesaran et al. (2001), to detect cointegration between the series.

The equation used is given below.

$$\Delta LNAGR_t = \tau_0 + \tau_1 LNAGR_{t-1} + \tau_2 LNCO2_{t-1} + \tau_3 LNFERT_{t-1} + \tau_4 LNAMRK_{t-1} + \tau_5 LNIRRI_{t-1} + \tau_6 GDP_{t-1} \sum_{i=1}^{q} \nu_1 \Delta LNAGR_{t-i} + \sum_{i=1}^{q} \nu_2 \Delta LNCO2_{t-i} + \sum_{i=1}^{q} \nu_3 \Delta LNFERT_{t-i} + \sum_{i=1}^{q} \nu_4 \Delta LNAMRK_{t-i} + \sum_{i=1}^{q} \nu_5 \Delta LNIRRI_{t-i} + \sum_{i=1}^{q} \nu_6 \Delta GDP_{t-i} \ \varepsilon_t \ (2)$$

DOLS Method

We employed DOLS, an expanded form of ordinary least squares estimation, to analyse the time series data. To take explanatory factors into consideration, the DOLS test incorporates the leads and lags of their original difference terms. By pooling the leads and lags across explanatory factors, this estimate removes small sample bias, endogeneity, and autocorrelation issues.

Findings & Discussion

Findings of the statistical summary across variables is illustrated in table 2.

Table 2: Descriptive statistics

	LAGR	LNIRRI	LNFERT	LNCO2	LNAMRK	GDP
Mean	80.90743	5.269055	5.295325	14.03179	12.05827	6.156958
Median	79.83000	5.052949	5.214827	13.98000	12.10673	6.453851
Maximum	112.9100	6.313729	5.980000	14.71417	14.60315	8.990000
Minimum	50.83000	4.660000	4.800326	13.24206	9.846917	1.056831
Std. Dev.	19.59376	0.563120	0.305520	0.455216	1.591825	2.013611
Skewness	0.132709	1.062107	0.052814	-0.073095	0.067700	-0.604098
Kurtosis	1.580153	2.480500	2.038845	1.737204	1.508500	2.523217
Observation	35	35	35	35	35	35

Table 3 shows that the independent variable's centred variance inflation factors (VIF) are less than 10, indicating that the model does not show significant multicollinearity.

Table 3: VIF results

Variables	Centered VIF
LNCO2	6.0945
LNFERT	7.9156
LNAMRK	7.4432
LNIRRI	1.7778
GDP	1.1799

From the below table 4 and 5, it is evident that at level LNAMRK and GDP are stationary at 10% significance level and LNIRRI is stationary at 1% level and the rest all have unit root. At the first order difference, every variable series are stationary.

Table 4: Unit Root ADF findings at Level

Variables	t-stat	p-value
LNAGR	0.327681	0.9758
LNCO2	-0.522662	0.8727
LNFERT	-0.864502	0.7849
LNAMRK	0.489221***	0.0611
GDP	-2.755853***	0.0772
LNIRRI	-28.43752*	0.0000

*, ** and ***: denotes one, five and ten % level of significance

Table 5: Unit Root ADF findings at First Difference

Variables	t-stat	p-value
LAGR	-6.390171*	0.0000
LCO2	-4.771963*	0.0007
LFERT	-4.197021*	0.0041

LNAMRK	-3.724461*	0.0082
LIRRI	-3.374663**	0.0211

*, ** and ***: denotes one, five and ten% level of significance

The below table (6) displays the findings of the bound test. The null hypothesis is that there isn't a lasting association. Since the computed F-value (9.76730) is outside the bottom and upper bound values for the 10%, 5%, and 1 % levels of significance, it contradicts the null hypothesis and indicates the existence of a long-term relation.

Table 6: ARDL Bounds Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Stat	Val	Sig.	I(0)	I(1)
F-Val	9.76 730	10%	2.13	3.49
K	2	5%	2.89	3.98
		2.5%	3.45	4.45
		1%	4.12	5.38

The coefficient of CO_2 emissions (LNCO2) is negative and statistically significant (β = −8.33, *p* = 0.0015), indicating that higher carbon emissions adversely affect agricultural productivity in the long run. Specifically, a 1 percent increase in CO_2 emissions leads to an approximate 8.3 percent decline in agricultural productivity, reflecting the detrimental impact of climate change induced stress such as rising temperatures, rainfall variability, and increased production uncertainty. However, agricultural marketing (LNAMRK) significantly improves agricultural productivity (β = 7.64, p = 0.0024). This suggests that greater price discovery, lower transaction costs, and better market access boost farm-level efficiency by 7.6% for every 1% gain in agricultural marketing infrastructure or efficiency. Irrigation (LNIRRI) has a positive and statistically significant effect (β = 5.17, p = 0.0058), indicating that expansion of irrigation facilities substantially improves agricultural productivity. The DOLS findings are shown in table 7. The coefficient of fertilizer consumption (LNFERT) is negative and weakly significant at the 10 percent level (β = −19.72, p = 0.0945). This suggests that excessive or inefficient fertilizer use may reduce agricultural productivity in the long run, possibly due to soil degradation, nutrient imbalance, and declining factor productivity. Finally, economic growth (GDP) shows a positive and significant relationship with agricultural productivity (β = 1.21, p = 0.0191). This suggests that overall economic expansion contributes to productivity improvements through better infrastructure, technological diffusion, and increased public and private investment in agriculture. Overall, the findings emphasize that while market development, irrigation, and growth promote agricultural productivity, environmental degradation and unsustainable input use remain critical long-run constraints.

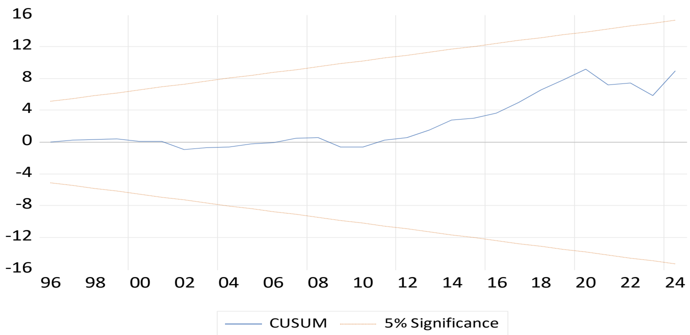
Table 7: DOLS Results

Variable	Coefficient	Std. Error	t-Stat	Prob. Val
LNCO2	-8.3308	7.7355	-4.1794	0.0015
LNFERT	19.7158	10.7788	-1.8291	0.0945
LNAMRK	7.6434	1.9542	3.9112	0.0024
LNIRRI	5.1661	1.5168	3.4058	0.0058
GDP	1.2095	0.8683	1.3928	0.0191

Structural stability tests

Figures 2 and 3 illustrate the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) plots introduced by Brown et al. (1975). They are significant at the 5% level, suggesting that the models' coefficients are structurally stable.

Figure 2: CUSUM Plot



Diagnostic tests

Table 8's diagnostic test findings attest to the model's lack of serial correlation and heteroscedasticity issues.

Table 8: Diagnostic test results

Diagnostic Tests	F Stat	P-Val	Hypothesis	Result
Serial Correlation test (Breusch-Godfrey)	9.269 22	0.2 979	Null hypothesis : No serial correlation	No serial correlation
Normality test (Jarque Bera test)	0.656 686	0.8 766	Null hypothesis : Normal Distribution	Normal Distribution
Heteroskedasticity Test (Glejser)	5.575 447	0.5 375	Null hypothesis : Homoskedasticity	No heteroskedasticity

Conclusion & Policy Suggestions

The empirical results from the DOLS estimation demonstrate that agricultural productivity in India is influenced by market efficiency, environmental conditions, and input and infrastructural factors. The findings indicate that CO_2 emissions have a substantial and statistically significant adverse effect on agricultural output, suggesting that climate change-related environmental stress represents a severe long-term danger to agricultural performance. Fertilizer consumption shows a weakly negative impact, indicating diminishing returns and potential soil degradation due to imbalanced input usage. Conversely, agricultural marketing development and irrigation are identified as crucial factors for productivity growth, highlighting the significance of efficient market access and dependable water supply. Economic growth positively influences agriculture investment and technology adoption, underscoring the need of comprehensive development. In light of these findings, policy initiatives should focus on enhancing agricultural marketing systems via improved market infrastructure, digital platforms, and diminished transaction costs; fostering climate-resilient and low-carbon agricultural practices to alleviate the negative impacts of increasing emissions; promoting balanced and efficient fertilizer application through soil health-oriented nutrient management; and augmenting sustainable irrigation infrastructure while preserving water resources. A cohesive policy framework that concurrently improves market efficiency and environmental sustainability is crucial for attaining sustained productivity development and resilience in Indian agriculture..

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