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Assessing GVA Contributions, FDI Impact, Economic Growth and Trade Openness on Agricultural Productivity in India: An ARDL Approach

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Abbreviations:

Sustainable Development Goals (SDGs); Auto Regressive Distributed Lag (ARDL); Foreign Direct Investment (FDI); Net FDI (NFDI); U. S Dollar (USD); Food & Agriculture Organisation (FAO); Gross Value Added (GVA); Ministry of Statistics and Programme Implementation (MoSPI); Research & Development (R&D0; European Union (EU); Public-Private Partnerships (PPP); Pradhan Mantri Garib Kalyan Anna Yojana (PMGKAY); Multinational Corporations (MNCs); Agricultural Value-Added (AVA); Economic globalization (EG); Agricultural Raw Material Exports (ARME); Error Correction Model (ECM); Gross Domestic Product (GDP); Trade Openness (TOP); Augmented Dickey-Fuller (ADF); Phillips-Perron (PP); Variance Inflation Factor (VIF).

Abstract

This study examines the structural composition and macroeconomic significance of agricultural production in India, analyzing its contribution to (GVA) from 2000 to 2023. The research identifies primary agrarian production as the predominant GVA driver, emphasizing the need for sustainable agricultural practices and enhanced livestock productivity to optimize economic performance. Policy recommendations advocate for targeted investments in high-impact sub-sectors and integrated agrarian systems to enhance resource efficiency and sectoral contributions. Employing the (ARDL) model, the study explores the relationship between agricultural value-added and key macroeconomic variables, including (FDI), net FDI stock, economic growth, and trade openness. Empirical results confirm significant short- and long-run associations between agricultural value-added, economic growth, and trade openness, whereas the direct impact of FDI remains constrained by structural capital absorption limitations. The ARDL Bound test confirms long-term cointegration, with a highly significant error correction term (−13.76), underscoring the sector's capacity for rapid post-shock adjustment. Findings highlight economic openness as a key driver of agricultural expansion, reinforcing agriculture's critical role in India's economic growth.

JEL Classification: F14; F63.

Introduction

Food Security and Sustainable Agricultural Development

Food security remains a cornerstone of the United Nations (SDGs) to eradicate poverty, enhance health and nutrition, and ensure environmental sustainability. The global demand for food is increasing exponentially, necessitating an annual investment of about 80 billion USD for food production and nearly 300 billion USD for productivity enhancement. Promoting environmentally sustainable technologies, expanding agricultural investments, advancing research and extension systems, and enhancing farmers' education—accompanied by technology transfer from developed countries—are pivotal components of policy frameworks to address global food security challenges [1-4]. Agriculture and allied sectors are integral to the global food system, driving livelihood generation, health improvements, equity, sustainability, and economic growth. In 2022, agriculture, forestry, and fishing contributed a global value-added of four trillion USD, with the Asian region accounting for 65% of this contribution [5, 3]. In India, where about two-thirds of the population depends on agriculture, the sector is critical in livelihoods, rural development, and nutritional security [6, 7]. The historical debate on agriculture's role in economic development underscores its indispensable contribution to national growth, income generation, and industrialization [8-10]. As populations in developing countries grow, alongside rising living standards and life expectancy, investments in agriculture and allied activities are essential for economic transformation, food security, and poverty alleviation. Empirical studies reveal that agricultural growth is two to four times more effective in raising incomes among the poorest populations than other sectors [11-13]. However, agrarian development imposes significant environmental challenges, including soil degradation, greenhouse gas emissions, and biodiversity loss, necessitating substantial investments to balance ecological sustainability with productivity [14, 15].

Global Challenges in Food Systems

Declining government spending on agriculture exacerbates these challenges, particularly in developing nations. Geopolitical events, such as the Russia-Ukraine war and related sanctions, have disrupted global food markets due to reduced wheat and fertilizer supplies, further compounded by the COVID-19 pandemic's implications on global trade and supply chains [16-18]. These disruptions highlight the critical need for international capital flows, such as (FDI), to bridge gaps in food production, land management, and climate change mitigation [19]. Endogenous growth theories emphasize FDI as a catalyst for economic growth, capable of addressing unemployment, improving productivity, and fostering rural transformation. Agriculture-led growth, supported by trade openness and investments in infrastructure, enhances rural incomes, drives national output, and transitions economies toward industrialization [20-22].

India: A Global Agricultural Powerhouse

India serves as a compelling case study of agriculture's transformative potential in driving economic growth and development. As the world's leading producer of milk, pulses, jute, and spices, and the second-largest producer of rice, wheat, and cotton, the country's agricultural sector has demonstrated remarkable resilience and adaptability. Despite global disruptions, the sector registered a 3.6% growth during the COVID-19 pandemic [23], underscoring its critical role in ensuring food security and economic stability. However, structural and systemic challenges continue to constrain the sector's full potential. Issues such as land fragmentation, subsistence farming practices, and environmental degradation pose significant barriers to productivity enhancement and sustainable growth. Furthermore, agricultural performance exhibits substantial regional disparities, influenced by diverse agro-climatic conditions, variations in cropping patterns, and differential access to infrastructure and technology. These disparities highlight the urgent need for targeted investments, the adoption of precision agriculture, and the integration of modern supply chain solutions to enhance productivity, efficiency, and long-term sustainability.

Agricultural (GVA): A Measure of Economic Impact

Agriculture's contribution to economic growth is commonly assessed using (GVA), which represents the sector's net output by accounting for the value of goods and services produced after deducting the cost of inputs. GVA serves as a crucial metric for evaluating productivity trends, sectoral efficiency, and policy impacts within agriculture.

Disparities in Agricultural GVA Across Regions: Empirical research highlights significant regional variations in agricultural GVA, influenced by factors such as land productivity, technological adoption, institutional frameworks, and climate conditions. For instance, in developed economies, such as those within the European Union (EU), agricultural GVA has remained below 2% of GDP between 2000 and 2018 due to industrial

diversification and a shift toward high-value agribusiness [11]. In contrast, India's agricultural GVA has consistently averaged around 17%, underscoring the sector's critical role in employment, rural livelihoods, and national food security. Similarly, many Sub-Saharan African and South Asian economies continue to rely on agriculture as a primary driver of GDP, albeit with lower productivity levels compared to high-income economies.

Determinants of Agricultural GVA and the Path to Optimization: The disparities in agricultural GVA are shaped by multiple factors, including:

- Capital Investments: Higher investments in farm mechanization, irrigation infrastructure, and rural credit contribute to increased agricultural productivity and GVA growth [24-26].
- Technological Advancements: The adoption of precision farming, biotechnology, and climate-resilient crop varieties enhances efficiency and reduces yield volatility [27].
- Agricultural Research & Development (R&D): Investment in R&D accelerates innovation in seed technology, pest management, and soil fertility enhancement, fostering long-term sustainability.
- Livestock & Dairy Sector Development: Expanding livestock production through improved breeding techniques, disease control programs, and value chain integration significantly boosts agricultural GVA.
- Market Access & Trade Policies: Efficient supply chain networks, reduced post-harvest losses, and trade facilitation measures are crucial for optimizing value addition in agriculture.

Sustainable Growth and Policy Imperatives: To sustain and enhance agriculture's contribution to economic growth, policymakers must focus on:

- Diversification Strategies: Encouraging a shift toward high-value crops, horticulture, and agro-processing industries to maximize value addition.
- Climate-Smart Agriculture: Implementing practices such as conservation agriculture, water-efficient irrigation, and carbon sequestration to mitigate environmental impacts.
- Institutional Reforms: Strengthening land tenure systems, farmer cooperatives, and extension services to improve resource allocation and farm productivity.
- Public-Private Partnerships (PPP): Facilitating investments in agri-tech startups, logistics, and digital marketplaces to modernize agricultural supply chains.
- By addressing these determinants, countries can enhance agricultural GVA, improve food security, and foster inclusive economic growth, ensuring the sector's resilience against global uncertainties and climate change challenges.

Bridging Research Gaps

Despite the recognized importance of (FDI) in agriculture, there is a paucity of literature examining its specific impact on economic growth and food security, particularly in India. The agricultural sector, a cornerstone of the Indian economy, faces challenges related to productivity, capital constraints, and environmental sustainability. Addressing these concerns requires empirical investigation into the role of FDI in fostering agricultural value-added and broader macroeconomic growth. This study bridges existing knowledge gaps by utilizing the (ARDL) model to analyze the dynamic interrelationships between agricultural value-added, FDI inflows, and economic growth. The ARDL model is particularly suitable for investigating both short-run and long-run equilibrium relationships in time-series data, making it an appropriate econometric framework for assessing the structural impact of FDI on India's agricultural sector. By integrating macroeconomic indicators and sector-specific variables, the study provides robust empirical evidence of FDI's role in enhancing agricultural productivity, employment generation, and rural development. The findings offer critical policy insights into optimizing FDI-driven agricultural investments. Key recommendations include strengthening institutional frameworks to attract and retain FDI, fostering trade openness to integrate Indian agriculture into global value chains, and implementing sustainable agricultural practices to mitigate environmental risks. Furthermore, the research underscores the necessity of technological innovation and infrastructure development in enhancing the sector's resilience against climate variability and resource constraints. Strategic investments in Indian agriculture, driven by well-calibrated FDI policies, could position the sector as a global leader in food production. By leveraging capital inflows for innovation, modernization, and sustainability, India can enhance food security, boost economic prosperity, and contribute to long-term environmental resilience, aligning with national and global development objectives.

Literature Review

The interplay between international capital flows and agriculture is interpreted through various theoretical lenses, namely Dependency Theory, Modernization Theory, and Globalization Impact. These perspectives offer divergent views on how foreign investments influence agricultural development and, consequently, food security. Dependency Theory argues that foreign capital inflows tend to reinforce economic dependency, resulting in income inequality and exacerbating food insecurity. By focusing on the extraction of resources for the benefit of developed nations, these capital flows limit the host country's capacity for self-sufficiency [28]. This view suggests that foreign investments often serve to entrench existing power dynamics rather than promote sustainable agricultural growth. In contrast, Modernization Theory emphasizes the potential of foreign investments to drive agricultural progress by facilitating the transfer of technology, knowledge, and managerial expertise. According to this perspective, foreign capital can lead to structural transformations in agriculture, boosting productivity and fostering economic development for both host and source countries [29]. It envisions a positive role for foreign capital in transforming agricultural practices, contributing to long-term development. Globalization Impact, however, presents a more nuanced view, suggesting that the effects of financial globalization are not uniformly beneficial to agriculture. While foreign investments have significantly contributed to the growth of manufacturing and services sectors, their impact on agriculture has been mixed [30]. Globalization often fosters dependency on external markets, policies, and multinational corporations, which can marginalize smallholder farmers. Regulations such as seed patenting and monopolization by agribusinesses limit local agricultural autonomy and exacerbate structural challenges within the sector. Consequently, the effects of globalization on agriculture are regionally varied and context-specific. The convergence of these theories reveals a complex relationship between foreign capital and agricultural development. While Dependency and Modernization theories offer opposing views on the role of foreign capital, Globalization Impact highlights the uneven distribution of benefits across regions, leading to a variety of outcomes depending on local contexts and regulatory frameworks.

Agriculture and Food Production

(FDI) plays a crucial role in enhancing food security by expanding markets, facilitating technological innovations, and providing employment opportunities [32, 33]. As [34] points out, FDI in agriculture, while beneficial in the medium to long term, requires robust institutional mechanisms to sustain investments. Agricultural FDI contributes to green total factor productivity [35], reduces unemployment [36], and promotes the expansion of cultivated land, ultimately improving food security [37]. Several studies affirm the link between FDI and economic growth, highlighting its role in poverty alleviation [38, 39]. In regions such as Africa, inward FDI has positively influenced agricultural production, providing advanced technology, and managerial expertise, and alleviating capital constraints [40]. However, [41] cautions that (MNCs) can disrupt local agricultural practices, undermining small farmers. Moreover, policies and regulations favoring developed countries and MNCs, such as WTO seed patenting regulations, further marginalize smallholders.

Agriculture and Economic Growth

The relationship between FDI and economic growth is multifaceted, encompassing positive, negative, and dependent perspectives. Neoclassical growth theory highlights the positive impact of FDI through technology diffusion, managerial improvements, and skill development [42, 43]. However, studies also point to the uneven distribution of FDI across sectors, with agricultural FDI sometimes crowding out domestic investment or exhibiting inconsistent effects on productivity [44, 45]. Recent studies underscore the transmission mechanisms of (AVA) on GDP, suggesting that FDI in agriculture remains concentrated in developed countries, with food-insecure regions receiving only a small share of global agricultural FDI [46]. Furthermore, investment in climate-smart agriculture (CSA) faces financial constraints, requiring public-private sector collaborations to address challenges such as food insecurity and climate change [47].

Agriculture and Trade Openness

Trade openness has been linked to enhanced agricultural performance and economic growth [48]. Studies suggest that open economies attract higher investments, fostering competitiveness and boosting production efficiency [49]. A comparative analysis of Latin American and East Asian countries reveals that export-led growth strategies outperform import substitution industrialization, leading to more robust agricultural performance [50]. Additionally, the adoption of advanced agricultural technologies under trade openness helps mitigate environmental challenges, such as reducing carbon emissions [51]. However, in some countries, trade openness does not yield consistent benefits. For instance, [52] found that trade openness and FDI had a negative short-term effect on Ghana's agricultural sector. Such discrepancies may arise due to differences in methodologies or study periods, as observed in the divergent findings of [53].

FDI and Agricultural Value-Added (AVA)

A review of the literature on FDI in India reveals a focus on manufacturing and services, with limited research on agriculture. FDI in agriculture has been shown to enhance exports and economic growth [54], although regulatory barriers remain a challenge [55, 56] note the dual impact of agricultural FDI, which contributes to economic growth but also exacerbates environmental degradation. The lack of sufficient research on FDI spillovers in the primary sector underlines the need for more focused studies in this area.

Studies further suggest that FDI in agriculture positively affects rural economies, generating economic benefits for farmers [57]. However, challenges remain, as evidenced by the underperformance of FDI in China's AVA despite its large market size. Regional differences complicate the relationship between FDI and AVA, with factors such as labor force participation, financial capital, and fertilizer consumption playing key roles in determining agricultural productivity.

Economic Globalization (EG) and AVA Across Income Levels

EG factors, including FDI, trade, and exchange rates, significantly influence AVA across different income levels. In high-income countries, AVA growth has stagnated due to reduced investments in agricultural research, while in low-income countries, FDI and Agricultural Raw Material Exports (ARME) positively impact AVA, though policies must be improved to maximize benefits [58-60]. In middle-income countries, FDI promotes technological advancements and employment, while trade openness shows mixed effects on agricultural productivity. In upper-middle-income countries, such as Malaysia and Ecuador, FDI and agricultural exports significantly boost AVA, highlighting the importance of financial performance and exchange rate appreciation. Despite the importance of FDI in agricultural value-added, there remains a significant gap in research on its role within international capital flows. Further studies are needed to inform policies that enhance agricultural productivity, attract foreign investment, and promote sustainable economic growth in developing economies.

Materials and Methods

The significance of agricultural production in India's overall economic activity can be assessed through various analytical approaches. However, the reliability and robustness of the analysis largely depend on the quality and availability of data. This study aims to evaluate both the short-term and long-term impact of agricultural value-added on FDI, international business, and economic development. Additionally, it seeks to understand the dynamic effects of agricultural value-added on inward FDI, international business, and economic development. GVA, a fundamental component of the gross domestic product GDP, represents the difference between the total value of output and intermediate consumption. The primary data sources include official reports from the MoSPI and the Ministry of Agriculture, Government of India, covering the period from 2000 to 2023. Since the variables exhibit a mixture of stationarity properties, with some being integrated of order zero, I (0), and others of order one, I (1), the (ARDL) model and the (ECM) are employed to analyze their relationships [61].

1. Variables

The key variables in this study include agricultural value-added, foreign capital, openness, and economic development.

Agricultural Value-Added: Measured as the sum of agriculture, forestry, and fishing value-added (AVA).

Foreign Capital: Proxied by net inflows of foreign direct investment (IFDI), and net inflows (% of GDP).

Economic Development: Measured using (GDP).

Trade Openness (TOP): Defined as the sum of exports and imports divided by GDP, representing the level of economic openness.

2. Control Variables

Agglomeration: The stock of FDI or net FDI (NFDI) is included as a control variable, as FDI tends to follow existing investments [62]. Investors leverage insights from prior investments in host countries to mitigate uncertainties and enhance decision-making efficiency. The stock of FDI serves as a proxy for agglomeration, with an expected positive effect.

3. Independent Variables

Agriculture, Forestry, and Fishing Value-Added: This variable is used to analyze the effect and direction of international business on the primary sector, as demonstrated in prior studies [53, 15]. Economic Development: GDP is utilized as a proxy for economic development [15]. Trade Openness: Defined by the sum of exports and imports divided by GDP, capturing the extent

of economic openness [44].

Econometric Methodology and Model Specification

The analysis begins with an examination of the stationarity properties of the variables to determine their order of integration. This is achieved through unit root tests such as the ADF and PP tests, ensuring that the chosen variables satisfy the necessary conditions for subsequent econometric modeling. Given the possibility of mixed integration orders among the variables, the ARDL model is employed to estimate both short-run and long-run relationships. To assess cointegration among the selected variables, the bound testing approach is applied within the ARDL framework. This technique determines whether a stable long-run equilibrium relationship exists between the dependent and explanatory variables. Upon confirmation of cointegration, an ECM is incorporated into the model to evaluate the speed of adjustment from short-run deviations to long-run equilibrium. The ECM coefficient, expected to be negative and statistically significant, quantifies the rate at which disequilibrium is corrected over time. Once the ARDL model satisfies the conditions for short-run equilibrium, long-run cointegration, and error correction, additional diagnostic tests are conducted to ensure the model's robustness and reliability. These tests include stability diagnostics to verify parameter consistency over time. Normality tests (e.g., Jarque-Bera test) assess the residual distribution, while (VIF) analysis is performed to detect potential collinearity among regressors. The ARDL methodology, complemented by cointegration and error correction analysis, has been widely employed in prior research to investigate both short-run and long-run economic dynamics. Its flexibility in handling variables with different integration orders and its ability to generate reliable policy insights make it a robust econometric approach for examining complex macroeconomic relationships [63, 61]. Notable studies employing ARDL include those by [64-66], which investigate the relationship between GDP and other economic indicators.

The ARDL model used in this study is specified as follows: Equation (1) is the functional relationship among Variables

$$DAVA_t = f\ \{DIFDI_t;\ DGDP_t;\ DTOP_t;\ DFDIN_{t.}\} \quad (1)$$

Equation (2) is the linear regression Functional Relation Among Variables

$$\delta DAVA_t = \alpha + \beta_0 \delta DAVA_{t-1} + \beta_1 \delta\ DIFDI_{t-1} + \beta_2 \delta\ DGDP_{t-1} + \beta_3 \delta\ DTOP_{t-1} + \beta_4 \delta\ DFDIN_{t-1} + \varepsilon_t \quad (2)$$

where, ΔDAVA(t) = agriculture value added

DIFDI = inward FDI

DGDP = GDP

DTOP = trade openness

DFDIN = net FDI

t = time from 2000 to 2022

t-1 = one period lag

α = intercept

β_0, β_1, β_2, β_3, β_4 = coefficients

ε = error term

Analysis and Results

This study investigates the value-added contribution of the agriculture, forestry, and fishing sectors as the dependent variables, with inward FDI, GDP, trade openness, and net FDI serving as independent variables. To examine the stationarity properties of the time series data, the ADF unit root test was employed. The results indicate that all variables are non-stationary at their level but achieve stationarity upon first differencing, implying integration of order I (1). The detailed stationarity test results are presented in Table 1. Given the I (1) integration order of all variables, the ARDL model is deemed suitable for capturing the dynamic relationships between the dependent and independent variables. The ARDL model, estimated with a one-period lag, exhibits strong statistical significance, with a p-value of 0.00. The estimated probability values reveal that GDP and trade openness have a statistically significant impact on agricultural value-added, whereas inward FDI and net FDI do not demonstrate statistical significance within the given framework. To, assess the presence of a long-run equilibrium relationship among the variables, a bounds test was conducted. The results

Table 1: Results of the Order of Integration.

Variables		At level	At first Difference
AVA	Constant	0.395(0.987)	-4.955(0.000)
	Constant & Linear	-3.469(0.069)	-4.572 (0.000)
	None	4.380 (0.979)	-3.648 (0.000)
IFDN	Constant	-1.1973(0.686)	-6.288 (0.000)
	Constant & Linear	-2.564(0.340)	-6.280(0.000)
	None	1.150(0.928)	-5.943(0.000)
GDP	Constant	-0.870(0.774)	-4.634 (0.000)
	Constant & Linear	-1.697 (0.762)	-4.790 (0.000)
	None	8.072 (1.000)	-0.740 (0.395)
IFDI	Constant	-2.392 (0.170)	-5.163(0.000)
	Constant & Linear	-2.272 (0.495)	-5.093 (0.002)
	None	-1.349 (0.174)	-5.284 (0.000)
TOP	Constant	-0.263(0.958)	-4.531(0.000)
	Constant & Linear	-0.870 (0.980)	-5.183 (0.000)
	None	-0.916 (0.256)	-4.443 (0.000)

Source: Authors' calculations from E-views.

Table 2: Results of the ADRL Bound Test.

Model	99 percent critical values		
LnAVAt = f (LnIFDIt, LnGDPt, LnTOPt)	Lower Bound	Upper Bound	F- stat.
Null Hypothesis No long-run relationship β1=β2=β3=β4 No short-run relationship Ø1=Ø2=Ø3=Ø4	3.47	5.26	6.74**

Source: Authors' calculations from E-views.

Table 3: Long-run Co-efficient estimates.

Independent Variables	Coefficient (Standard Error)	t- stat. prob.
IFDI	−0.033(0.014)	−2.01(0.05)
GDP	0.522(.0.033)	14.81(0.00)
TOP	−0.00(0.00)	−6.31(0.00)
FDIN	−0.033(0.01)	−2.01(0.00)
R-Square 0.77 Adjusted R-Square 0.74 Durbin Watson Stat−1.82 F Stat 16.70 Prob (F-Stat) 16.70 Normality [Jarque-Bera] 1.291 Heteroskedasticity test Breusch-Pagan-Godfrey (p-value) 0.281 Ramsey RESET test [F-statistics] 0.981		

Source: Authors' calculations from E-views.

confirm the existence of cointegration, as the computed F-statistic exceeds both the lower and upper critical bounds at conventional significance levels, as reported in Table 2. This provides robust evidence of a stable long-run equilibrium association among the examined variables.

Further, the estimation of long-run coefficients reveals that GDP and trade openness exert a statistically significant influence on agricultural value-added at the 5% significance level, while inward FDI and net FDI remain statistically insignificant. The estimated long-run coefficients indicate that a 1% increase in agricultural value-added is associated with a 52.9% increase in GDP, as demonstrated in Table 3. These empirical findings underscore the pivotal role of the agriculture, forestry, and fishing sectors in driving economic growth. While trade openness and GDP significantly contribute to agricultural value-added, the lack of statistical significance for inward FDI and net FDI suggests structural limitations in the absorption of foreign capital within the agricultural sector. This study highlights the necessity for policy interventions aimed at enhancing capital utilization efficiency and fostering sustainable agricultural growth to maximize economic contributions.

The ECM provides a comprehensive framework for estimating adjustments, causality, feedback mechanisms, and dynamic interrelationships among variables. By integrating both short-run and long-run equilibrium relationships, the ECM effectively mitigates the risks of spurious regression while preserving essential long-run information. The coefficient of the error correction term (ECT) quantifies the speed at which deviations from the long-run equilibrium, induced by short-run fluctuations, are corrected over time, ensuring model stability and economic consistency. In this study, the error correction term is found to be statistically significant, confirming the presence of a robust long-run causality relationship. The ECM coefficient is estimated at −13.76, suggesting that 137.6% of the previous year's disequilibrium is corrected within the current year. This indicates a rapid adjustment process, implying that short-run deviations from equilibrium do not persist over time and that the system quickly reverts to its long-run path. Such a high rate of adjustment underscores the strong resilience and dynamic stability of the underlying economic relationships. The model demonstrates strong explanatory power, with an R-squared value of 0.77 (77%) and an adjusted R-squared of 0.74 (74%), signifying that the independent variables account for a substantial portion of the variance in the dependent variable. Furthermore, the F-statistic (16.70) and its associated probability values confirm the overall statistical significance and fitness of the model. The Durbin-Watson statistic further indicates no significant autocorrelation, reinforcing the robustness of the estimated relationships. To ensure the reliability of the findings, several diagnostic tests were conducted, including normality tests (Jarque-Bera), heteroscedasticity tests (Breusch-Pagan-Godfrey), serial correlation tests (Durbin-Watson and Breusch-Godfrey LM test), and model stability tests. These tests collectively validate the robustness, consistency, and predictive accuracy of the ECM framework, strengthening the empirical evidence supporting the study's conclusions.

Heteroskedasticity Test: The Breusch-Pagan-Godfrey test confirmed the absence of heteroskedasticity, ensuring homoscedasticity in the residuals.

Normality Test: The Jarque-Bera test was used to assess the normality of residuals, confirming that they follow a normal distribution.

Stability Tests: The Cumulative Sum test and Cumulative Sum of Squares test were evaluated to test model stability over time. The results indicate that the model remains stable, as the Cumulative Sum and Cumulative Sum of Squares statistics remain within the critical upper and lower red boundary lines.

Overall, the diagnostic tests confirm that the model is free from heteroskedasticity, non-normality, and serial correlation, thereby ensuring its statistical validity and robustness for policy implications.

Discussion

This study contributes to the relatively limited literature investigating the relationship between inward (FDI) and agricultural value addition, with a particular focus on its dynamic effects on international business, agglomeration economies, and economic development. The empirical results derived from the ARDL model confirm that in the short run, agricultural value addition significantly influences economic growth and trade openness, consistent with previous studies. However, in the long run, economic growth and trade openness remain the primary determinants of agricultural value addition, aligning with the findings of [36, 20]. A critical takeaway from this study is that FDI absorption is a time-intensive process, and its sectoral impact is contingent upon multiple factors, including domestic absorptive capacity, technological adaptability, and institutional quality. The ability of domestic industries to assimilate foreign capital effectively plays a pivotal role in transforming FDI into a driver of economic growth and agricultural development [42, 67, 68]. The error correction term derived from the

ARDL model indicates a high speed of adjustment towards long-run equilibrium, suggesting economic resilience and stability within India's agricultural sector. These conditions enhance India's attractiveness for foreign capital inflows, positioning the sector as a viable destination for international business expansion and reinforcing the importance of a stable macroeconomic environment for sustained economic progress. By integrating the primary sector with global trade, investment, and development dynamics, this study offers novel insights into the role of FDI in agriculture, addressing a critical gap in the existing literature. The findings underscore the need for strategic policy interventions to maximize the benefits of FDI in agriculture, particularly through technology transfer, infrastructure development, physical asset creation, and supply chain enhancement. Strengthening institutional frameworks, fostering innovation-driven investments, and enhancing trade facilitation measures will be essential to harnessing FDI's full potential in India's agricultural sector, ensuring long-term economic and environmental sustainability.

Policy Implications

1. Strengthening Institutional and Policy Frameworks for Agricultural FDI

2. Given the time lag in FDI absorption, targeted policy interventions should encourage foreign investments in technology-driven agriculture, such as precision farming, cold storage, and post-harvest management systems.

3. The government must develop sector-specific FDI policies, ensuring technology spillovers and knowledge transfers to domestic firms.

4. Enhancing Trade Openness and Market Reforms

- Trade liberalization policies must be complemented with domestic market reforms to enhance agricultural competitiveness.

- The removal of trade barriers—as seen in India's temporary suspension of tariffs on select agricultural commodities (e.g., crude palm oil, soybean oil, lentils)—should be systematically assessed to balance food security and trade objectives.

5. Rural Infrastructure and Digital Transformation

6. Investments in rural infrastructure, cold storage, and rural logistics networks are essential to reduce post-harvest losses and increase agricultural exports.

7. The digitalization of agriculture, including the expansion of financial services for farmers and the promotion of agricultural technology start-ups (as supported by the National Bank for Agriculture and Rural Development), can bridge gaps between rural producers and international markets.

8. Ensuring Environmental Sustainability in Agricultural Development

Agricultural growth must be aligned with sustainable environmental policies. The adverse ecological effects of intensive agricultural expansion—such as deforestation, pollution, and climate change [69.70]—necessitate integrated policy responses.

Encouraging eco-friendly farming practices and promoting greenfield FDI in sustainable agricultural technologies should be prioritized.

9. Food Security and Long-Term Trade Policy Alignment

Food security has been a longstanding priority in India's agricultural policies, and initiatives such as the PMGKAY and agriculture infrastructure programs must be reinforced to ensure stable food production while mitigating external shocks.

A well-coordinated policy response is needed to balance international trade policies with domestic agricultural stability, considering past instances where budgetary interventions failed to yield the desired impact due to external market fluctuations [71].

Directions for Future Research

1. Firm-Level Analysis of Agricultural FDI Absorption

Future research should examine the firm-level dynamics of inward FDI absorption in agriculture, focusing on how domestic enterprises integrate foreign technology and capital into production processes.

2. Evaluating Environmental and Social Impacts of Agricultural FDI

- Expanding the research scope to assess the ecological footprint and social consequences of agricultural FDI will provide deeper insights into sustainable economic development.

- The Pollution Haven Hypothesis, which suggests that FDI may contribute to environmental degradation in developing economies, should be explored in the

context of India's agriculture and trade policies [72, 73].

3. Sector-Specific FDI Policies and Regional Disparities

- Analyzing regional disparities in FDI inflows within the agricultural sector can highlight variations in absorptive capacities across states with different agro-climatic conditions.
- Research should assess how policy variations at the state level impact FDI effectiveness in boosting agricultural productivity.

4. The Role of Globalization in Reshaping Agricultural Value Chains.

5. Future studies should focus on the effects of Global Value Chains (GVCs) and multinational agribusiness investments on India's agriculture sector.

6. Understanding the impact of international trade agreements, such as WTO regulations and bilateral trade deals, will be crucial in shaping future trade policies.

7. Technology, Innovation, and Agricultural Productivity

- Research should explore the adoption of Artificial Intelligence (AI), blockchain, and smart agriculture in improving productivity and sustainability.
- The role of digital platforms in connecting small farmers to global markets is an area that warrants further investigation.

8. Agriculture, Climate Change, and Food Security

9. Investigating the long-term impact of climate change on agricultural productivity and food security can provide essential policy guidance.

10. The integration of climate-resilient crop varieties and sustainable farming practices should be evaluated within the broader framework of agricultural FDI.

11. Ethical and Responsible Business Practices in Agricultural FDI

- Given the increasing presence of multinational corporations in agriculture, future studies should assess whether foreign investors adhere to ethical business standards, particularly concerning labor rights, fair trade, and environmental sustainability.

By addressing these research gaps, policymakers and stakeholders can develop comprehensive, evidence-based strategies to maximize the benefits of agricultural FDI while ensuring long-term sustainability and economic inclusivity.

Limitations

Certain limitations to this study must be acknowledged to ensure a comprehensive understanding of its scope and the potential areas for improvement in future research. One notable limitation is the potential for omitted variable bias, which arises when relevant explanatory variables are not included in the model, potentially leading to biased or inconsistent estimates. Although the study incorporates key macroeconomic indicators to analyze the impact of capital expenditure and economic growth on unemployment, it is possible that other structural and institutional factors—such as labor market rigidity, skill mismatches, demographic shifts, and sectoral employment trends—may have influenced the observed relationships. The exclusion of such variables could lead to an over- or underestimation of the actual effects. To mitigate this issue, future research should consider incorporating a more extensive set of explanatory variables that capture broader economic and labor market dynamics. Employing techniques such as instrumental variable regression or panel data models may also help account for potential endogeneity concerns and improve the robustness of the findings. Another limitation of the study pertains to data constraints, particularly regarding the temporal scope of the analysis. The study covers the period between 2000 and 2022, which, while providing a substantial dataset for empirical analysis, may not fully capture the most recent economic trends and policy shifts. The exclusion of post-2022 data could affect the study's ability to reflect the latest developments in capital expenditure policies, labor market dynamics, and broader macroeconomic conditions. Incorporating more recent data would enhance the precision and relevance of the findings, allowing for a more accurate assessment of the evolving relationship between capital expenditure, economic growth, and unemployment. Future research should prioritize updating the dataset to include the most current economic indicators, enabling a more dynamic and policy-relevant analysis.

Furthermore, methodological refinements could strengthen the study's analytical rigor. While time-series econometric techniques have been employed to establish relationships between the studied variables, alternative approaches such as structural vector autoregression (SVAR) or difference-in-differences (DiD) methodologies could be explored to assess causality more explicitly. Additionally, conducting comparative studies across

different economies or subnational regions could provide deeper insights into how varying policy frameworks and economic structures influence the effectiveness of capital expenditure in reducing unemployment. By addressing these limitations, future studies can enhance the reliability, applicability, and policy relevance of findings in this domain, ultimately contributing to a more nuanced understanding of the interplay between fiscal policy, economic growth, and labor market outcomes.

Conclusion

By addressing these limitations, future studies can enhance the reliability, applicability, and policy relevance of findings in this domain, ultimately contributing to a more nuanced understanding of the interplay between fiscal policy, economic growth, and labor market outcomes.

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Conflict of Interest

I declare no conflicts of interest regarding the publication of this article.

Data Availability Statement

Data supporting the findings of this study are sourced from various publications by the Government of India. Data sharing does not apply to this article as no new data were created or analyzed in this study.

Author Contribution Statement

Roles and contributions include conceptualization, methodology, validation, investigation, resource management, data curation, original draft writing, review and editing, visualization, supervision, formal analysis, and final draft preparation.

Ethical Statement

This study contains no studies with human or animal subjects performed by the author.

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