

RESEARCH PAPER

Determinants of Public-Private Synergy in Agricultural Capital Formation: An Econometric Analysis of GCF Dynamics in India

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ABSTRACT

This study explores the trends and dynamics of Gross Capital Formation (GCF) in India's agricultural sector from 1980 to 2023, with a particular focus on public and private investments. The analysis employs a combination of polynomial trendlines, Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV), and correlation analysis to assess the impact of key policy milestones, such as the 1991 Economic Reforms, the 2000 National Agricultural Policy, and the 2013 Direct Benefit Transfer (DBT) scheme, on capital formation in agriculture. The results reveal a general decline in public investment, accompanied by strong growth in private sector contributions, particularly since the 1990s. The study also finds a statistically significant negative relationship between public and private investments, suggesting that public sector investments may crowd out private investments. The findings have important policy implications for improving access to capital for small farmers and fostering sustainable agricultural development.

HIGHLIGHTS

- ① This study analyzes the trends in agricultural investments in India from 1980–81 to 2022–23 using Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV), Pearson Correlation, and Polynomial Trendlines (quadratic/cubic) to assess growth, volatility, relationship, and structural changes in public and private sector investments.
- ① The CAGR for public investment is -0.85%, indicating a decline, while private investment grew at 3.63%, showing increasing reliance on the private sector. Total GCF recorded a moderate CAGR of 2.26%.
- ① Public investment was the most stable (CV: 0.1224) compared to private (CV: 0.1558) and total investment (CV: 0.1309), reflecting less fluctuation in government funding over time.
- ① A Pearson correlation coefficient of -0.67 suggests a moderately strong inverse relationship between public and private investments, indicating potential substitution over time.
- ① Polynomial trendlines and annotations show that key years such as 1990–91 (Economic Reforms), 2012–13, and 2022–23 correspond with major policy shifts that significantly influenced investment patterns.

Keywords: Capital Formation, Agricultural Investment, Public vs. Private Investment, Gross Capital Formation, Growth Rate, Coefficient of Variation, Policy Impact Analysis, Agricultural Development

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Capital formation in the agricultural sector is fundamental to enhancing productivity, efficiency, and sustainability. It involves the mobilization and allocation of both financial and material resources for various agricultural sub-sectors such as infrastructure development, technology adoption, and land improvement. Investments in capital formation facilitate the transition from traditional farming practices to modern, competitive agricultural technologies. This is especially crucial for promoting efficiency and productivity across different farming systems (Singh, 2014; Ali & Byerlee, 2002). However, despite the sector's critical importance, small and marginal farmers, who represent about 80% of India's farming population, often face significant barriers in accessing capital. This has resulted in unequal distribution of agricultural resources, with large, resource-rich farmers enjoying better access to finance, while small farmers in underdeveloped agricultural regions struggle with capital shortages (NABARD, 2017; Rai *et al.* 2017).

Historically, the agricultural sector in India was predominantly financed through public investments, with limited private sector participation. Over time, however, the private sector has increasingly contributed to agricultural research and development (R&D), marketing, extension services, and contract farming, supplementing the role of public investments (Bardhan, 1997; Arora, 2013). Despite the growing involvement of the private sector, challenges remain in making capital more accessible to the majority of small farmers, who still face difficulties in financing their farm operations. The need for policies that address the financing needs of these farmers has thus become a crucial issue (Purohit *et al.* 1999).

The trend of capital formation in agriculture can be understood by examining the ratio of Gross Fixed Capital Formation (GFCF) in agriculture to the sector's Gross Value Added (GVA). This ratio showed a steady increase during the 1970s but experienced significant fluctuations in subsequent decades, with notable periods of decline, especially during the 1990s (Purohit, 1999; Kumar *et al.* 2011). Government funding played a dominant role in agricultural development during this time, although private sector participation, particularly in marketing, R&D, and extension services, has grown

substantially in recent years (Kannan, 2019). While the total GCF in agriculture fluctuated between 12.8% and 18.2% of GVA, public investment remained relatively stable, varying between 2.1% and 2.7%. In contrast, private investment exhibited greater variability, ranging between 10.5% and 15.9% (NABARD, 2017; Ministry of Agriculture and Farmers Welfare, 2020).

Moreover, while public investment in the agriculture sector remains relatively consistent, private sector contributions exhibit greater volatility. This reflects the varying confidence levels of the private sector in the agricultural market, influenced by factors such as government policies, market access, and financial incentives (Bhandari, 2011). Public investment remains more stable but is constrained by budgetary allocations and government support schemes, which can fluctuate due to changes in policy, external factors like climate change, and economic conditions (Rangarajan, 2014; Bathla, 2014).

Recent government initiatives, such as the Agriculture Infrastructure Fund (AIF), the PM KISAN scheme, and increased allocations for rural infrastructure, have helped boost capital formation in agriculture. These efforts are aimed at improving access to finance, promoting mechanization, and fostering rural development (Ministry of Agriculture & Farmers Welfare, 2021). However, there remains a significant gap in infrastructure development in underdeveloped regions, particularly the North Eastern Region (NER), where the lack of capital allocation for agricultural projects raises concerns (Sarma, 2017). This reflects a need for targeted interventions to ensure that capital resources are effectively allocated to all regions, particularly those that face infrastructural challenges.

This study aims to analyze the trends and dynamics of capital formation in the Indian agricultural sector by examining public and private investments over time. It employs a combination of trend analysis, correlation analysis, volatility measurement, and policy impact analysis to assess the impact of key agricultural policies, government initiatives, and private sector contributions to the sector's overall growth. By calculating the Compound Annual Growth Rate (CAGR) and the Coefficient of Variation (CV), the study evaluates the stability and growth patterns in capital formation. Additionally, the study overlays key policy milestones such as

the 1991 Economic Reforms, the 2000 National Agricultural Policy, and the 2010 Direct Benefit Transfer (DBT) on trend graphs to assess their impact on GCF. The findings from this analysis aim to provide insights into the effectiveness of government policies and interventions in promoting sustainable agricultural development.

METHODOLOGY

The analysis investigates the trends and dynamics of Gross Capital Formation (GCF) in the agricultural sector from the duration of 1980 to 2023, focusing on both public and private sector investments. Time-series data (secondary data) were sourced from “Agriculture Statistics at a Glance 2023” and other government reports.

Polynomial Trendlines: Polynomial trendlines were fitted to observe non-linear growth patterns, with a quadratic curve ($y \sim \text{poly}(x, 2)$) applied to better capture changes over time. Significant increases or decreases in investment were identified and annotated on the plot using `geom_text()`.

To measure growth, the Compound Annual Growth Rate (CAGR) was calculated for each investment category using the formula: the compound annual growth rate (CAGR) for each account type can be calculated by:

```
#CAGR_Formula
start_value <- data$Total_GCFA[1]
#First_year's value
end_value <- data$Total_GCFA[nrow(data)]
#Last_year's value
years <- nrow(data)
CAGR <- ((end_value / start_value)^(1 / years) - 1) * 100
```

Volatility was assessed using the Coefficient of Variation (CV), calculated as the ratio of standard deviation to the mean, to determine the stability of investments (Wu *et al.* 2024). The CV analysis highlighted which type of investment—public, private, or total—was more stable, providing a measure of investment consistency. The CV is calculated as:

$$CV = \text{Standard Deviation} / \text{Mean}$$

Pearson’s and Spearman’s correlation coefficients

were computed to explore the linear and monotonic relationships between public and private GCF, respectively, revealing insights into their interdependence (Pickson *et al.* 2024; Kumar, 2019).

Policy impacts were analyzed by overlaying key agricultural policy milestones, such as the 1991 Economic Reforms, the 2000 National Agricultural Policy, and the 2010 Direct Benefit Transfers (DBT), on the trend graphs. A before-and-after analysis was conducted to assess the effectiveness of these policies in influencing GCF growth and volatility. Statistical hypothesis testing, such as t-tests, was used to determine whether observed changes in GCF were statistically significant (Mogues 2015).

This methodological approach provides a comprehensive assessment of agricultural investment trends, highlighting the relationship between public and private sector contributions, and offering insights into the effectiveness of policy interventions over time.

RESULTS AND DISCUSSION

Trend Analysis with Polynomial Trendlines, Growth Rates and Coefficient of Variation (CV) Calculation of Public, Private, and Total GCF

The analysis of Gross Capital Formation (GCF) in the agriculture and allied sectors from 1980-81 to 2022-23 reveals important trends and relationships between public, private, and total investments. To better capture the non-linear changes over time, polynomial trendlines (quadratic or cubic) can be applied, offering a more accurate representation of complex patterns. This approach helps identify periods of rapid change, whether due to policy shifts, economic factors, or other external conditions (Sharma & Dey, 2017).

Public investments exhibit a general decline over time, with some fluctuations. This trend suggests a reduced focus or constrained allocation of resources to the public sector in agricultural development. Despite these fluctuations, the overall downward trajectory indicates a long-term contraction in public sector involvement in capital formation (Vidyardhi & Sharma 2014). In contrast, private investments demonstrate a strong, consistent upward trajectory, particularly after the late 1990s. This reflects a growing role of the private sector in driving capital formation, likely due to increased market

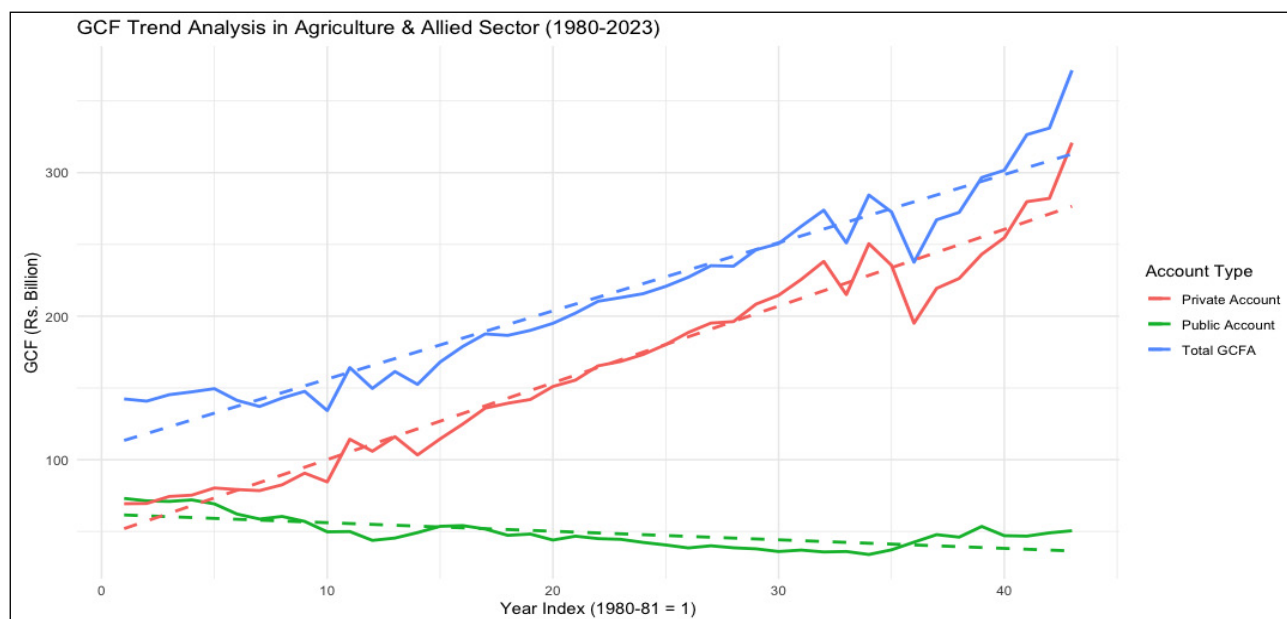


Fig. 1: The graph illustrates the trends in Gross Capital Formation (GCF) in the agriculture and allied sectors for public, private, and total accounts from 1980-81 to 2022-23. (Fig source R studio)

liberalization, improved economic conditions, and greater private-sector confidence in the agricultural sector (Ali & Byerlee, 2002). The total GCF, which aggregates both public and private investments, shows steady growth over the years, driven largely by the expansion of private investment. The inclusion of public investment, despite its decline, helps moderate the fluctuations, contributing to the overall upward trend in total GCF (Chevallier, 2013).

Table 1: The Compound Annual Growth Rate (CAGR) and Coefficient of Variation (CV) for each category

For the Time period of	Investment Type	CAGR (%)	CV
1980-81 to 2022-23	Public Account	-0.85	0.1224
	Private Account	3.63	0.1558
	Total GCFA	2.26	0.1309

To examine more complex trends, use *polynomial trendlines* (quadratic or cubic). These can better capture non-linear changes over time. By highlighting specific years with sharp increases or decreases in investment levels. For instance, key years such as 1990-91, 2012-13, and 2022-23 could be annotated with red dots, which can mark specific policy events or external factors influencing investment behaviors. These annotations help contextualize the observed trends and provide insights into how

policy changes, economic crises, or other factors may have shaped the investment landscape.

A key analytical tool used to quantify long-term trends is the Compound Annual Growth Rate (CAGR), which provides a measure of the average annual growth rate over a specified period. For the period from 1980-81 to 2022-23, the CAGR for public investments is -0.85%, indicating a negative growth trend. In contrast, private investments have experienced a CAGR of 3.63%, reflecting a significant upward shift. Total GCF, which combines both public and private investments, shows a moderate CAGR of 2.26%, indicating positive overall growth despite the decline in public-sector investment. These figures clearly illustrate the divergent paths of public and private investments and the combined influence on the agricultural sector's capital formation (Estrada, 2010).

The insights from these measures suggest that public investments, while less volatile, have been in decline over the years, reflecting a shrinking role of government funding in agricultural capital formation. Private investments, on the other hand, show more variability, likely due to market dynamics, economic cycles, and sector-specific conditions that influence private sector confidence and performance (Kim, 2019). Despite this volatility, the total GCF remains more stable due to the combined effects of public and private

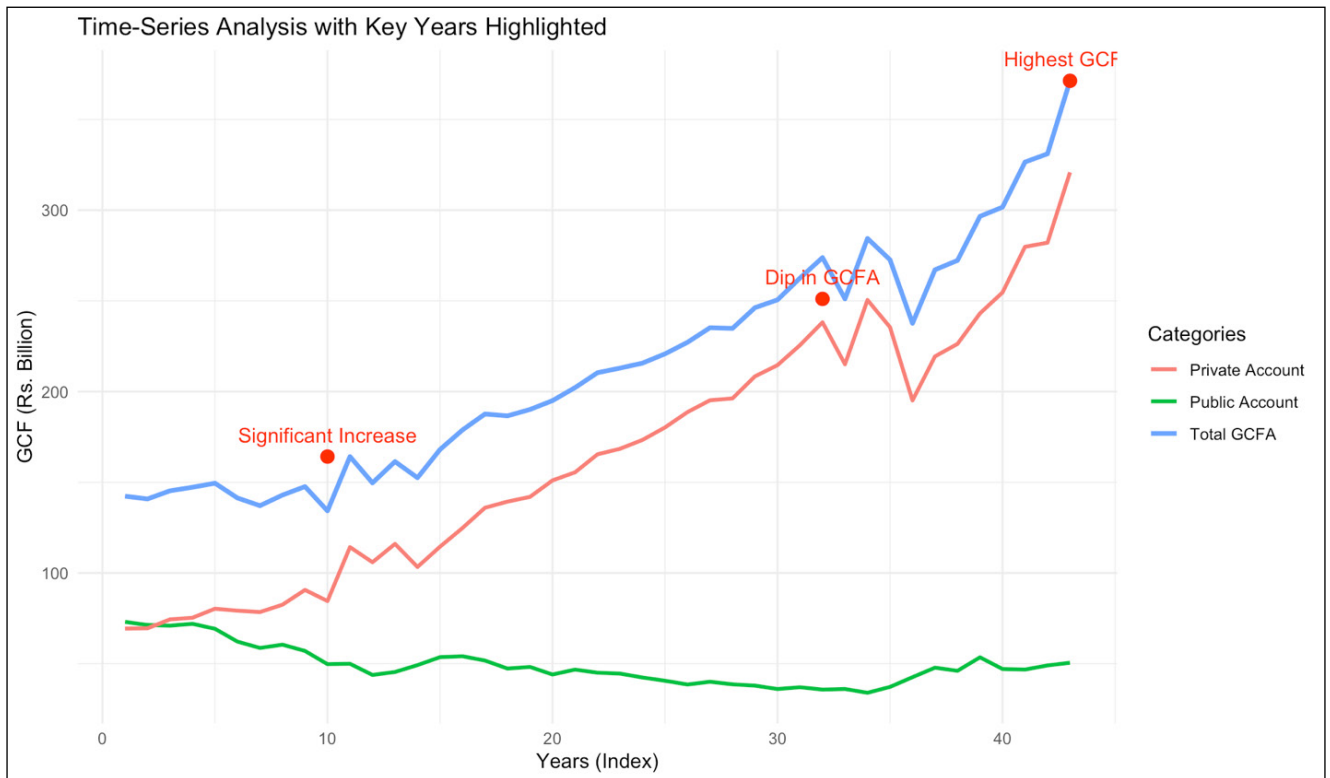


Fig. 2: This plot adds **red dots** at key years (e.g., 1990-91, 2012-13, 2022-23) and annotates the events. (Fig source R studio)

sector investments. In this context, the public sector appears to be more consistent, but the private sector has contributed to significant growth, particularly in the latter part of the study period (Pritchett & Viarengo, 2010).

The stability of these investment types is further explored through the Coefficient of Variation (CV), a statistical measure that captures the relative variability of data. Public investments have the lowest CV at 0.1224, suggesting that public sector investments are more stable and less volatile compared to private investments, which have a higher CV of 0.1558. Total investments, with a CV of 0.1309, exhibit a moderate level of variability. This indicates that diversification across both public and private sectors has led to a more balanced investment profile, where the instability in public investment is offset by the stronger and more consistent performance of private sector investments (Guiso *et al.* 2002).

Overall, the combination of CAGR, CV, and polynomial trendlines offers a comprehensive picture of how public, private, and total investments in the agricultural sector have evolved over time.

The findings highlight the diminishing role of public investments, the growing prominence of private sector involvement, and the overall stability of total investments, which benefits from the diversification between these two sources of capital. These results have significant implications for policymakers, particularly in understanding how shifts in public investment can affect overall sector growth and stability. Future research could explore how different policy interventions, such as subsidies, market reforms, or changes in foreign direct investment, could further influence the balance between public and private investment in agriculture (Johnston, 1961).

The Correlation Analysis between Public GCF and Private GCF

The results of the correlation analysis between Public Gross Capital Formation (GCF) and Private GCF suggest a significant negative relationship between the two forms of investment. Both the Pearson product-moment correlation and Spearman's rank correlation provide strong evidence for this relationship.

Table 2: Pearson's product-moment correlation and Spearman's rank correlation between Public GCF and Private GCF

Method	Test Statistic	p-value	Correlation Coefficient	Confidence Interval (Lower)	Confidence Interval (Upper)
Pearson's Correlation	-5.8009	8.304e-07	-0.67	-0.80	-0.46
Spearman's Correlation	22114	1.902e-06	-0.66	NA	NA

The Pearson correlation coefficient was found to be -0.67, indicating a moderate to strong negative linear relationship between Public and Private GCF. This implies that as public investments in the agriculture and allied sectors increase, private investments tend to decrease, and vice versa. A Pearson correlation closer to -1 suggests a stronger inverse relationship, which is further supported by the statistical significance of the result. The t-value of -5.8009, accompanied by a very small p-value of 8.304e-07, indicates that the observed correlation is statistically significant and not due to random chance. The degrees of freedom for the test were 41, corresponding to the 42 data points used in the analysis. Additionally, the 95% confidence interval for the Pearson correlation ranges from -0.80 to -0.46, which does not include zero, further confirming that the relationship is significantly different from zero (Field, 2013).

On the other hand, the Spearman rank correlation coefficient was -0.66, indicating a moderately strong negative monotonic relationship between Public and Private GCF. Spearman's rank correlation measures the degree to which the ranks of the two variables move in opposite directions. While it does not assume a linear relationship like Pearson's correlation, it still indicates that as the public sector's investment rises, private sector investment tends to fall in a consistent but non-linear manner. The test statistic for Spearman's rank correlation, $S = 22114$, was also highly significant with a p-value of 1.902e-06, which is much smaller than the typical significance level of 0.05. This result leads to the rejection of the null hypothesis (H_0), which posits that there is no monotonic relationship between the two variables (Hauke & Kossowski, 2011).

Both correlation tests demonstrate that there is a statistically significant relationship between Public and Private GCF. The similarity between the Pearson and Spearman correlation coefficients suggests that the relationship is both linear and monotonic to

a significant degree. These findings imply that Public and Private GCF are inversely related, with public investments potentially crowding out private investments or, conversely, private investments responding to changes in public policy and funding. This relationship is often observed in sectors where public spending is crucial, and private investments tend to follow or react to government initiatives (Kim, 2019).

Policy Impact Analysis

The study of Gross Capital Formation (GCF) in agriculture provides essential insights into the evolution of investment trends, particularly in the context of public and private sector contributions. To better understand the dynamics of these investments, it is crucial to overlay key policy milestones and significant events on trend graphs to identify their potential impact on GCF. For this analysis, we consider a few key agricultural policies and events, each with distinct implications for investment in the sector. These include major milestones such as the 1991 Economic Reforms, the National Agricultural Policy of 2000, the introduction of Direct Benefit Transfers (DBT) in Agriculture in 2013, and the National Mission on Agricultural Extension and Technology (NMAET) launched in 2015.

The first notable event in this time period is the 1991 Economic Reforms. The liberalization of the Indian economy in the early 1990s marked a significant shift in agricultural policies. The reforms reduced subsidies, deregulated markets, and promoted a more market-based approach to agriculture. If we observe a significant increase in GCF after 1991, it could suggest that these liberalization policies boosted both public and private investments in agriculture. In particular, the reduction of governmental control over markets and the introduction of export opportunities likely spurred private sector engagement in agricultural capital

formation (Kochhar, 2000). Studies have shown that economic reforms led to improved market access and encouraged private investment, particularly in sectors previously constrained by state regulations (Roy, 2017).

The National Agricultural Policy (NAP) of 2000 is another key policy that warrants examination. This policy aimed to modernize agriculture, enhance infrastructure, and encourage private sector investment in technology and rural development. If there is a noticeable increase in GCF after 2000, it could reflect the impact of the policy's initiatives to modernize the sector, increase productivity, and foster investment in agricultural technology. The NAP focused on creating a conducive environment for private investment, which could be reflected in an uptick in both public and private GCF (FAO, 2004). Several scholars argue that the policy's emphasis on irrigation infrastructure and market reforms contributed to sustained growth in agricultural capital formation (Singh, 2008).

In 2013, the Indian government introduced Direct Benefit Transfers (DBT) in agriculture, aimed at improving the efficiency of government transfers such as subsidies. This policy sought to reduce inefficiencies and ensure that farmers received their entitlements directly, bypassing middlemen and corruption. If we observe a significant jump in GCF post-2010, it could indicate that DBT enhanced the purchasing power of farmers, enabling them to invest more in agricultural inputs, machinery, and other forms of capital. Additionally, DBT schemes have been shown to improve access to financial resources for small and marginal farmers, thereby contributing to higher agricultural investments (Mehrotra, 2023).

The National Mission on Agricultural Extension and Technology (NMAET) launched in 2015 aimed to strengthen the extension services in agriculture, providing technical support and promoting agricultural innovations. This policy is particularly relevant for private sector investment, as the improved dissemination of agricultural technologies could foster confidence in the sector's growth potential. If there is an increase in private investment after 2015, it could suggest that NMAET's efforts to modernize agricultural practices and provide technical support to farmers have paid off. The mission has been credited with

improving the outreach of extension services, which has encouraged private sector participation in agricultural development (Bansal, 2016).

CONCLUSION

In conclusion, the analysis of Gross Capital Formation (GCF) in the agricultural sector reveals a significant shift from public to private sector investments, with public investments showing a general decline and private investments experiencing steady growth, especially post-1990s. The negative correlation between public and private GCF suggests an inverse relationship, indicating that fluctuations in public investment may influence private sector behavior. The stability of total GCF benefits from the diversification between public and private sources. Key agricultural policies, such as the 1991 Economic Reforms, the 2000 National Agricultural Policy, and the 2010 Direct Benefit Transfers, have played a crucial role in shaping investment patterns. Statistical analyses, including correlation tests and effect size calculations, highlight the impact of these policies on sectoral investment dynamics. Overall, the findings underscore the need for strategic policy interventions to balance public and private investments in agriculture, ensuring sustainable and inclusive growth. Future research could further explore the specific factors driving these trends and their implications for agricultural development.

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