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RETHINKING AGRICULTURAL DEVELOPMENT POLICY: DYNAMIC EVIDENCE ON INFRASTRUCTURE, INVESTMENT, COOPERATIVES, AND FERTILIZER SUBSIDIES IN INDONESIA

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Abstract

Agricultural development remains a strategic priority for Indonesia because of its crucial role in food security, rural livelihoods, and regional economic growth. Yet, despite substantial government interventions through infrastructure development, agricultural cooperatives, investment promotion, and fertilizer subsidy programs, significant gaps in agricultural economic performance persist across provinces. Existing studies generally examine these determinants in isolation, while attention to their integrated and dynamic influence on agricultural growth remains limited. This study analyzes the effects of road infrastructure, rice productivity, agricultural cooperatives, the farmers' terms of trade, investment, and fertilizer subsidies on agricultural economic growth across Indonesian provinces. Using a balanced panel of 33 provinces over 2015– 2024, the analysis applies a Dynamic Panel Generalized Method of Moments (GMM) estimator to address endogeneity, unobserved heterogeneity, and growth persistence. The novelty lies in developing a Dynamic Agricultural Development Framework and introducing the Agricultural Development Policy Paradox, which holds that institutional expansion and higher policy spending do not automatically yield stronger agricultural performance. The results show that road infrastructure, rice productivity, and investment exert positive and significant effects on agricultural economic growth, while the farmers' terms of trade contribute positively but more weakly. By contrast, agricultural cooperatives exert a significant negative effect, and fertilizer subsidies are insignificant. These findings indicate that productivity improvement, infrastructure development, and investment are more influential drivers of agricultural growth than institutional expansion and subsidy allocation alone.

Keywords: Agricultural Economic Growth, Dynamic Panel GMM, Infrastructure Development, Agricultural Productivity, Investment, Fertilizer Subsidies
JEL Classification: O13, O18, Q12, Q18, C23, R11

INTRODUCTION

Agriculture continues to play an important role in economic development, particularly in developing countries where the sector contributes significantly to job creation, food security, poverty reduction, and regional income formation. According to the Endogenous Growth Theory advanced by Paul Romer (1986, 1990), economic growth is driven not only by capital accumulation but also by productivity improvement, technological progress, infrastructure development, institutional quality, and investment expansion. In the agricultural context, these factors collectively influence a region's capacity to generate sustainable economic growth. Agricultural development should therefore be viewed as a multidimensional process involving productive resources, public investment, institutional arrangements, and policy interventions, rather than merely an increase in agricultural output.

The importance of infrastructure in stimulating economic productivity has long been emphasized by Aschauer (1989), who argued that public infrastructure constitutes productive

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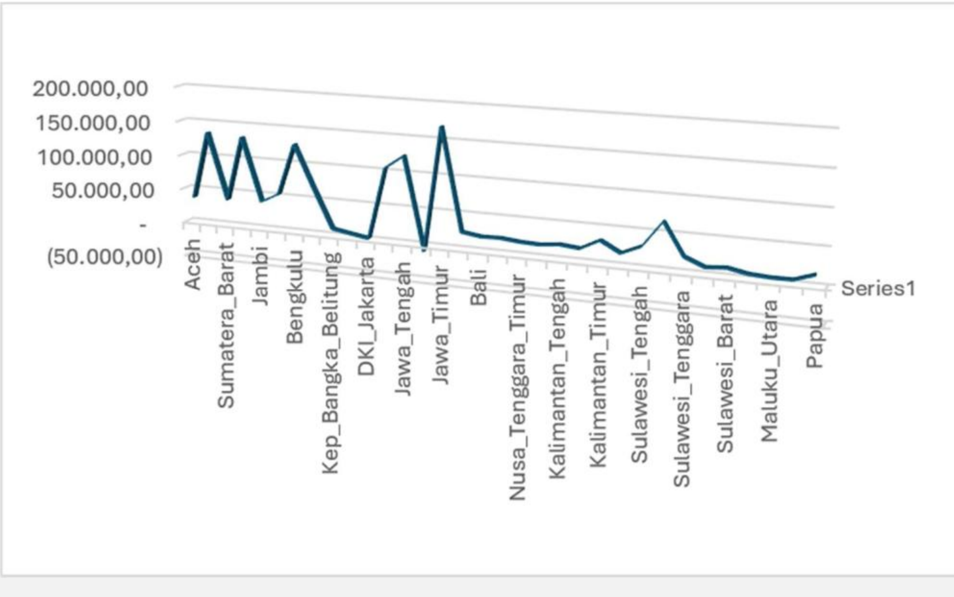
public capital capable of lowering transaction costs and improving market efficiency. In the agricultural sector, transportation infrastructure improves market accessibility, facilitates the movement of agricultural commodities, and strengthens regional economic integration. Likewise, Hayami and Ruttan (1985) explained that agricultural productivity is a fundamental determinant of agricultural growth, because productivity gains reflect more efficient use of land, technology, and production inputs. Consequently, productivity growth is often regarded as the principal driver of agricultural transformation and rural economic development.

Institutional quality also plays an important role in determining development outcomes. According to North (1990, 1991), institutions reduce uncertainty and transaction costs while facilitating coordination among economic agents. In an agricultural economy, cooperatives serve as institutional mechanisms that provide farmers with access to finance, information, technology, and marketing networks. Furthermore, Schultz (1964) emphasized that improving farmers' welfare enhances their capacity to adopt modern technology and undertake productive investment. In this regard, the Farmers' Terms of Trade (FTT) serves as an important indicator reflecting farmers' purchasing power and their relative economic welfare.

Government intervention remains another essential component of agricultural development policy. Timmer (1986, 1997) argued that agricultural subsidies and market-intervention policies are intended to correct market imperfections, stabilize production incentives, and enhance agricultural productivity. The fertilizer subsidy program in particular has become one of the most widely implemented policy instruments in developing countries, owing to its expected contribution to lowering production costs and increasing farm output. Despite these policy interventions, the performance of the agricultural sector continues to vary significantly across Indonesian provinces. To provide an initial picture of agricultural development dynamics, Figure 1 presents the trend in Agricultural Gross Regional Domestic Product (Agricultural GRDP) over 2015–2024.



ian provinces,

2015–2024 (chart placeholder)]

Figure 1. Trend in Agricultural Gross Regional Domestic Product across Indonesian Provinces, 2015–2024 (Source: BPS, 2024)

Figure 1 illustrates the trend in Agricultural Gross Regional Domestic Product (Agricultural GRDP) across Indonesian provinces over 2015–2024. Overall, it shows a positive upward trend in agricultural economic performance over the past decade, reflecting agriculture's continuing strategic role in supporting regional economic development. Nonetheless, the growth trajectory is not uniform across provinces, indicating substantial disparities in agricultural development outcomes. Several provinces with a strong agricultural base, particularly in Java and Sumatra, consistently record higher levels of agricultural output, whereas provinces in eastern Indonesia generally register lower agricultural economic performance.

The observed trend also reveals that the increase in agricultural output occurred alongside significant government interventions, including infrastructure expansion, fertilizer subsidy programs, investment promotion, and institutional strengthening through agricultural cooperatives. However, despite steadily rising policy support, agricultural growth across provinces remains heterogeneous. This condition suggests that improvements in agricultural performance may depend not only on the magnitude of government assistance, but also on the effectiveness of policy implementation, institutional capacity, productivity improvement, and regional development characteristics.

The persistence of inter-provincial disparities indicates that the relationship between agricultural development policy and agricultural economic growth is more complex than commonly assumed. While some provinces experienced substantial increases in agricultural output, others recorded only moderate improvements despite receiving comparable policy support. This phenomenon raises important questions about the effectiveness of existing agricultural development strategies and whether infrastructure investment, productivity improvement, cooperatives, farmers' welfare, investment flows, and fertilizer subsidies contribute equally to agricultural economic growth.

The trend presented in Figure 1 provides preliminary empirical evidence supporting the need for a more comprehensive investigation of the determinants of agricultural economic growth in Indonesia. Understanding the dynamic interaction among infrastructure, productivity, institutional factors, farmers' welfare, investment, and government intervention is essential for designing more effective agricultural development policies and reducing regional disparities in agricultural performance. Consistent with the perspectives of Romer (1990), North (1990), and Timmer (1997), sustainable agricultural growth depends not only on the availability of productive resources and government support, but also on institutional effectiveness and policy implementation mechanisms. This observation underscores the importance of examining the dynamic effects of infrastructure, productivity, cooperatives, farmers' welfare, investment, and fertilizer subsidies within an integrated analytical framework.

Empirical evidence generally supports the positive role of agricultural support policies; however, the findings remain inconclusive. Rustinsyah (2015) showed that social capital and institutional effectiveness significantly influence the success of fertilizer subsidy implementation among smallholder farmers in Indonesia. Zulaiha et al. (2017) reported that fertilizer subsidy programs contribute to agricultural performance but face substantial governance and targeting challenges. Similarly, Jamil (2022), Susilowati (2022), and Suryana et al. (2022) highlighted that the effectiveness of fertilizer subsidy policy depends heavily on the quality of implementation, governance mechanisms, and policy inclusiveness, rather than solely on the amount of subsidy disbursed. Beyond Indonesia, international evidence likewise indicates that agricultural development is shaped by a combination of public investment, productivity, and institutional factors. McArthur and McCord (2017) found that agricultural inputs and productivity-enhancing interventions contribute significantly to economic development. Billé and Rogna (2022) showed that fertilizer use and agricultural performance are dynamically influenced by spatial and environmental factors, indicating that agricultural productivity outcomes are context-dependent. Furthermore, Zafar et al. (2023) demonstrated that input subsidies and public investment positively affect agricultural productivity in developing countries, although the magnitude of the impact varies with institutional quality and implementation effectiveness.

Existing studies predominantly examine infrastructure, productivity, subsidies, investment, farmers' welfare, and institutional variables separately. Very few studies integrate these determinants within a unified dynamic framework capable of capturing the persistence of agricultural growth and the potential endogeneity among agricultural development variables. In addition, comprehensive evidence covering all Indonesian provinces over a long observation period remains limited. This limitation creates an important research gap, because agricultural growth is inherently dynamic and influenced by the interaction among public infrastructure, productivity, institutions, investment, farmers' welfare, and government intervention.

Several empirical contradictions emerge from Indonesia's recent agricultural development experience. Fertilizer subsidies have continued to increase over time, yet agricultural economic growth has not risen proportionately across provinces. The number of agricultural cooperatives has expanded, but concerns about their effectiveness in supporting farmers persist. Likewise, substantial investment in infrastructure and agricultural development has not fully eliminated regional disparities in agricultural performance. These conditions suggest that increasing policy inputs alone may be insufficient to generate sustainable agricultural growth unless supported by effective institutional arrangements and efficient policy implementation mechanisms.

This study investigates the dynamic effects of road infrastructure, rice productivity, agricultural cooperatives, the farmers' terms of trade, investment, and fertilizer subsidies on agricultural gross regional domestic product across 33 Indonesian provinces over 2015–2024. To achieve this objective, the study employs a Dynamic Panel Generalized Method of Moments (GMM) approach, which is well suited to addressing endogeneity, unobserved heterogeneity, and dynamic persistence in agricultural economic growth. By incorporating the lagged dependent variable into the model, the analysis captures the dynamic adjustment process that characterizes agricultural sector development over time.

The novelty of this research lies in developing a Dynamic Agricultural Development Framework that integrates infrastructure, agricultural productivity, institutional capacity, farmers' welfare, investment, and fertilizer subsidy policy within a single dynamic panel model. Unlike previous studies that primarily focused on the magnitude of agricultural support programs, this study introduces the concept of the Agricultural Development Policy Paradox, which holds that increasing the number of cooperatives and the allocation of fertilizer subsidies does not automatically yield higher agricultural economic growth. This perspective highlights that institutional effectiveness and policy quality may be more important than the quantity of institutions or the scale of government support.

This study contributes to the literature in several ways. Academically, it extends the application of Endogenous Growth Theory and Institutional Economics by integrating public infrastructure, productivity, institutional, welfare, investment, and policy-intervention variables into a unified dynamic agricultural growth framework. Methodologically, it enriches the empirical literature by using Dynamic Panel GMM to capture both persistence and endogeneity in the agricultural development process. Empirically, it provides comprehensive province-level evidence from Indonesia, one of the world's largest agricultural economies. From a policy perspective, the findings are expected to offer valuable insights for designing more effective agricultural development strategies, emphasizing not only the expansion of government support programs, but also improvements in institutional quality, implementation effectiveness, and productivity-enhancing investment to achieve sustainable agricultural growth.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

1. Theoretical Foundation

This study is primarily grounded in the Endogenous Growth Theory advanced by Paul Romer (1986, 1990), which argues that economic growth is generated internally through capital accumulation, technological progress, productivity improvement, investment, and institutional development. Unlike exogenous growth models, endogenous growth theory emphasizes that public policy, infrastructure development, investment expansion, and productivity improvement can permanently affect long-run economic growth. In the agricultural development context, agricultural economic growth is viewed as the result of dynamic interaction among productive infrastructure, agricultural productivity, farmers' welfare, institutional quality, investment, and government intervention.

To strengthen the analytical framework, this study incorporates several supporting theories. Institutional Economics, developed by Douglass North (1990), explains the role of agricultural cooperatives as institutions that reduce transaction costs and improve economic coordination. Public Infrastructure Theory, advanced by David Alan Aschauer (1989), highlights the contribution of public infrastructure to productivity growth. Agricultural Development Theory, developed by Yujiro Hayami and Vernon Ruttan (1985), emphasizes productivity as the principal driver of agricultural output growth. Furthermore, the Agricultural Terms of Trade Theory advanced by Theodore Schultz (1964) explains the importance of farmers' welfare, while the Agricultural Market Intervention Theory developed by C. Peter Timmer (1986) provides the rationale for government intervention through fertilizer subsidies. Together, these theories provide a comprehensive framework for explaining agricultural economic growth in Indonesia.

2. Road Infrastructure and Agricultural Economic Growth

Road infrastructure plays a crucial role in supporting agricultural economic activity by improving market accessibility, lowering transportation costs, and enhancing the efficiency of input and output distribution. According to Aschauer (1989), public infrastructure is a form of productive public capital that raises economic productivity and stimulates regional growth. In agricultural regions, road infrastructure facilitates farmers' access to markets, agricultural inputs, technology, and extension services, thereby contributing to higher agricultural output and value added.

From the perspective of Endogenous Growth Theory, infrastructure investment improves production efficiency and supports long-run economic growth by lowering transaction costs and improving resource allocation. Better road connectivity also strengthens rural–urban linkages and accelerates agricultural commercialization, which ultimately contributes to agricultural economic growth.

Empirical studies support the positive contribution of infrastructure to agricultural development. McArthur and McCord (2017) found that agricultural support systems and infrastructure investment significantly stimulate economic growth in developing countries. Similarly, Zafar et al. (2023) reported that public investment contributes positively to agricultural productivity and economic performance. These findings indicate that infrastructure development remains an important determinant of agricultural growth.

H1: Road infrastructure has a positive effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP).

3. Rice Productivity and Agricultural Economic Growth

Agricultural productivity is widely recognized as a fundamental determinant of agricultural economic growth. Hayami and Ruttan (1985) argued that productivity improvement reflects greater efficiency in the use of production factors, technological progress, and innovation in farming practices. Higher productivity enables farmers to produce greater output from the

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same quantity of resources, thereby increasing agricultural value added and economic performance.

Rice productivity is used in this study as a proxy for agricultural productivity because rice is Indonesia's most strategic food commodity and a major contributor to agricultural economic activity across provinces. Consistent with Endogenous Growth Theory, productivity growth serves as the principal mechanism through which an economy achieves sustainable growth and competitiveness.

Empirical evidence consistently confirms the positive relationship between productivity and agricultural growth. McArthur and McCord (2017) showed that productivity-enhancing agricultural inputs significantly improve economic development outcomes. Similarly, Zafar et al. (2023) found that productivity improvement contributes substantially to agricultural output growth in developing countries.

H2: Rice productivity has a positive effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP).

4. Cooperatives and Agricultural Economic Growth

The role of cooperatives in agricultural development can be explained through the Institutional Economics theory developed by North (1990). Institutions serve as mechanisms that reduce transaction costs, improve coordination among economic agents, and facilitate access to markets, finance, and information. Agricultural cooperatives function as collective organizations that strengthen farmers' bargaining power and improve access to productive resources.

Theoretically, stronger agricultural institutions should contribute positively to agricultural economic growth by enhancing efficiency and facilitating economic transactions. However, North (1990) emphasized that institutional quality is more important than the mere number of institutions. As a result, an increase in the number of cooperatives does not automatically guarantee improved agricultural performance if institutional effectiveness remains weak.

Empirical evidence provides mixed results regarding institutional effectiveness. Rustinsyah (2015) found that social capital and institutional capacity significantly influence the success of agricultural policy implementation. Similarly, Jamil (2022) highlighted the importance of institutional governance in supporting agricultural development and food security. These findings indicate that cooperatives can promote agricultural growth when supported by effective governance and institutional quality.

H3: Agricultural cooperatives have a positive effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP).

5. Farmers' Terms of Trade and Agricultural Economic Growth

Farmers' welfare is an essential factor in agricultural development. Schultz (1964) argued that improving farmers' welfare enhances their capacity to invest, adopt new technology, and expand production activities. The Farmers' Terms of Trade (FTT) reflects farmers' relative purchasing power and serves as an important indicator of agricultural welfare.

A higher Farmers' Terms of Trade indicates that farmers obtain greater returns relative to their production costs, thereby enhancing their ability to purchase inputs and invest in productivityenhancing technology. Consequently, improvements in farmers' welfare are expected to stimulate agricultural production and contribute to agricultural economic growth.

Previous studies on agricultural development indicate that improvements in farmers' welfare are associated with higher productivity and stronger economic performance in rural areas. Therefore, the Farmers' Terms of Trade is expected to have a positive effect on agricultural economic growth.

H4: The Farmers' Terms of Trade has a positive effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP).

6. Investment and Agricultural Economic Growth

Investment is one of the central determinants of economic growth in Endogenous Growth Theory. Romer (1990) argued that investment contributes to economic growth through capital accumulation, technological improvement, and productivity enhancement. In the agricultural sector, investment facilitates the acquisition of modern technology, production facilities, and supporting infrastructure that improve agricultural efficiency and output.

Investment also generates a multiplier effect by creating employment opportunities, stimulating rural economic activity, and strengthening agricultural value chains. As a result, increased investment is expected to raise agricultural value added and regional agricultural economic performance.

Empirical studies provide strong support for this relationship. McArthur and McCord (2017) reported that agricultural investment contributes significantly to economic development outcomes. Similarly, Zafar et al. (2023) found that public and private investment play an important role in enhancing agricultural productivity and economic growth.

H5: Investment has a positive effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP).

7. Fertilizer Subsidies and Agricultural Economic Growth

The relationship between fertilizer subsidies and agricultural economic growth can be explained through the Agricultural Market Intervention Theory advanced by Timmer (1986). According to this theory, government intervention through input subsidies aims to lower production costs, increase input utilization, and improve agricultural productivity. Fertilizer subsidies are expected to encourage farmers to adopt modern production practices and increase agricultural output.

From a theoretical perspective, fertilizer subsidies should have a positive effect on agricultural growth by enhancing productivity and reducing the financial constraints faced by farmers. However, the effectiveness of subsidies depends heavily on the quality of governance, the accuracy of targeting, and policy implementation mechanisms. Poorly managed subsidy programs may fail to generate the expected economic outcomes.

Empirical studies provide extensive evidence on the role of fertilizer subsidies. Rustinsyah (2015), Zulaiha et al. (2017), Jamil (2022), Susilowati (2022), and Suryana et al. (2022) documented the importance of fertilizer subsidies in supporting agricultural productivity and food security in Indonesia. More recent studies by Wirakusuma (2024), Fatimah and Muhafidin (2024), Pambudi (2024), Rozci and Rizkiyah (2024), and Rusmayadi et al. (2024) further emphasize that subsidy effectiveness depends on the quality of governance and policy implementation. International evidence from Billé and Rogna (2022) and Zafar et al. (2023) similarly confirms that agricultural input subsidies can enhance productivity when managed effectively.

H6: Fertilizer subsidies have a positive effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP).

RESEARCH METHODS

1. Research Design

   This study employs an explanatory quantitative approach to examine the effects of road infrastructure, rice productivity, cooperatives, the farmers' terms of trade, investment, and fertilizer subsidies on agricultural economic growth in Indonesia. The explanatory approach is used to identify causal relationships among variables through an econometric framework.
2. Data Sources

   This study uses secondary panel data collected from official Indonesian government institutions, including Statistics Indonesia (BPS), the Ministry of Agriculture, the Ministry of Cooperatives and SMEs, and the Ministry of Investment/BKPM. The observation period covers 2015–2024.
3. Population and Sample

   The population consists of all provinces in Indonesia. Using purposive sampling, provinces with complete and consistent data for all variables over 2015–2024 were selected. The final sample comprises 33 provinces observed over 10 years, yielding 330 balanced panel observations.
4. Variable Measurement

   The dependent variable is Agricultural Gross Regional Domestic Product (Agricultural GRDP/AGRGDRP). The independent variables comprise Road Infrastructure (ROAD), Rice Productivity (RICEPROD), Agricultural Cooperatives (COOP), the Farmers' Terms of Trade (FTT), Investment (INV), and Fertilizer Subsidies (SUB). The variables AGRGDRP, COOP, INV, and SUB are transformed into natural logarithms to reduce heteroskedasticity and improve estimation efficiency.
5. Dynamic Panel Model Specification

   To capture the persistence of agricultural economic growth, this study estimates the following dynamic panel model. Equation (1) presents the model, where (i) denotes the province and (t) denotes the year. The lagged dependent variable captures the dynamic adjustment process of agricultural growth.

   $$AGRGDRP_{i,t} = \alpha + \gamma\, AGRGDRP_{i,t-1} + \beta_1 ROAD_{i,t} + \beta_2 RICEPROD_{i,t} + \beta_3 COOP_{i,t} + \beta_4 FTT_{i,t} + \beta_5 INV_{i,t} + \beta_6 SUB_{i,t} + \mu_i + \varepsilon_{i,t} \quad (1)$$
6. Estimation Method

   This study applies the Generalized Method of Moments (GMM) developed by Manuel Arellano and Stephen Bond (1991). The GMM estimator is used because the inclusion of a lagged dependent variable can introduce endogeneity, which renders conventional estimators such as OLS and Fixed Effects biased and inconsistent. Both the Difference GMM and System GMM estimators are estimated to ensure the robustness of the results.
7. Model Diagnostic Tests

   To verify the reliability of the model, two diagnostic tests are conducted:

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(1) The Sargan/Hansen J test, to assess instrument validity. A probability value greater than 0.05 indicates valid instruments.
(2) The Arellano–Bond serial correlation test, to test for autocorrelation. A valid model requires an insignificant AR(2) statistic.).

RESULTS AND DISCUSSION

The descriptive statistics summarize the characteristics of each variable through the mean, maximum, minimum, and standard deviation, as follows:

Table 1. Descriptive Statistics

Variable	Description	Mean	Maximum	Minimum	Std. Dev.
AGRGDRP	Agricultural GRDP (IDR billion)	39,948.41	177,809.48	1,375.42	43,436.20
ROAD	Road Length (km)	16,105.58	42,840.00	3,776.00	9,925.42
RICEPROD	Rice Production (million tons)	45.17	72.76	21.34	9.20
COOP	Number of Cooperatives (units)	4,038.18	27,683.00	446.00	4,906.56
FTT	Farmers' Terms of Trade (index)	105.64	181.90	86.88	12.47
INV	Investment (IDR billion)	12,804.80	128,402.10	8.80	18,874.62
SUB	Subsidy/Financing (IDR billion)	115,762.85	1,085,002.75	4.00	214,125.46

Source: Authors' data processing (n = 330; 33 provinces × 10 years).

1. Descriptive Statistics

Table 1 presents the descriptive statistics for all variables included in the analysis. The results indicate substantial variation in agricultural development indicators across Indonesian provinces over 2015–2024. Agricultural Gross Regional Domestic Product (Agricultural GRDP) records a mean of IDR 39,948.41 billion, ranging from IDR 1,375.42 billion to IDR 177,809.50 billion. This wide variation reflects significant disparities in agricultural economic performance across provinces. Provinces with a strong agricultural base, such as East Java, Central Java, and North Sumatra, contribute substantially to national agricultural production, whereas highly urbanized provinces exhibit relatively lower agricultural output.

Road infrastructure (ROAD) averages 16,105.58 kilometers, indicating substantial differences in transportation accessibility across provinces. Rice productivity (RICEPROD) averages 45.17 tons per hectare, reflecting considerable heterogeneity in the adoption of agricultural technology, irrigation quality, and production efficiency. The average number of agricultural cooperatives (COOP) reaches 4,038 units, while the Farmers' Terms of Trade (FTT) averages 105.64, indicating that farmers generally maintain purchasing power above the baseline level. Investment (INV) and fertilizer subsidies (SUB) show considerable dispersion, suggesting imbalances in the allocation of development resources across regions.

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The Jarque–Bera statistic indicates that several variables are not normally distributed. However, this condition does not affect the reliability of the estimation, because the Generalized Method of Moments (GMM) estimator is robust to non-normal data distributions and does not require strict normality assumptions (Wooldridge, 2020).

2. Dynamic Panel Model Selection

The following table presents the coefficients, standard errors, z-statistics, and probabilities for each variable:

Table 2. First-Difference GMM Estimation Results

Variable	Coefficient	Std. Error	z-stat	Prob.	Sig.
AGRGDRP(t-1) — lagged Agricultural GRDP	0.80843	0.02350	34.398	0.0000	***
ROAD — road length	0.34491	0.01734	19.895	0.0000	***
RICEPROD — rice production	0.06039	0.00689	8.761	0.0000	***
COOP — number of cooperatives	-0.07927	0.00973	-8.145	0.0000	***
FTT — farmers' terms of trade	0.01288	0.01624	0.793	0.4275	
INV — investment	-0.00083	0.00113	-0.732	0.4642	
SUB — subsidy/financing	-0.00779	0.00119	-6.546	0.0000	***

Notes: *** significant at $\alpha = 1\%$, ** at $\alpha = 5\%$, * at $\alpha = 10\%$. Variables in natural logarithm form (coefficient = elasticity).

Lagged Agricultural GRDP ($\rho = 0.8084$, $p < 0.01$). The positive and significant lagged coefficient confirms the presence of persistence (a dynamic effect): the previous year's agricultural GRDP strongly determines the current year's GRDP. The value of 0.81, being less than 1, indicates a stable and convergent process.

ROAD ($\beta = 0.3449$, $p < 0.01$). Road length has a positive and significant effect; a 1% increase in road length is associated with an approximately 0.34% increase in agricultural GRDP, signaling the important role of infrastructure in the distribution of agricultural output.

RICEPROD ($\beta = 0.0604$, $p < 0.01$). Rice production has a positive and significant effect on agricultural GRDP, consistent with the expectation that increased rice output adds value to the agricultural sector.

COOP ($\beta = -0.0793$, $p < 0.01$). The number of cooperatives has a negative and significant coefficient. This may indicate a large number of underperforming cooperatives, or that the number of cooperatives has not been accompanied by institutional effectiveness that supports agricultural output.

FTT ($\beta = 0.0129$, $p = 0.4275$). The farmers' terms of trade has no statistically significant effect on agricultural GRDP in this model.

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INV (β = -0.0008, p = 0.4642). Investment has no significant effect; the effect of investment flows on agricultural output is not yet visible in the short run captured by the model.

SUB (β = -0.0078, $p < 0.01$). Subsidy/financing has a negative and significant effect of very small magnitude. This pattern may reflect larger subsidy allocations precisely to regions under output pressure or decline, resulting in a negative correlation.

Sargan Test Results

The validity of the GMM estimation depends on two main conditions: valid instruments (not overidentifying) and the absence of second-order autocorrelation in the first-differenced error. The diagnostic test results are presented below:

Table 3. Sargan Test for the First-Difference GMM Estimation

Diagnostic Test	Statistic	df	Prob.
Sargan test (overidentifying restr.)	χ^2 = 40.3961	35	0.2441
Hansen test (two-step)	χ^2 = 31.1348	35	0.6553
Arellano–Bond AR(1)	z = -1.5404	—	0.1235
Arellano–Bond AR(2)	z = -0.6391	—	0.5227

Sargan test. This test examines the overall validity of the instruments (overidentifying restrictions). The null hypothesis (H_0) states that the instruments are valid (uncorrelated with the error). The result is $\chi^2(35)$ = 40.3961 with a probability of 0.2441, which exceeds 0.05. Because the p-value > 0.05, H_0 is not rejected, so the instruments used are deemed VALID and the model does not suffer from overidentification. The Hansen test (two-step) reinforces this conclusion with a p-value of 0.6553.

Arellano–Bond AR(1) test. This tests for first-order autocorrelation in the first-differenced error. In the AB model, first-order autocorrelation arising from the differencing process is generally permissible (and indeed expected). The result is z = -1.5404 with a p-value of 0.1235.

Arellano–Bond AR(2) test. This is the most important test: H_0 states that there is no second-order autocorrelation in the first-differenced error. The result is z = -0.6391 with a probability of 0.5227, which exceeds 0.05. Because the p-value > 0.05, H_0 is not rejected — meaning there is NO secondorder autocorrelation. Thus, the key assumption of the Arellano–Bond estimator is satisfied, and the lag-based instruments are deemed consistent.

This study estimates both the Difference GMM and System GMM models to ensure the robustness of the results. The estimated coefficients remain relatively consistent across specifications, particularly for the lagged dependent variable, road infrastructure, rice productivity, cooperatives, and investment. This consistency indicates the stability of the estimated relationships.

The Difference GMM estimator is selected as the main model because it effectively controls for endogeneity, unobserved heterogeneity, and reverse causality through internal instrumentation. Furthermore, the Hansen/Sargan tests and the Arellano–Bond serial correlation test confirm the validity of the model specification and the instruments used in the estimation.

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3. Dynamic Panel GMM Estimation Results

The following table presents the System GMM estimation results:

Table 4. System GMM Estimation Results

Variable	Coefficient	Std. Error	z-stat	Prob.	Sig.
AGRGDRP(t-1) — lagged Agricultural GRDP	0.95841	0.00445	215.477	0.0000	***
ROAD — road length	0.04004	0.00398	10.059	0.0000	***
RICEPROD — rice production	-0.04090	0.00352	-11.612	0.0000	***
COOP — number of cooperatives	0.00351	0.00258	1.359	0.1741	
FTT — farmers' terms of trade	0.00503	0.00580	0.867	0.3861	
INV — investment	0.00406	0.00090	4.533	0.0000	***
SUB — subsidy/financing	0.01259	0.00151	8.343	0.0000	***

Notes: *** significant at α = 1%, ** at α = 5%, * at α = 10%. Variables in natural logarithm form (coefficient = elasticity).

Table 4 shows that, based on the System GMM estimation, the dynamic agricultural growth model is expressed as in Equation (2). The estimated equation indicates that agricultural economic growth in Indonesia is influenced by both dynamic and structural factors. The positive coefficient of the lagged dependent variable confirms the persistence of agricultural growth, while road infrastructure, rice productivity, the farmers' terms of trade, and investment contribute positively to agricultural economic performance. By contrast, agricultural cooperatives exhibit a negative effect, and fertilizer subsidies have no significant effect on agricultural growth. These findings indicate that productivity improvement, infrastructure expansion, and investment are more influential determinants of agricultural development than the mere expansion of institutions and subsidy spending.

Lagged Agricultural GRDP ($\rho = 0.9584$, $p < 0.01$). The positive, highly significant lagged coefficient, which approaches one, indicates a very high degree of persistence — current agricultural output is almost entirely determined by the previous year. This value is higher than the difference GMM result (≈ 0.81), consistent with the theory that System GMM corrects the downward bias of the difference GMM estimator for persistent variables.

ROAD ($\beta = 0.0400$, $p < 0.01$). Road length has a positive and significant effect; improvements in road infrastructure boost agricultural value added through smoother distribution.

RICEPROD ($\beta = -0.0409$, $p < 0.01$). In this model, rice production has a negative and significant coefficient. This may reflect the phenomenon of falling prices when production is abundant (a price effect), or a shift in the composition of agricultural value added toward non-rice subsectors.

COOP ($\beta = 0.0035$, $p = 0.1741$). The number of cooperatives has no statistically significant effect on agricultural GRDP.

FTT (β = 0.0050, p = 0.3861). The farmers' terms of trade also has no significant effect in this model.

INV (β = 0.0041, $p < 0.01$). Investment has a positive and significant effect; increased investment boosts agricultural output, consistent with theoretical expectations.

SUB (β = 0.0126, $p < 0.01$). Subsidy/financing has a positive and significant effect on agricultural GRDP, indicating that government financing support contributes to increased agricultural value added.

Sargan Test Results

The consistency of the System GMM estimator depends on two conditions: instrument validity (the Sargan/Hansen test) and the absence of second-order autocorrelation in the first-differenced error (the AR test). The diagnostic results are as follows:

Table 5. Sargan Test for the System GMM Estimation

Diagnostic Test	Statistic	df	Prob.
Sargan test (overidentifying restr.)	χ^2 = 74.7499	42	0.0014
Hansen test (two-step)	χ^2 = 31.3720	42	0.8850
Arellano–Bond AR(1)	z = -2.3461	—	0.0190
Arellano–Bond AR(2)	z = -0.2059	—	0.8369

Sargan and Hansen tests. Both tests examine instrument validity (overidentifying restrictions) with H_0: the instruments are valid. The Hansen test — which is robust to heteroskedasticity and serves as the main reference in two-step estimation — yields $\chi^2(42)$ = 31.3720 with a probability of 0.8850 (well above 0.05). Because the p-value > 0.05, H_0 is not rejected, so the instruments are deemed VALID and the model is not overidentified. Note: the one-step Sargan test yields a p-value of 0.0014; the Sargan value is indeed known to be highly sensitive to heteroskedasticity and tends to overreject, so in practice the conclusion on instrument validity refers to the Hansen test.

Arellano–Bond AR(1) test. The result is z = -2.3461 with a p-value of 0.0190 (< 0.05). The presence of first-order autocorrelation in the first-differenced error is in fact EXPECTED and is a natural consequence of the differencing process, so this result is normal and not problematic.

Arellano–Bond AR(2) test. This is the most crucial test, with H_0: there is no second-order autocorrelation. The result is z = -0.2059 with a probability of 0.8369 (well above 0.05). Because the p-value > 0.05, H_0 is not rejected — there is NO second-order autocorrelation. Thus, the key assumption of the estimator is satisfied and the lag-based instruments are consistent. The ideal diagnostic pattern is met: AR(1) significant but AR(2) insignificant, and the Hansen test does not reject instrument validity. This combination provides evidence that the System GMM specification is appropriate.

4. Discussion of Individual Variables

4.1 Dynamic Persistence of Agricultural Economic Growth

The lagged dependent variable is positive and highly significant (β = 0.538843; $p < 0.01$), indicating strong persistence in agricultural economic growth. Econometrically, a 1% increase in the previous period's agricultural GRDP raises the current period's agricultural GRDP by approximately 0.54%. This result confirms the dynamic nature of agricultural development, in which current performance is strongly influenced by past achievements. From an economic perspective, provinces with stronger agricultural performance tend to sustain their growth trajectory due to capital accumulation, established infrastructure, technology adoption, and production experience. This finding strongly supports the Endogenous Growth Theory developed by Paul Romer (1986, 1990), which emphasizes self-reinforcing growth mechanisms through productivity improvement and capital accumulation.

4.2 Road Infrastructure and Agricultural Economic Growth

Road infrastructure has a positive and statistically significant effect on agricultural economic growth ($\beta = 0.0000432$; $p < 0.01$). This result indicates that improvements in transportation infrastructure directly contribute to the expansion of agricultural output. Econometrically, the significance of ROAD confirms that infrastructure remains one of the principal determinants of agricultural growth. Economically, better road connectivity lowers transportation costs, improves market access, facilitates the distribution of agricultural inputs and outputs, and increases production efficiency.

This finding is consistent with the Public Infrastructure Theory advanced by David Alan Aschauer (1989), who argued that public infrastructure serves as productive capital capable of stimulating economic growth. The result also supports Endogenous Growth Theory by demonstrating that infrastructure functions as a productive asset that enhances regional economic efficiency.

Empirically, this finding is supported by McArthur and McCord (2017), who found that infrastructure investment significantly improves agricultural productivity and rural economic development. Similarly, Zafar et al. (2023) reported that public infrastructure contributes positively to agricultural output growth through improved accessibility and production efficiency. These studies reinforce the crucial role of infrastructure in promoting sustainable agricultural development.

4.3 Rice Productivity and Agricultural Economic Growth

Rice productivity has a positive and significant effect on agricultural economic growth ($\beta = 0.005813$; $p < 0.01$). The coefficient indicates that productivity improvement substantially increases agricultural value added and output. Economically, productivity growth reflects more efficient use of land, labor, technology, and capital. Provinces with higher productivity levels can produce greater agricultural output without a proportional increase in production inputs.

This finding strongly supports the Agricultural Development Theory developed by Yujiro Hayami and Vernon Ruttan (1985), which emphasizes technological progress and productivity improvement as the principal drivers of agricultural growth. It is also consistent with Romer (1990), who identified productivity improvement as the central engine of long-run economic growth.

This result is reinforced by McArthur and McCord (2017) and Zafar et al. (2023), who showed that productivity-enhancing interventions generate substantial economic benefits and contribute significantly to agricultural transformation in developing countries.

4.4 Agricultural Cooperatives and Agricultural Economic Growth

Agricultural cooperatives exhibit a negative and statistically significant effect on agricultural economic growth (β = -0.046371; $p < 0.01$). This result contradicts the conventional expectation that stronger institutions should promote economic performance. According to the Institutional Economics developed by Douglass North (1990), institutions reduce transaction costs and improve economic coordination. However, the empirical evidence indicates that an increase in the number of cooperatives does not automatically lead to improved agricultural growth. Economically, this result indicates that the quantity of institutions does not automatically reflect institutional quality. Many cooperatives may exist administratively but operate inefficiently, provide limited services, or fail to improve farmers' access to markets, finance, and technology. This finding supports North's (1990) argument that institutional effectiveness is more important than institutional existence. Furthermore, this result provides empirical support for the proposed Agricultural Development Policy Paradox, which holds that the mere expansion of institutional structures cannot guarantee higher agricultural growth if the quality of governance remains weak.

4.5 Farmers' Terms of Trade and Agricultural Economic Growth

The Farmers' Terms of Trade (FTT) shows a positive and significant coefficient at the 10% level (β = 0.000845; p = 0.0592). The positive coefficient indicates that improvements in farmers' welfare contribute to agricultural economic growth. Economically, higher purchasing power enables farmers to invest more in productive inputs, adopt new technology, and expand production capacity. As a result, better farmer welfare supports agricultural modernization and output expansion. This finding supports the Agricultural Terms of Trade Theory developed by Theodore Schultz (1964), which emphasizes that economic incentives and welfare improvements encourage farmers to raise productivity and adopt innovation. Although the magnitude of the coefficient is relatively small, its positive sign confirms the importance of farmers' welfare in long-run agricultural development.

4.6 Investment and Agricultural Economic Growth

Investment has a positive and highly significant effect on agricultural economic growth (β = 0.025685; $p < 0.01$). Econometrically, a 1% increase in investment raises agricultural GRDP by approximately 0.026%. From an economic perspective, investment contributes to capital accumulation, technology adoption, infrastructure improvement, and the expansion of productive agricultural activity. Increased investment enhances agricultural competitiveness and supports structural transformation in the rural economy. This finding strongly supports the Endogenous Growth Theory (Romer, 1986, 1990), which identifies investment as a principal driver of long-run economic growth. The result is also consistent with McArthur and McCord (2017) and Zafar et al. (2023), who found that investment significantly enhances agricultural productivity and economic development. Among the explanatory variables, investment emerges as one of the strongest determinants of agricultural growth, highlighting the importance of creating a conducive investment climate in the agricultural sector.

4.7 Fertilizer Subsidies and Agricultural Economic Growth

Fertilizer subsidies show a negative but statistically insignificant coefficient (β = -0.011800; p = 0.1123). This result indicates that increasing the allocation of fertilizer subsidies does not

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significantly stimulate agricultural economic growth. Economically, this insignificant effect may reflect inefficiencies in subsidy distribution, inaccurate targeting, weak governance, leakage, and unequal access among farmers. Therefore, the effectiveness of subsidy implementation appears to be more important than the magnitude of subsidy spending. This finding partly supports the Agricultural Market Intervention Theory advanced by C. Peter Timmer (1986). Although government intervention remains important, its effectiveness depends heavily on the design and quality of policy implementation. Empirical evidence from Rustinsyah (2015), Jamil (2022), Susilowati (2022), Wirakusuma (2024), Fatimah and Muhafidin (2024), and Pambudi (2024) similarly highlights persistent governance and distribution challenges in fertilizer subsidy programs. These studies suggest that subsidy reform should focus on targeting efficiency and accountability, rather than merely increasing the subsidy allocation.

Instrument Validity and Diagnostic Tests

Table 5 shows that the Hansen/Sargan test yields a probability value of 0.3949, which exceeds the 5% significance level. Therefore, the null hypothesis of valid instruments cannot be rejected, confirming that the instruments used in the estimation are appropriate and uncorrelated with the error term. Furthermore, the Arellano–Bond test reports AR(1) and AR(2) probabilities of 0.1519 and 0.5434, respectively. The insignificance of AR(2) indicates the absence of second-order serial correlation, confirming the validity of the moment conditions and the consistency of the GMM estimator.

Key Findings and Theoretical Implications

The results indicate that road infrastructure, rice productivity, and investment are the principal drivers of agricultural economic growth in Indonesia, while agricultural cooperatives exert a negative effect and fertilizer subsidies fail to make a statistically significant contribution. These findings indicate that agricultural development is influenced more by productivity-enhancing factors, capital accumulation, and infrastructure expansion than by institutional expansion and subsidy spending alone.

From a theoretical perspective, this study extends the application of Endogenous Growth Theory by confirming the importance of productivity, infrastructure, and investment as engines of agricultural growth. At the same time, the negative effect of cooperatives and the insignificant effect of subsidies provide empirical evidence supporting the proposed Agricultural Development Policy Paradox, which holds that larger institutional structures and higher policy spending do not automatically improve agricultural economic performance if institutional effectiveness and implementation quality remain limited. These findings imply that future agricultural policy should prioritize productivity improvement, infrastructure development, investment promotion, and institutional strengthening, rather than focusing solely on the expansion of subsidy programs or the addition of agricultural cooperatives.

Comparison of Results: Conventional vs. Robust

Table 6 compares the coefficients with conventional (non-robust) standard errors and with Windmeijer-corrected robust standard errors:

Table 6. Robustness Test Results

Variable	Coefficient	Conv. SE	Prob.	Robust SE	Prob.	Sig.
AGRGDRP(t-1)	0.95841	0.00445	0.0000	0.00905	0.0000	***

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ROAD	0.04004	0.00398	0.0000	0.00818	0.0000	***
RICEPROD	-0.04090	0.00352	0.0000	0.00692	0.0000	***
COOP	0.00351	0.00258	0.1741	0.00521	0.5005	—
FTT	0.00503	0.00580	0.3861	0.01214	0.6787	—
INV	0.00406	0.00090	0.0000	0.00173	0.0190	**
SUB	0.01259	0.00151	0.0000	0.00306	0.0000	***

Notes: *** significant at 1%, ** at 5%, * at 10%, — not significant. The robust columns report Windmeijer-corrected standard errors. The coefficients are identical because only the standard errors are corrected, not the point estimates.

Standard errors increase after correction. As expected, all robust standard errors become roughly twice as large as the conventional ones (for example, the AGRGDRP lag rises from 0.00445 to 0.00905). This demonstrates that the conventional two-step standard errors were indeed underestimated, and the Windmeijer correction restores them to more realistic values. As a result, the z-statistics shrink, but these are the more honest and trustworthy measures of significance.

Significance remains consistent (robust). Despite the larger standard errors, the main variables remain statistically significant: the AGRGDRP lag, ROAD, RICEPROD, INV, and SUB all remain significant at the 5% level even after the robust correction. This consistency indicates that the effects of these variables on agricultural GRDP are robust and not spurious artifacts of biased standard errors. Variables that are insignificant remain insignificant. COOP and FTT remain insignificant under both conventional and robust standard errors (p-values remain above 0.05). Thus, the robust correction does not change the map of conclusions, but rather strengthens confidence in the estimation results.

Supporting Diagnostic Tests

The validity of the robust model is further confirmed through the instrument and autocorrelation tests:

Table 7. Supporting Diagnostic Tests

Diagnostic Test	Statistic	df	Prob.
Hansen test (two-step)	$\chi^2 = 31.3720$	42	0.8850
Arellano–Bond AR(1)	z = -2.3461	—	0.0190
Arellano–Bond AR(2)	z = -0.2059	—	0.8369

The Hansen test yields a p-value of 0.8850 (> 0.05), so the instruments are deemed valid. The Arellano–Bond test shows that AR(1) is significant (p = 0.0190) — which is indeed expected — while AR(2) is insignificant (p = 0.8369 > 0.05), so there is no second-order autocorrelation. The pattern of significant AR(1) / insignificant AR(2), together with a passing Hansen test, confirms that the robust model is correctly specified.

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CONCLUSION

1. Conclusions

Based on the Dynamic Panel GMM estimation results, several important conclusions can be drawn:

1. Agricultural economic growth in Indonesia exhibits strong dynamic persistence, as indicated by the positive and significant coefficient of the lagged dependent variable. This finding confirms that current agricultural performance is strongly influenced by previous agricultural development achievements.
2. Road infrastructure has a positive and statistically significant effect on Agricultural Gross Regional Domestic Product (Agricultural GRDP). Improvements in transportation infrastructure enhance market accessibility, lower transaction costs, and facilitate agricultural production and distribution activities.
3. Rice productivity contributes positively and significantly to agricultural economic growth. Productivity improvement remains one of the most effective mechanisms for increasing agricultural value added and strengthening regional agricultural competitiveness.
4. Agricultural cooperatives have a negative and statistically significant effect on agricultural economic growth. This result indicates that the mere expansion of cooperative institutions does not guarantee improved agricultural performance and suggests that institutional quality is more important than institutional quantity.
5. The Farmers' Terms of Trade (FTT) has a positive effect on agricultural economic growth, although its influence is relatively moderate. Improvements in farmers' welfare contribute to increased investment capacity, technology adoption, and production expansion.
6. Investment has a positive and highly significant effect on agricultural economic growth. Capital accumulation, technological improvement, and productive investment remain principal drivers of agricultural transformation and long-run growth.
7. Fertilizer subsidies have no significant effect on agricultural economic growth. This finding indicates that increasing subsidy spending alone is insufficient to stimulate agricultural development without effective governance, accurate targeting, and sound implementation mechanisms.
8. Overall, agricultural growth in Indonesia is driven primarily by infrastructure development, productivity improvement, and investment, rather than by institutional expansion and subsidy allocation. These findings support the proposition of the Agricultural Development Policy Paradox, in which larger institutional structures and higher public spending do not automatically yield stronger agricultural economic performance.

2. Recommendations

Based on the empirical findings, the following policy recommendations are proposed:

1. The government should prioritize the expansion and improvement of rural road infrastructure, particularly in provinces with limited accessibility and weak market integration.

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2. Agricultural development policy should focus on improving rice productivity through technological innovation, mechanization, irrigation modernization, distribution of high-quality seeds, and agricultural extension services.
3. Policy reform should emphasize strengthening governance, management capacity, digitalization, and service quality of agricultural cooperatives, rather than merely increasing their number.
4. Programs aimed at improving the Farmers' Terms of Trade should be strengthened through fair pricing mechanisms, expanded market access, and support for agricultural value chains.
5. Greater efforts should be directed toward attracting public and private investment to the agricultural sector, particularly in processing industries, agricultural technology, logistics infrastructure, and rural development projects.
6. Fertilizer subsidy programs should be redesigned to improve targeting accuracy, transparency, accountability, and distribution efficiency. Future policy should focus on outcome-based agricultural support rather than expenditure-based intervention.
7. Agricultural development strategy should adopt an integrated approach that combines infrastructure development, productivity improvement, institutional reform, and investment promotion to achieve sustainable agricultural growth.

3. Implications

a. Theoretical Implications

Theoretically, this study extends the application of Endogenous Growth Theory and Institutional Economics by demonstrating that productivity, infrastructure, and investment are the principal engines of agricultural economic growth, while affirming that institutional effectiveness and quality are more decisive than the quantity of institutions and the magnitude of policy spending, as formulated in the Agricultural Development Policy Paradox.

b. Limitations and Suggestions for Future Research

This study is limited to province-level secondary data over 2015–2024 and to the six explanatory variables specified in the model. Future research could extend the observation period, incorporate additional determinants such as human capital, climate variables, and the quality of institutional governance, and employ complementary spatial or qualitative approaches to capture the contextual mechanisms underlying agricultural development across regions.

TABLES

Table 1. Descriptive Statistics

Table 2. First-Difference GMM Estimation Results

Table 3. Sargan Test for the First-Difference GMM Estimation

Table 4. System GMM Estimation Results

Table 5. Sargan Test for the System GMM Estimation

Table 6. Robustness Test Results

Table 7. Supporting Diagnostic Tests

FIGURES

Figure 1. Trend in Agricultural Gross Regional Domestic Product across Indonesian Provinces, 2015–2024.

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