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# Agriculture-led growth vs. post-agriculture: A comparative VECM analysis of Indonesia and Japan

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## ABSTRACT
**Background:** This study examines the role of agriculture in non-agricultural performance across two contrasting development stages, Indonesia (agriculture-anchored) and Japan (post-agriculture), spanning 1994-2023. To mitigate compositional endogeneity when agriculture is both an explanatory variable and part of total Gross Domestic Product (GDP), this study uses non-agricultural GDP (Net GDP), defined as total GDP minus agricultural value added, as the dependent variable. **Methods:** This study uses annual World Development Indicators data analyzed through a Vector Error Correction Model (VECM). The analysis was conducted after testing for unit roots using the Augmented Dickey-Fuller (ADF) test and confirming long-run cointegration through the Johansen cointegration test. Granger causality, impulse response functions (IRF), and forecast error variance decomposition (FEVD) were also used to examine dynamic relationships and shock transmission. **Findings:** The results show that, in Indonesia, agricultural value added has a positive and significant long-run effect on Net GDP, with a larger elasticity than capital and exports. The IRF and FEVD results further indicate that agricultural shocks generate a positive and relatively persistent response in Indonesia's Net GDP. In Japan, agricultural value added does not have a significant long-run effect on Net GDP, while capital and exports are the principal drivers. Japan's Net GDP response to agricultural shocks is weak or negative. **Conclusion:** These findings suggest that the role of agriculture in economic growth is stage-specific and supports different policy priorities for transition versus post-agricultural economies. **Novelty/Originality of this article:** This study contributes by comparing the role of agriculture in two economies at different stages of structural transformation. By using Net GDP rather than total GDP, the study shows that agriculture remains an important growth channel in Indonesia, while its role in Japan is more limited in a post-agricultural economy. This finding clarifies that agriculture-led growth is not universal but depends on the stage of development.

**KEYWORDS**: agricultural value added; Indonesia; Japan; net GDP; structural transformation; VECM

## 1. Introduction

In the context of an agrarian country, the agricultural sector plays a very strategic role, not only as a provider of employment and a main source of livelihood, but also as a pillar in ensuring food security and as an important instrument in poverty alleviation strategies. The contribution of this sector to the national economy cannot be ignored. Classical development literature notes that agriculture is the foundation for early growth and structural change, especially in low- and middle-income countries (Timmer, 1988). A report from the Food and Agriculture Organization (FAO) notes that globally, agriculture contributes about 4% to the Gross Domestic Product (GDP), but this figure can reach 25%

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in many developing countries, indicating a high economic dependence on this sector (FAO, 2021).

Structural transformation is characterized by a shift in the role of the agricultural sector towards the industrial and service sectors, which is a central theme of development economics (Kuznets, 1955b; Lewis, 1954). In the neoclassical framework, long-term growth is supported by capital deepening and technological progress (Solow, 1956), but modern literature emphasizes the paradoxical role of agriculture, even though its share of Gross Domestic Product (GDP) and employment is declining, a surge in agricultural productivity is often a prerequisite for inclusive and sustainable growth (Timmer, 2009). Linkage theory adds that agricultural performance triggers input–output and income spillovers to non-agricultural sectors (Hirschman, 1960). Empirically, agriculture growth linkages depend on the stage of development, being strong in developing/transition economies (Gollin, 2010; Valdés & Foster, 2010) and more functional-social in post-agricultural advanced economies (Spolador & Roe, 2013).

Structural transformation as an indicator of successful economic development in the context of global economic history (Jumono et al., 2024). Various evidence confirms that agriculture remains crucial to the economic transformation process, especially in developing countries (Chand, 2025; Korgbeelo, 2022; Nhemachena et al., 2020). The contrast between Indonesia and Japan represents two development regimes: Indonesia, as a transitional economy, still places agriculture as the mainstay of livelihoods and a source of inter-sectoral linkages, while Japan, as a post-agricultural economy, is dominated by industry and services, with agriculture serving more for food security, quality, and rural governance. However, comparative evidence across stages with a uniform econometric framework is still limited. Existing studies are single-country (Beckman & Countryman, 2021; Chebokchinova & Kapsargina, 2021; Korgbeelo, 2022). Although Awokuse & Xie (2014) address this issue by using non-agricultural GDP, their study focuses on developing countries and does not compare transitional and post-agricultural economies within a unified framework.

This study integrates the canon of structural transformation theory (Kuznets, 1955a; Lewis, 1954; Solow, 1956; Timmer, 2009) into a multivariate Vector Error Correction Model (VECM) time series framework in order to separate short-term dynamics and long-term relationships between Net GDP, agricultural value added, gross fixed capital, and exports of goods and services (Engle & Granger, 1987; Johansen & Juselius, 1990). The interaction between agriculture and capital accumulation is key to the direction and speed of structural transformation. In the context of advanced economies, the impact of agricultural quantity on aggregates tends to weaken and is replaced by dimensions of efficiency, quality, and socio-ecological functions. This study estimates the long-term and short-term relationships between Net GDP and agricultural value added, capital, and exports in Indonesia and Japan using VECM, and compares the transmission of agricultural shocks to Net GDP through the Impulse Response Function (IRF).

### *1.1 Literature review*

The role of agriculture in economic growth has long been a topic of discussion in development economics, particularly because agriculture can function differently at each stage of structural transformation. In the dual economy model, Lewis (1954) explains that the development process occurs through the expansion of the capitalist sector, which absorbs labor from the subsistence sector—a sector typically associated with traditional agriculture. However, agriculture's role within Lewis's framework extends beyond merely supplying labor. The expansion of the capitalist sector also requires increased food production, as industrial growth will boost food demand. Stagnant food production leads to rising food prices, squeezes the profits of the capitalist sector, and hinders capital accumulation. Therefore, industrialization in an agrarian economy requires increased agricultural productivity, not merely the migration of labor from rural areas to cities (Lewis, 1954; Timmer, 1988). Timmer (1988) reaffirms this argument by citing Lewis's classical logic that manufacturing production will not be profitable unless agricultural production grows simultaneously, thus making industrialization dependent on agricultural improvement.

Structural transformation explains why agriculture is important in the early stages of development but declines as per capita income rises. Kuznets (1955b) defines economic development as a long-term process of change in the structure of production, income distribution, and the shift of economic activity from the agricultural sector toward industry and services. This framework explains the decline in agriculture's share of GDP and the labor force as a common feature of modernizing economies. Timmer (1988) demonstrates that agricultural transformation is a relatively uniform process: as per capita income rises, agriculture's share of the labor force and national output tends to decline, yet agricultural growth often needs to precede or accompany overall economic growth. This highlights a paradox in agricultural transformation: while the agricultural sector declines relatively, continued growth in agricultural productivity remains essential to drive the transition toward an industrial and service-based economy.

This paradox is important because the decline in agriculture's share of the economy is often misinterpreted as a sign that agriculture no longer requires policy attention. Timmer (1988) explains that agricultural growth and agricultural decline are not mutually exclusive processes. In a growing economy, the agricultural share may decline due to Engel's Law and a shift in demand toward non-agricultural goods, while agricultural output continues to rise through productivity growth. If agricultural productivity does not increase, food prices may rise and burden growth in other sectors. Conversely, increased agricultural productivity allows labor and resources to shift to more productive sectors without creating excessive food price pressures. Timmer (2009) demonstrates that as an economy transitions from poor to rich, the share of agriculture in GDP and the labor force declines, but the absolute value of agricultural output and output per agricultural worker can still increase due to rising productivity. Therefore, the decline in agriculture's relative contribution must be distinguished from a decline in the economic relevance of agriculture.

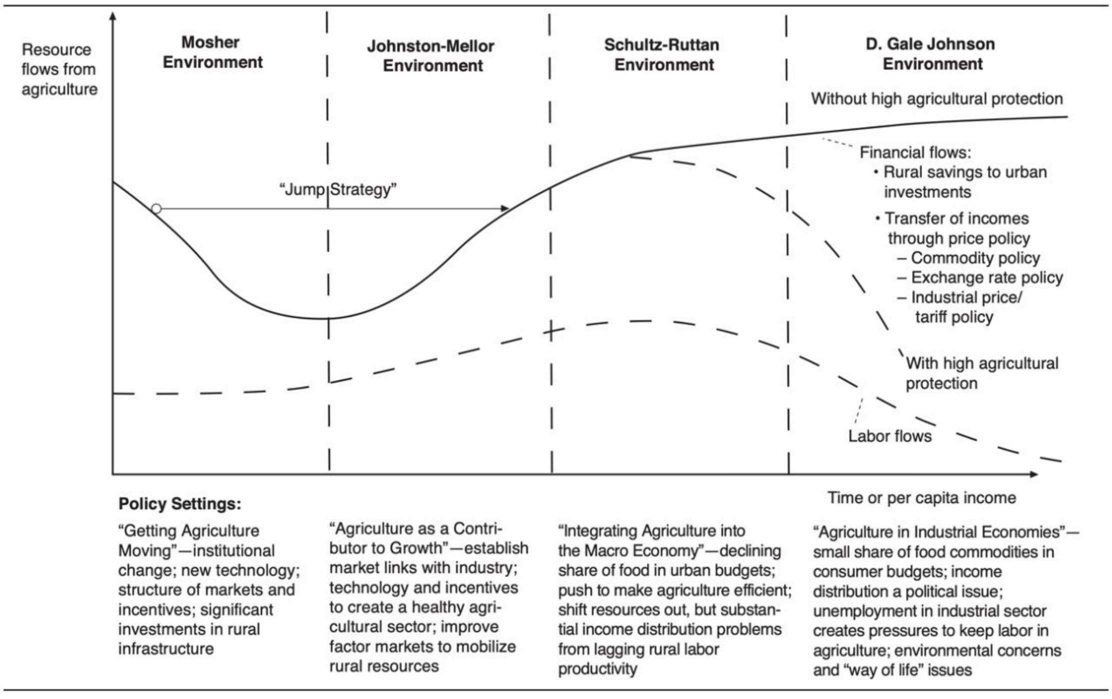



Fig. 1. Changing environments for agriculture's contribution to economic growth (Timmer, 1988)

The framework for agricultural contributions developed by Timmer (Figure 1) provides a conceptual basis for comparing transitional economies and post-agricultural economies. The role of agriculture shifts from the getting agriculture moving stage to becoming a contributor to growth through market linkages and resource mobilization, then integrating into the macroeconomy, and finally shifting to issues of farmer income, food security, environmental protection, and the social functions of rural areas within the industrial economy. In the early stage, agriculture plays a crucial role as a source of food, labor, savings, raw materials, and demand for industrial goods. In the later stage, agriculture's quantitative contribution to aggregate output weakens, but its socio-ecological functions remain significant. This framework is relevant for distinguishing between Indonesia and Japan, where Indonesia can be positioned as a transitional economy that still maintains agricultural–non-agricultural linkages, while Japan represents a post-agricultural economy whose growth is largely determined by capital, technology, exports, and the service sector.

Theoretically, the relationship between agriculture and growth can also be understood through Solow's neoclassical growth model. Solow (1956) identified capital accumulation, labor, and technological progress as the primary determinants of long-term output growth. Awokuse & Xie (2014) expanded this framework by incorporating agriculture, capital, exports, and terms of trade into the growth model. Their findings indicate that the relationship between agriculture and economic growth varies across countries. In some countries, results from VECM, Directed Acyclic Graph (DAG), IRF, and Forecast Error Variance Decomposition (FEVD) models support an agriculture-led growth pattern, while in others, a growth-led agriculture pattern or a two-way relationship is observed. These findings suggest that agriculture's contribution to growth cannot be generalized but depends on each country's economic structure and stage of development. This study adopts the measurement strategy (Awokuse & Xie, 2014), but expands upon it by comparing Indonesia with Japan as two economies at different stages of transformation. This comparison is crucial to test whether the impact of agriculture on Net GDP is stage-specific—that is, stronger in transitional economies and weaker in post-agricultural economies.

## 2. Methods

This study uses a comparative time series design for Indonesia (agriculture-led) and Japan (post-agriculture) for the period 1994–2023 (t = 30). The main econometric approach is the Vector Error Correction Model (VECM) to separate short-term dynamics from long-term equilibrium between cointegrated variables (Engle & Granger, 1987; Johansen & Juselius, 1990). All research variables are secondary data taken from the World Bank's World Development Indicators (WDI) to ensure uniform definitions and measurement methodologies across countries. The use of uniform data sources follows best practices in comparative econometric studies as applied in Awokuse & Xie, 2014 and Pesaran et al., 2001. The analysis was performed using EViews software.

### *2.1 Linear models and operational definitions*

Based on the Solow growth theoretical framework augmented with the agricultural sector (Awokuse & Xie, 2014; Solow, 1956), this study adopts a linear production model that is considered most appropriate for determining the relationship between dependent and independent variables. The linear model with natural logarithm transformation used in this study is as follows:

$$lnY_t = \beta_0 + \beta_A lnA_t + \beta_K lnK_t + \beta_x lnX_t + u_t \qquad \text{(Eq. 1)}$$

In this study, the variable Y used is Non-Agricultural GDP to overcome the endogeneity problem that may arise in the relationship between the agricultural sector and GDP. The endogeneity problem can arise because the agricultural sector variable (Agricultural Value Added) is an integral component of total GDP, which can cause bias in the estimation of its coefficient (Wooldridge, 2010).

Table 1. Definition and measurement of variables

| Variable | Concept Definition | Measurement |
|---|---|---|
| Net GDP (Y) | Aggregate output of non-agricultural sectors adjusted to constant price levels | Total GDP minus Agriculture Value Added (constant 2015 US Dollar (USD)) |
| Agricultural Sector (A) | Contribution of the agricultural sector to economic output | Agriculture value added (constant 2015 USD) |
| Capital (K) | Accumulation of capital in fixed assets to increase economic production capacity | Gross fixed capital (constant 2015 USD) |
| Exports (X) | Degree of economic openness reviewed through outward orientation, which reflects the role of exports in GDP | Exports of goods and services (constant 2015 USD) |

### *2.2 Research hypothesis*

Based on structural transformation theory and the results of previous empirical studies (Lewis, 1954; Timmer, 1988; Awokuse & Xie, 2014; Guzel & Akin, 2021), this study's hypothesis is formulated as follows:

1. $\mathrm{H}_1$: $|\beta_{A\_IND}| > |\beta_{A\_JPN}|$

The influence of the agricultural sector on Net GDP is greater in Indonesia than in Japan, in line with the different stages of structural transformation as proposed by Lewis (1954) and empirically confirmed by Awokuse & Xie (2014).

2. $\mathrm{H}_2$: $\beta_A \neq 0, \beta_K \neq 0, \beta_X \neq 0$

The agriculture, capital, and export sectors jointly influence Net GDP with different patterns between countries, following the predictions of the extended Solow theory (Solow, 1956; Meijerink & Roza, 2007).

3. $\mathrm{H}_3$: Impact comparison between Indonesia and Japan

The impact of shocks to the agricultural sector on net GDP is greater and longer lasting in Indonesia than in Japan, consistent with the sensitivity of developing economies to sectoral shocks (Gollin, 2010; Valdés & Foster, 2010).

Table 2. Expectation of coefficient signs

| Variable | Indonesia | Japan | Theoretical Justification | Supporting Studies |
|---|---|---|---|---|
| Agricultural Sector ($\beta_A$) | + | - | Structural transformation: advanced substitution | Awokuse & Xie (2014); Guzel & Akin (2021); Afriyanti et al. (2023) |
| Capital ($\beta_K$) | + | + | Capital accumulation drives production capacity | Meijerink & Roza (2007); Spolador & Roe (2013); Guzel & Akin (2021) |
| Exports ($\beta_X$) | + | + | Specialization and economies of scale in trade | Ijirshar (2015); Bakari & Tiba (2022) |

## 2.3 Analysis methods

### 2.3.1 Stationarity test (unit root test)

The analysis begins with a unit root test to determine whether the time series data used in the study is stationary. If the data is not stationary, the resulting regression risks displaying a spurious relationship (Engle & Granger, 1987). In this study, the Augmented Dickey-Fuller (ADF) test was used to test data stationarity. ADF has the advantage of accommodating residual autocorrelation through the addition of lags, thereby producing more reliable estimates than the conventional Dickey-Fuller test (Dickey & Fuller, 1979; Gujarati, 2009). In addition, ADF is sufficient to determine the integration order of variables required in the application of the Johansen cointegration test and VECM (Engle & Granger, 1987).

### 2.3.2 Johansen cointegration test

Cointegration tests whether linear combinations between variables have a stable long-term relationship, even though individual variables are non-stationary (Engle & Granger, 1987). This study uses the Johansen Cointegration Test procedure based on a multivariate Vector Autoregression (VAR) framework to determine whether there is long-term equilibrium between economic growth, the agricultural sector, capital, and exports. If all variables are integrated of order one (I(1)) and the Johansen test indicates cointegration, the study estimates VECM to separate short-term and long-term dynamics (Engle & Granger, 1987; Johansen & Juselius, 1990).

### 2.3.3 Vector error correction model (VECM)

VECM Model VECM is used to separate short-term and long-term dynamics as developed by Engle & Granger, 1987 and Johansen & Juselius, 1990. VECM is used when the research variables are non-stationary at the level but stationary after first differentiation (I(1)) and there is a cointegration relationship between variables. This model allows for the analysis of short-term interrelationships as well as adjustment mechanisms towards long-term equilibrium. Thus, VECM is considered appropriate for answering the research questions that focus on the role of the agricultural, capital, and export sectors on Net GDP in Indonesia and Japan. In general, the VECM form can be derived from the VAR model as follows:

$$\Delta lnY_t = a_0 + \lambda ECT_{t-1} + \sum_{i=1}^{p} \Phi_{1i}\Delta lnY_{t-i} + \sum_{i=1}^{q} \Phi_{2i}\Delta lnA_{t-i} + \sum_{i=1}^{r} \Phi_{3i}\Delta lnK_{t-i} + \sum_{i=1}^{s} \Phi_{4i}\Delta lnX_{t-i} + \varepsilon_t \quad \text{(Eq. 2)}$$

Where $ECT_{t-1}$ is the lagged cointegration term representing long-run disequilibrium and λ speed of adjustment toward long-run equilibrium, with the expectation that $ECT_{t-1} < 0$ and is significant to confirm the validity of the cointegration relationship (Lütkepohl, 2005).

### 2.3.4 Granger causality

Causality tests are used to determine the direction of causal relationships between variables, particularly between the agricultural sector and Net GDP, using Granger causality tests within the VECM framework (Engle & Granger, 1987). The null hypothesis in this test is that there is no Granger causality, with particular relevance for understanding the patterns of agriculture-led growth versus "growth-led agricultural transformation" as discussed in the development literature (Timmer, 1988).

*2.3.5 Impulse response function (IRF)*

The IRF analyzes the response of Net GDP to shocks in the agricultural sector over the next 10 periods to measure the persistence and magnitude of the shock impact (Lütkepohl, 2005). FEVD measures the relative contribution of each variable to Net GDP variability to confirm the IRF findings, following the methodology applied in (Awokuse & Xie, 2014; Pesaran et al., 2001).

## 3. Results and Discussion

*3.1 Descriptive analysis*

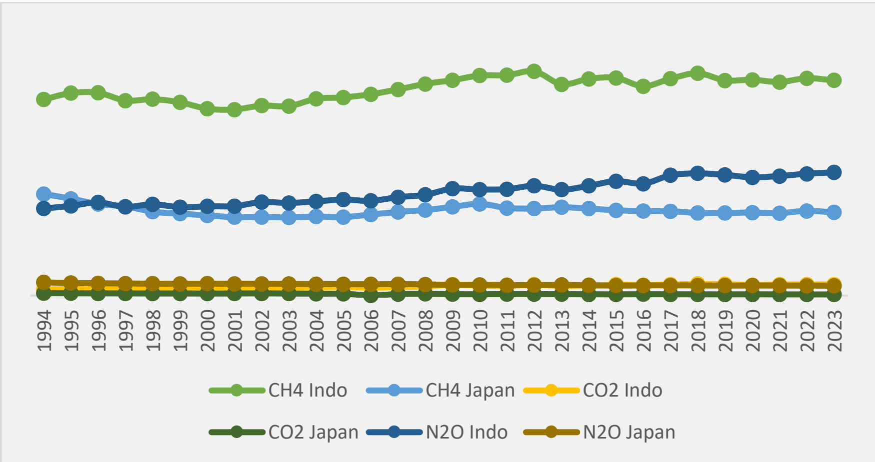



Fig. 2. Greenhouse gas emissions from the agricultural sector Indonesia-Japan, 1994-2023 (World Bank Group, 2026)

Before turning to the econometric estimates, it is useful to situate agriculture growth linkages within broader environmental and price stability patterns. Agriculture's contribution to global greenhouse gas emissions is reported to range from 10-12% (Chachei, 2024; Lin et al., 2011; Mohanty, 2024) and can reach 20-25% when land use change is included (Laborde et al., 2021; Litskas et al., 2020; Tubiello, 2018). Agriculture directly contributes to greenhouse gas (GHG) emissions through activities such as fertilizer use, soil management, and livestock farming. These activities primarily produce nitrous oxide ($N_2O$) and methane ($CH_4$), which are very potent greenhouse gases (Jeppiaar, 2010; Mohanty, 2024; Rosenzweig, 2015; Sutawi et al., 2024). The main source of $N_2O$ emissions is the use of synthetic and organic fertilizers, which significantly contribute to global $N_2O$ levels (Jeppiaar, 2010; Mohanty, 2024; Sharma, 2015). The main sources of $CH_4$ include enteric fermentation in ruminant livestock and rice paddies (Jeppiaar, 2010; Mohanty, 2024; Rosenzweig, 2015; Sharma, 2015; Sutawi et al., 2024).

Emissions patterns are also influenced by agricultural models of mechanization/chemical/energy levels, labor and capital productivity, with different effects according to income levels (Czyżewski & Kryszak, 2018). Emissions highlight the contrast: Indonesia remains dominated by the agricultural sector, where the expansion of rice cultivation and ruminant livestock increases $CH_4$ emissions, so that any push for growth in the agricultural sector carries increasingly high carbon costs. Agricultural carbon emissions pose a challenge to sustainable development (Guan et al., 2023). Japan shows decreasing emission decoupling because its economy is dominated by the non-agricultural sector, indicating that the role of agriculture is more related to efficiency and social functions than production scale. Therefore, without rapid methane mitigation, agriculture's contribution to Indonesia's net GDP risks being limited by carbon pressures, while Japan primarily needs to optimize residual efficiency. Indonesia has demonstrated its commitment to reducing greenhouse gases through the ratification of the Paris Agreement and the Nationally

Determined Contribution (NDC) document, with a projected reduction in GHG emissions of 29% by 2030 under a business-as-usual scenario, and 41% with international support (Suroso et al., 2022; Tenrini et al., 2021).

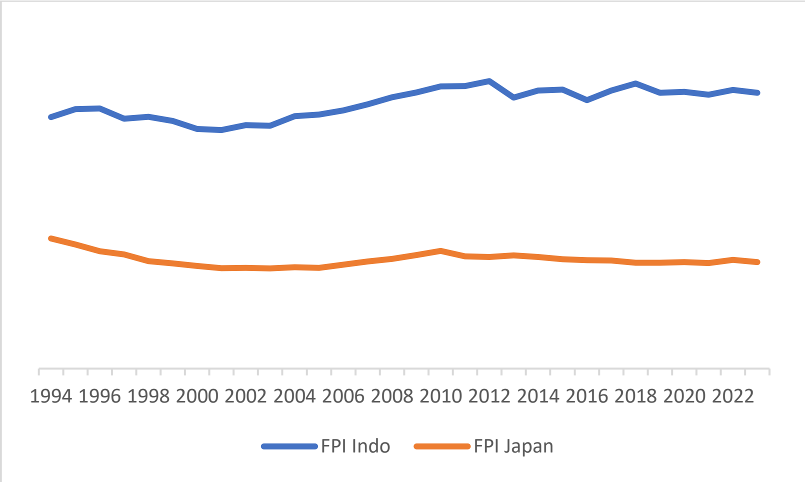



Fig. 3. Food price index Indonesia-Japan 1994-2023
(World Bank Group, 2026)

Indonesia's Food Production Index (FPI) rose and remained above Japan's throughout 1994–2023, indicating an expansion of domestic food production capacity relative to the 2014–2016 consistent with a development pattern still anchored in agriculture. Japan's FPI is flat to slightly declining, reflecting a stagnant or shrinking domestic production base in a more mature economy that relies more on efficiency and imports. In line with the emissions evidence, Indonesia's rising FPI coincides with higher $CH_4$, implying the need for methane mitigation so production growth is not accompanied by a high carbon burden.

The trend graph in Figure 3 clearly shows the differences in the economic structures of Indonesia and Japan. Indonesia shows rapid Net GDP growth after 2000 with significant shocks to exports due to the 1997/1998 and 2008 crises, while agriculture grew moderately but its share continued to decline. In contrast, Japan shows stable movements in both Net GDP and capital, with flat and small agricultural value added throughout the period. This pattern forms the basis for cointegration analysis and VECM estimation, to test whether the agricultural sector acts as an engine of growth (agriculture-led growth) or merely a buffer for macroeconomic stability in each country.

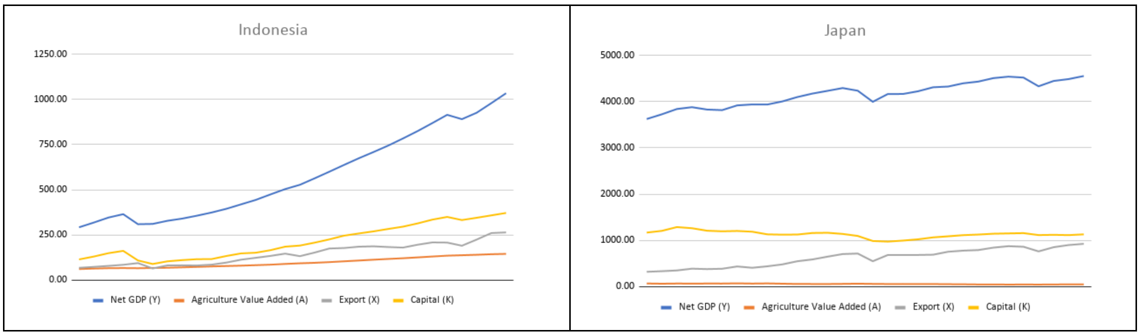



Fig. 4. Trend graph of NET GDP, capital, exports, and agricultural share (in billions of USD) Indonesia-Japan, 1994-2023
(World Bank Group, 2026)

### *3.2 Unit root test*

The stationarity test was conducted using Augmented Dickey-Fuller (ADF), confirming that all variables in both countries were non-stationary at the level but stationary at first difference, classifying them as I(1) according to the Dickey & Fuller (1979) procedure.

Table 3. Stationary test results *(ADF test)*

| Variable | Indonesia | | Japan | |
|---|---|---|---|---|
| | Level | First Diff | Level | First Diff |
| ln(Y) | 0.213 (0.969) | -4.321* (0.002) | -1.689 (0.426) | -5.521* (0.000) |
| ln(K) | -1.893 (0.628) | -3.960* (0.005) | -2.355 (0.163) | -3.389* (0.020) |
| ln(X) | -0.622 (0.851) | -6.879* (0.000) | -1.337 (0.598) | -6.839* (0.000) |
| ln(A) | 0.161 (0.965) | -4.415* (0.002) | -1.071 (0.714) | -5.997* (0.000) |

Note: Values in parentheses are p-values. ***, **, and * indicate rejection of the unit root null hypothesis at the 1%, 5%, and 10% significance levels, respectively.

(E-Views results, 2025)

The test results show that all variables in both countries are non-stationary at the level (all p-values > 0.16) but stationary at the first difference (all p-values < 0.021). This confirms that all variables are consistently integrated at order I(1). The uniformity of the integration order also validates the use of the Johansen cointegration and VECM methodologies so that spurious regressions that can occur in non-stationary data do not occur (Engle & Granger, 1987).

### *3.3 Optimum lag selection*

The results of the optimal lag selection show that for Indonesia, all information criteria (LR, FPE, AIC, SC, and HQ) are consistent at lag 2, so p=2 is used in the VECM estimation. Meanwhile, for Japan, there is a difference: AIC and FPE point to lag 2, but SC, HQ, and the LR test choose lag 1. Considering the principles of parsimony and consistency of the majority of criteria, this study sets lag 1 as the main specification for Japan. Additional estimates with lag 2 are still carried out as a robustness check to ensure that the empirical results are not biased towards lag selection.

### *3.4 Johansen cointegration test*

Table 4. Johansen cointegration test

| Hypothesis | Indonesia | | | Japan | | |
|---|---|---|---|---|---|---|
| | Trace Stat | Critical Value | Prob. | Trace Stat | Critical Value | Prob. |
| None* | 103.952 | 63.876 | 0.0000* | 65.825 | 55.246 | 0.0044* |
| At most 1* | 54.159 | 42.915 | 0.0026* | 36.793 | 35.011 | 0.0319* |
| At most 2 | 23.274 | 25.872 | 0.1018 | 13.984 | 18.398 | 0.1859 |
| At most 3 | 11.29003 | 12.51798 | 0.0795 | 2.110118 | 3.841466 | 0.1463 |

*Significant at the 5% level.

(E-Views results, 2025)

The results of the Johansen cointegration test show that both Indonesia and Japan have two cointegration vectors that are significant at the 5% level. This finding confirms the existence of a stable long-term relationship between Net GDP, agriculture, capital, and exports in both countries. Thus, the use of the VECM model is relevant to distinguish between short-term and long-term dynamics (Engle & Granger, 1987; Johansen & Juselius, 1990). For Indonesia, the existence of cointegration indicates that structural transformation is still supported by close links between the non-agricultural sector and other sectoral variables, consistent with the spillover effects theory in development literature (Awokuse & Xie, 2014). Meanwhile, in Japan, although the agricultural sector only contributes a small portion to GDP, the cointegration results still show a long-term connection. This is in line with the concept of a post-agricultural economy, in which agriculture plays more of a stabilizing role than a growth engine (Timmer, 2009).

### *3.5 Granger causality*

Table 5. Granger causality

| Relationships between variables | Indonesia | Japan |
|---|---|---|
| Agriculture Value Added (A) ↔ Net GDP (Y) | Bidirectional<br>Y → A (F=11.089***, p=0.0004)<br>A → Y (F=4.475**, p=0.023) | Unidirectional<br>A → Y<br>(F=5.322**, p=0.013) |
| Net GDP (Y) → Capital (K) | Unidirectional<br>Y → K (F=8.817***, p=0.0014) | No causality<br>(F=1.106, p=0.348) |
| Net GDP (Y) → Exports (X) | Unidirectional<br>Y → X (F=10.906***, p=0.0005) | No causality<br>(F=0.307, p=0.739) |

(E-Views results, 2025)

The test results show a complex causal relationship, with a two-way link between the agricultural and non-agricultural sectors, as well as the role of Net GDP as a driver for capital accumulation and export expansion. A bidirectional relationship was found between Net GDP and the agricultural sector, indicating a close relationship between the agricultural and non-agricultural sectors in line with Hirschman (1960) theory of intersectoral linkages. In addition, there is causality from Net GDP to Capital and to Exports, indicating that the growth of the non-agricultural sector is the main driver of investment and trade expansion. On the other hand, in Japan, the pattern that emerges is simpler, namely that there is only causality. This illustrates the characteristics of an advanced economy in which the agricultural sector has a positive but limited influence, in line with the concept of decoupling in post-agricultural economy theory (Timmer, 2009).

### *3.6 Vector error correction model (VECM)*

Short-term analysis shows that there are no significant variables for Indonesia's observed data. However, the error correction coefficient (ECT) is negative and significant, indicating that the Net GDP variable is driven by an adjustment mechanism to the long-term relationship between the variables of exports, capital, and agricultural value added. Indonesia's economic growth is determined more by long-term structural convergence processes than by temporary annual fluctuations.

Japan's observation data shows that in the short term, the ECT value is negative but not significant. This condition indicates that in the coming year, GDP growth will not immediately adjust to long-term equilibrium deviations. According to (Antzoulatos & Angelos, 1996), a negative but statistically insignificant coefficient value indicates that there is a correction towards equilibrium, but the adjustment process is weak or undetectable in the observation period. The agricultural sector at lag one has a negative effect on GDP. This reflects the pattern of post-agricultural economies in which the contribution of agriculture to GDP is relatively small and its fluctuations are more indicative of composition effects, harvest cycles, or competition for resources between sectors. Thus, these findings do not indicate a detrimental structural impact, but rather a normal short-term dynamic in countries with diversified economic structures.

Table 6. VECM

| Country | Indonesia | | Japan | | |
|---|---|---|---|---|---|
| Variable | Coefficient | T-Statistic | Variable | Coefficient | T-Statistic |
| Short Term | | | | | |

| | D(LNY) | | | | |
|---|---|---|---|---|---|
| D(LNY(-1)) | 1.138 | [ 1.148] | D(LNY(-1)) | 0.292 | [ 0.473] |
| D(LNY(-2)) | 0.057 | [ 0.073] | D(LNK(-1)) | 0.043 | [ 0.217] |
| D(LNK(-1)) | -0.221 | [-0.862] | D(LNX(-1)) | -0.095 | [-0.863] |
| D(LNK(-2)) | -0.130 | [-0.603] | D(LNA(-1)) | -0.185 | [-2.357]** |
| D(LNX(-1)) | 0.016 | [ 0.104] | | | |
| D(LNX(-2)) | 0.018 | [ 0.1460] | C | 0.009 | [ 0.982] |
| D(LNA(-1)) | 1.184 | [ 0.815] | CointEq1 | -0.528 | [-0.692] |
| D(LNA(-2)) | 0.121 | [ 0.069] | | | |
| C | -0.037 | [-0.969] | | | |
| CointEq1 | -2.994 | [-2.419]** | | | |
| Long Term | | | | | |
| LNY(-1) | 1.000 | | LNY(-1) | 1.000 | |
| LNK(-1) | -0.117 | [-3.394]* | LNK(-1) | -0.197 | [-9.187]* |
| LNX(-1) | -0.128 | [-5.222]* | LNX(-1) | -0.198 | [-19.02]* |
| LNA(-1) | -1.572 | [-12.242]* | LNA(-1) | -0.0186 | [-0.854] |
| C | 18.733 | | C | -17.759 | |

Note: LNY = Ln(GDP) or Log of Y; LNK = Log of Capital; LNX = Log of Exports; LNA = Log of Agriculture; * = 1%, ** = 5%, *** = 10%.

(E-Views results, 2025)

In the long term, Indonesia's estimates show that the variables of agriculture value added, exports, and capital have a significant effect on GDP growth. Cointegration estimates show that all variables move together towards long-term equilibrium. A 1% increase in agriculture value added causes a 1.57% increase in GDP, indicating that agriculture has the greatest elasticity for the economy. This is in line with (Andono, 2022), who states that the agricultural sector in Indonesia plays an important role in economic development. This pattern is consistent with the characteristics of transition economies, where the agricultural sector still plays an important role in driving growth through the support of the industrial and service sectors (Ho, 2024). A 1% increase in exports causes a 0.13% increase in GDP, reflecting the role of economic openness and technology diffusion. A 1% increase in capital increases GDP by 0.12%, confirming the role of capital accumulation in strengthening production capacity and competitiveness.

Japan's long-term estimates show that its GDP is mainly supported by capital and exports, both of which have a significant positive impact. A 1% increase in capital increases GDP by 0.19%, reflecting the role of investment in strengthening the foundations of growth through modern infrastructure development, industrial technology development, and increased production capacity. A 1% increase in exports increases GDP growth by nearly 0.20%, underlining the importance of trade openness. The agricultural sector does not show a significant contribution to long-term growth. This is in line with the characteristics of a post-agricultural economy, which is marked by the dominance of the industrial and service sectors in the economic structure. This is in line with (Pohl, 2012) findings that Japan's agricultural sector is less dominant than the industrial and service sectors.

### 3.7 Model validation

Table 7. Diagnostic tests for model validation

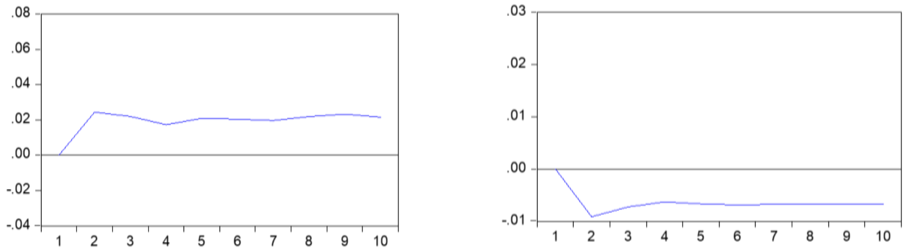
| Test | Indonesia – Statistic | Indonesia – p-value | Japan – Statistic | Japan – p-value |
|---|---|---|---|---|
| Serial Correlation (LM, lag 1) | 19.373 | 0.250 | 12.060 | 0.740 |
| Heteroskedasticity (White, joint) | 174.278 ($\chi^2$, df=180) | 0.606 | 190.893 ($\chi^2$, df=180) | 0.275 |
| Normality (Doornik–Hansen, joint skewness) | 4.067 | 0.397 | 2.904 | 0.574 |
| Normality (Doornik–Hansen, joint kurtosis) | 5.568 | 0.234 | 5.279 | 0.260 |
| Normality (Jarque–Bera, joint, additional information) | 9.635 | 0.292 | 8.183 | 0.416 |
| Stability (AR Roots) | All < 1.0 | Stable | All < 1.0 | Stable |

(E-Views results, 2025)

The diagnostic test results show that the estimated model has met the basic econometric assumptions. First, the model residuals are free from autocorrelation, as indicated by the insignificant LM test. This means that there are no repeating patterns in the errors, so that the dynamics captured by the model can be considered to originate purely from variable interactions, rather than from systematic prediction errors. Second, the White test results indicate no co-heteroscedasticity. Thus, the error variance can be considered homogeneous so that the coefficients obtained remain efficient and the significance test is unbiased. Third, normality testing using the Doornik–Hansen and Jarque–Bera approaches consistently does not reject the null hypothesis of normal distribution. This condition is important because it supports the validity of statistical inferences based on the normality distribution of residuals, especially in parameter testing and confidence interval formation. Fourth, the stability test using AR Roots confirms that all characteristic roots are within the unit circle. This means that the VECM system used is dynamically stable, so that further simulations such as impulse response functions (IRF) can be interpreted economically without the risk of divergence. Overall, the combination of these test results confirms that the constructed VECM model is valid and reliable. The model not only meets the technical requirements for estimation but is also suitable for analyzing both short-term and long-term relationships between the research variables.

### 3.8 Impulse response function (IRF)

The Impulse Response Function provides an overview of the impact of a shock from one variable on another variable. The following IRF estimation results show the shock effects of two countries, namely Indonesia as a representative of a developing country and Japan as a representative of a developed country. The results of the impulse response function are used to examine the dynamic response of Net GDP (Ln(GDP) or Log of Y (LNY)) to a shock in agricultural value added (Log of Agriculture (LNA)) over a ten-period horizon.




Indonesia Japan

Fig. 5. Impulse response function of LNY to LNA
(E-Views results, 2025)

The impulse response function (IRF) results show differences in GDP response patterns due to shocks in the agricultural sector between transition economies such as Indonesia and post-agricultural economies such as Japan. Indonesia shows that GDP variables respond positively to shocks in the agricultural sector, reflecting the role of the agricultural sector as a contributor to economic growth. Shocks to agricultural value added do not merely have a temporary impact; rather, they continue to boost Net GDP through the end of the observation horizon. This finding can be understood through several economic channels. An increase in agricultural value added can bolster rural household income, boost demand for non-agricultural goods and services, strengthen linkages with the agro-industrial sector, and provide raw materials for downstream economic activities. Based on this, the results of the Indonesia IRF support the argument that agriculture remains relevant as a source of growth momentum in an economy undergoing structural transformation.

In contrast, Japan shows a negative response, indicating that in an economy dominated by industry and services, an increase in agricultural output no longer drives aggregate growth. In an economic structure dominated by industry, services, technology, and high-value-added exports, shocks to the agricultural sector often reflect sectoral adjustment processes rather than macroeconomic growth drivers. This situation can arise because increases in agricultural value added are not always accompanied by a significant expansion of non-agricultural economic activity.

A comparison between Indonesia and Japan reveals differences in the role of agriculture depending on the stage of structural transformation. In Indonesia, an agricultural shock produces a positive and persistent response in Net GDP. This indicates that the agricultural sector remains linked to non-agricultural economic dynamics through income, production, and demand channels. In Japan, the response of Net GDP to agricultural shocks is negative and relatively weak. This suggests that in a post-agricultural economy, agriculture no longer serves as the primary engine of macroeconomic growth. Thus, the IRF results reinforce the argument that the relationship between agriculture and economic growth is stage-specific—that is, it differs between countries still undergoing structural transformation and those that have entered the post-agricultural stage.

### *3.9 Forecast error variance decomposition (FEVD)*

Table 8. Forecast error variance decomposition

| **Period** | **Indonesia** | | | | | **Japan** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **S.E.** | **LNY** | **LNK** | **LNX** | **LNA** | **S.E.** | **LNY** | **LNK** | **LNX** | **LNA** |
| 1 | 0.0341 | 100.00 | 0.00 | 0.00 | 0.00 | 0.0200 | 100.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.0586 | 79.67 | 1.05 | 1.99 | 17.30 | 0.0314 | 88.62 | 0.26 | 2.56 | 8.55 |
| 3 | 0.0788 | 80.39 | 1.22 | 1.11 | 17.29 | 0.0386 | 87.40 | 0.22 | 3.17 | 9.21 |
| 4 | 0.0959 | 79.67 | 1.71 | 3.71 | 14.91 | 0.0455 | 87.01 | 0.16 | 4.24 | 8.59 |
| 5 | 0.1187 | 78.52 | 5.00 | 3.65 | 12.82 | 0.0520 | 86.57 | 0.12 | 5.06 | 8.25 |
| 6 | 0.1396 | 80.86 | 5.07 | 2.66 | 11.40 | 0.0578 | 86.16 | 0.10 | 5.65 | 8.08 |
| 7 | 0.1541 | 82.49 | 4.31 | 2.22 | 10.98 | 0.0632 | 85.89 | 0.08 | 6.10 | 7.93 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 0.1672 | 82.88 | 3.92 | 2.18 | 11.02 | 0.0682 | 85.68 | 0.07 | 6.45 | 7.79 |
| 9 | 0.1816 | 82.80 | 4.07 | 2.14 | 10.99 | 0.0729 | 85.52 | 0.06 | 6.73 | 7.69 |
| 10 | 0.1953 | 83.06 | 4.22 | 2.01 | 10.71 | 0.0773 | 85.38 | 0.06 | 6.95 | 7.61 |

Note: LNY = Ln(GDP) or Log of Y; LNK = Log of Capital; LNX = Log of Exports; LNA = Log of Agriculture. (E-Views results, 2025)

The forecast error variance decomposition results show that the forecast variation in Net GDP (LNY) in both Indonesia and Japan is still largely dominated by shocks to LNY itself. This is expected because changes in Net GDP in a dynamic model are generally influenced by the historical behavior and internal innovations of the variable. However, the contribution of shocks from agricultural value added (LNA), capital (Log of Capital (LNK)), and exports (Log of Exports (LNX)) shows different patterns between Indonesia and Japan. This difference indicates that the role of agriculture in Net GDP dynamics is not uniform, but depends on each country's stage of structural transformation.

In Indonesia, the variation in LNY in the first period is fully explained by its own shock. The contribution of LNY then declines to 79.67% in the second period and fluctuates within the range of 78.52% to 83.06% through the tenth period. This decline indicates that, over a longer forecast horizon, the variation in Indonesia's Net GDP is increasingly explained by shocks from other variables, particularly agricultural shocks. This finding is consistent with the IRF results, which show that the response of LNY to an LNA shock remains positive throughout the observation horizon. Therefore, agricultural value added not only generates a positive response in Net GDP, but also contributes substantially to explaining its forecast variation. This further strengthens the argument that agriculture continues to play an important role in supporting non-agricultural economic activity in Indonesia.

In Japan, the variation in LNY is also dominated by its own shock. In the first period, LNY accounts for 100% of its forecast variation, before declining to 88.62% in the second period and remaining high at 85.38% in the tenth period. The contribution of LNA in Japan is smaller than in Indonesia. Agricultural shocks explain around 7.61% to 9.21% of the variation in LNY, indicating that agriculture still contributes to Net GDP variation, but to a more limited extent. However, this contribution should not be interpreted as evidence that agriculture positively drives Japan's Net GDP. FEVD measures the relative contribution of shocks to forecast variation, while the direction of the response is shown by the IRF. Since the IRF results for Japan indicate a negative response, the contribution of LNA is better interpreted as a form of sectoral adjustment or pressure within a post-agricultural economy, rather than as a positive growth stimulus.

Another important difference can be observed in the role of exports in Japan. The contribution of LNX increases from 2.56% in the second period to 6.95% in the tenth period. This pattern suggests that, over a longer horizon, export shocks become increasingly relevant in explaining the variation in Japan's Net GDP. Comparatively, the FEVD results show that agricultural shocks contribute more to Net GDP variation in Indonesia than in Japan. This supports the argument that the relationship between agriculture and economic growth is stage-specific. In Indonesia, as a transitional economy, agriculture remains an important source of shocks for Net GDP dynamics and generates a positive response. In contrast, in a post-agricultural economy such as Japan, the contribution of agriculture to Net GDP variation is smaller and the response is negative, indicating that agriculture no longer functions as the main engine of macroeconomic growth.

Overall, the variance decomposition results reinforce the main findings of this study. In Indonesia, agriculture makes a meaningful contribution to Net GDP variation and is associated with a positive response in the IRF. This supports the relevance of agriculture-led growth in the context of an economy that is still undergoing structural transformation. In Japan, agricultural shocks still affect Net GDP variation, but their contribution is more limited and the direction of the response is negative. Therefore, the role of agriculture in Japan is more appropriately understood as part of food security, rural landscape management, and environmental sustainability, rather than as a primary driver of national economic growth.

### 3.10 Policy implications

The findings of this study imply that agricultural policy should be designed according to each country's stage of structural transformation rather than based on a uniform agriculture-led growth prescription. The comparative evidence indicates that agriculture still has a stronger growth linkage with Net GDP in Indonesia, while in Japan its macroeconomic role has become more limited and indirect. This difference is consistent with the structural transformation literature, which argues that the contribution of agriculture changes as economies move from agrarian and transitional structures toward industrial and post-agricultural systems (Briones & Felipe, 2013;Timmer, 1988, 2009). Therefore, the policy implication is not that agriculture should always be treated as the main driver of growth, but that its function must be interpreted in relation to the broader economic structure, labor transition, food system, and rural development trajectory of each country.

For Indonesia, the evidence supports the continued relevance of agriculture as a channel of growth, but the policy direction should move beyond primary production expansion. Agricultural growth will have a stronger effect on non-agricultural performance when it is connected to value-added activities, rural industries, logistics, processing, storage, market access, and quality standardization. Studies on Indonesia's rural transformation show that agricultural change is increasingly linked to shifts toward higher-value commodities, non-farm rural employment, and stronger rural–urban economic linkages (Sudaryanto et al., 2021; Sudaryanto et al., 2023). This means that agricultural policy should not only aim to increase output at the farm level, but also strengthen the transmission channel from agriculture to non-agricultural sectors. Policy instruments such as agro-processing development, cold-chain infrastructure, farmer–industry partnerships, rural entrepreneurship, and post-harvest technology can help convert agricultural value added into broader economic gains.

Indonesia also requires spatially differentiated agricultural policy because rural transformation does not occur evenly across regions. Areas with stronger infrastructure and market access can be directed toward agroindustry, export-oriented value chains, and higher-value agricultural products. In contrast, regions with weaker transformation capacity still require basic rural infrastructure, extension services, farmer organization, access to credit, and market integration. Evidence from Indonesian rural transformation studies shows that the pace and pattern of agricultural change differ across regions and ecosystems, which affects household income, poverty reduction, and employment transition (Sudaryanto et al., 2023; Susilowati et al., 2021). Therefore, national agricultural strategies should not be implemented as one-size-fits-all programs. They need to be translated into region-specific interventions based on land characteristics, irrigation capacity, commodity specialization, farmer institutions, and proximity to markets.

At the same time, Indonesia's agriculture-led growth pathway should be supported by food security, input efficiency, and environmental safeguards. This does not shift the focus of the study away from agriculture–growth linkages; rather, it clarifies the quality of agricultural growth needed to sustain its contribution to Net GDP. Food security policy in Indonesia cannot rely solely on production expansion because it also depends on land protection, food diversification, distribution systems, farmer income, and resilience to climate-related shocks (Rozaki, 2021). Large-scale food expansion programs also need careful evaluation because their effectiveness depends on land suitability, water availability, farmer capacity, infrastructure, and local institutional readiness (Vinolina & Supriana, 2025). Thus, Indonesia's agricultural policy should prioritize productivity growth that is efficient, regionally appropriate, and connected to stable food supply systems.

Input efficiency is particularly important because agricultural growth can create pressure on land, water, fertilizer use, and greenhouse gas emissions. In rice-based systems, improved water management can reduce methane emissions while maintaining production when implemented under suitable irrigation and institutional conditions. Practices such as intermittent irrigation or alternate wetting and drying should therefore be promoted selectively in areas where water control, farmer coordination, and extension support are available. Fertilizer policy also needs to move from a distribution-oriented approach toward nutrient efficiency. Site-specific nutrient management can improve fertilizer use efficiency by adjusting nutrient application to local soil and crop conditions (Rodriguez, 2020). Simpler tools such as chlorophyll meters and leaf color charts can also support need-based nitrogen management, especially for smallholders who may not yet have access to more advanced precision technologies (Varinderpal-Singh et al., 2010). In addition, compost and biochar application can be considered as complementary practices to improve soil conditions and mitigate greenhouse gas emissions in paddy fields (Pramono et al., 2021). These policy directions are important because agricultural growth that depends on inefficient input use may increase output in the short term but weaken long-term sustainability and production resilience.

For Japan, the policy implication is different. Agriculture should not be forced to return as a major engine of macroeconomic growth because Japan's economic structure is already dominated by industry, services, technology, capital accumulation, and trade. Instead, agricultural policy should position the sector as a resilience sector that supports food security, rural continuity, and strategic domestic production capacity. Japan's agricultural policy has long been shaped by reform efforts, market liberalization pressures, institutional constraints, and debates over the future of small-scale farming (Honma, 2009; Honma & George Mulgan, 2018; Sekine, 2023). In this context, the objective of policy should not be large-scale expansion of agricultural output for GDP growth, but the maintenance of a viable agricultural base under conditions of limited land, aging farmers, rural depopulation, and labor shortages.

Smart agriculture is a central policy instrument for Japan because it directly responds to the structural problem of declining agricultural labor. Technologies such as remote sensing, artificial intelligence, big data, robotics, autonomous machinery, and precision farming can help sustain production capacity with fewer workers and improve the efficiency of farm management (Inoue, 2023; Li et al., 2023). However, technology adoption should not be treated as a purely technical solution. Its effectiveness depends on land consolidation, farmer training, financing schemes, data standardization, and institutional support. Simplified smart agriculture systems may also be relevant for smaller-scale farms because not all producers can adopt expensive and complex technologies at the same pace (Rubanga et al., 2019). Therefore, Japan's agricultural modernization should combine digital technology with farm succession policies, coordinated land use, agricultural corporations, cooperatives, and rural revitalization programs.

Japan's agricultural policy should also recognize that the value of agriculture is not fully captured by GDP-based indicators. Agricultural landscapes, especially paddy-field systems and traditional rural landscapes, provide ecosystem services such as water regulation, flood control, biodiversity conservation, erosion prevention, cultural landscape preservation, and rural amenity values (Jiao et al., 2019; Sasaki et al., 2021). Farmland abandonment can therefore reduce not only food production capacity but also the ecological and social functions of rural areas. Policy instruments such as payment for ecosystem services, support for multifunctional agriculture, organic farming incentives, and community-based land management can help preserve these non-GDP functions. Evidence from Japan shows that payment-based approaches can support community efforts to counter land abandonment and maintain agricultural landscapes in rural and mountainous areas (Shoyama et al., 2021).

Overall, the policy implications of this study point to two different agricultural strategies. Indonesia needs agriculture as a growth channel, but this channel should be strengthened through value-added transformation, rural industrialization, food system resilience, input efficiency, and lower-emission production practices. Japan, in contrast, needs agriculture as a resilience sector that protects food security, rural communities, technological adaptation, and ecosystem services. These contrasting directions confirm that agriculture-led growth is not a universal policy formula. Its relevance depends on whether agriculture still has strong linkages with non-agricultural output, how far structural transformation has progressed, and what strategic functions agriculture performs beyond its direct contribution to GDP.

## 4. Conclusions

This study shows that the role of agriculture in non-agricultural economic performance differs between Indonesia and Japan. By using Net GDP, defined as total GDP minus agricultural value added, this study seeks to avoid the compositional problem that may arise when agricultural value added is used as an explanatory variable in a growth model based on total GDP. Through the VECM approach, the findings indicate that the relationship between agriculture, capital, exports, and Net GDP is not uniform, but is strongly shaped by each country's stage of structural transformation.

In the case of Indonesia, agricultural value added has a positive and significant long-run relationship with Net GDP. The IRF results also show that shocks to the agricultural sector generate a positive and relatively persistent response in Net GDP, while the FEVD results indicate that agricultural shocks contribute more to the variation in Net GDP than in Japan. These findings suggest that agriculture still functions as one of the channels of growth in the Indonesian economy through rural income linkages, demand for non-agricultural sectors, and connections with downstream economic activities.

In contrast, the case of Japan shows a different pattern. Agricultural value added does not have a significant long-run effect on Net GDP. Japan's non-agricultural economic performance is explained more strongly by capital and exports, while the response of Net GDP to agricultural shocks tends to be weak and negative. This finding reinforces Japan's character as a post-agricultural economy, where agriculture no longer serves as the main engine of macroeconomic growth, but continues to play a strategic role in food security, rural sustainability, and socio-ecological functions.

Theoretically, this study confirms that agriculture-led growth is stage-specific. Agriculture can be an important growth channel in a transitional economy such as Indonesia, but its role weakens in an advanced economy that has undergone structural diversification, such as Japan. Therefore, the declining relative contribution of agriculture in the economic structure does not necessarily imply the loss of the sector's relevance. The role of agriculture changes from a driver of macroeconomic growth into a broader functional sector, depending on the stage of development, production structure, and strategic needs of each country.

This study has several limitations. First, the number of observations is relatively limited because the analysis uses annual data for the period 1994–2023, requiring the model specification to remain parsimonious. Second, this study does not explicitly incorporate structural breaks, although economic crises, policy reforms, and global shocks may affect the relationship between agriculture and Net GDP. Third, institutional variables, technology, labor dynamics, and environmental indicators are not directly included in the main model. Future research may extend the country coverage, incorporate structural break tests or time-varying parameter models, and integrate technology, institutional, and environmental variables to provide a more comprehensive understanding of the relationship between agriculture and economic transformation.

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## Author Contribution

A.A.P.; Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software.

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The authors declare no conflict of interest.

### Declaration of Generative AI Use

During the preparation of this work, the author used Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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