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Agricultural Infrastructure and Green Economic Growth in Indonesia

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Abstract

Indonesia's development agenda toward 2045 prioritizes the transition toward a low-carbon economy, yet agri-food systems still face logistics inefficiencies, resource constraints, and climate vulnerability. This study examines whether Enabling Infrastructure Capacity (EIC) and Agricultural Production Support Capacity (APSC) contribute to green economic performance and whether Socioeconomic Performance (SEP) mediates these relationships. A quantitative multi-method approach is applied by combining Partial Least Squares Structural Equation Modeling (PLS-SEM) and fixed-effects panel regression. The study uses secondary data from 33 Indonesian provinces over the 2011–2020 period. The PLS-SEM model evaluates structural relationships among EIC, APSC, SEP, and the Green Economy Index (GEI), while the panel regression assesses the association between observed infrastructure-service indicators and Gross Regional Domestic Product (GRDP). The results show that EIC and APSC have positive and significant direct relationships with GEI and SEP. However, SEP does not significantly mediate the relationships between EIC/APSC and GEI. The panel results show that access to safe drinking water is positively associated with GRDP, while electricity access, road length, and irrigation rehabilitation are not significant. These findings emphasize the importance of infrastructure service quality, agricultural production-support capacity, and green-oriented policy instruments.

Keywords: Green Economic Growth, Enabling Infrastructure, Agricultural Production Support, Socioeconomic Performance, PLS-SEM

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INTRODUCTION

The Medium-Term National Development Plan (RPJMN) 2025–2029 of Indonesia outlined eight national priority strategies for the realization of "Advanced Indonesia" toward Indonesia Emas 2045. To achieve this long-term vision, the country requires sustained economic growth of at least 6% annually by 2029 (Kementerian PPN/Bappenas, 2019). Indonesia's development trajectory, however, is characterized by several challenges, including resource degradation, climate change, inefficient infrastructure, and the need to align with the global shift towards low-carbon production.

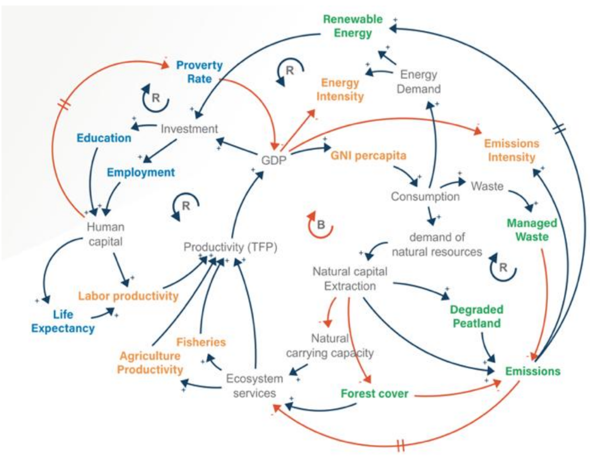

Figure 1. The Ierrelationship Between 15 Green Economy Indicators
Source: Lestari et al., 2022

In the agri-food sector, these challenges intersect in three key areas: increasing productivity, improving distribution, and more effective use of land and water, all in the context of climate change (Dash & Sahoo, 2010). The green economy is thus not merely an environmental agenda but a development agenda aimed at high economic growth through the efficient use of resources, the development of low-carbon infrastructure, environmental conservation, and social inclusion (Acosta et al., 2023).

Green growth has been adopted by the Government of Indonesia as a way of doing development, which has been increasingly integrated with economic performance, environmental sustainability and social well-being (Acosta et al., 2023; Dual Citizen, 2020; Lestari et al., 2022; OECD, 2017; OECD, 2021; OECD, 2023). In relation to agriculture and food, the green economy framework can be used as a strategic tool to transform agriculture and food systems, reduce dependence on conventional inputs, improve distribution efficiency, increase climate change resilience, and integrate necessary supporting infrastructure into development planning (Lestari et al., 2022).

Agriculture and food systems are crucial components of agricultural transformation, yet they face many challenges. These challenges include reliance on conventional production inputs, ineffective distribution practices, sensitivity to climate change, and a lack of integration with supporting infrastructure (Gobel et al., 2025). As such, adopting a green economy, defined as a system of green production, distribution, and consumption (Gobel et al., 2025; Dogaru, 2020), is necessary.

Infrastructure development is strategically important and is viewed in the context of green infrastructure here. In addition to environmentally sound physical infrastructure, green infrastructure also comprises systems and measures that conserve resources, reduce emissions and sustain ecosystems (Lestari et al., 2022; Alam et al., 2021).

In this study, green-oriented infrastructure is understood to comprise, for example, enabling infrastructure and agricultural production-support capacity. It is supposed to support production, distribution, efficient resource use, and regional resilience.

Green-oriented infrastructure is important for ensuring national food security, promoting sustainable production, improving distribution efficiency, and strengthening farmers' position in a more equal green economy. Integration between infrastructure development and sustainable agri-food system transformation is still below par (Tolinggi et al., 2018; LAB 45 dan CSIS, 2022).

More important than the availability of physical facilities is whether or not the planning of the infrastructure has been designed to be resource efficient, climate resilient, low carbon, and support sustainable food system outcomes (LAB 45 dan CSIS, 2022; Kementerian PPN/Bappenas, 2019a; Kementerian PPN/Bappenas, 2019b).

If infrastructure development is still geared towards achieving conventional growth objectives, then the agri-food system will continue to suffer from inefficiencies in the logistics system, high distribution costs, post-harvest losses, inadequate storage and cold chain facilities, and will be unable to reduce the environmental impact of production and distribution (Kementerian PPN/Bappenas, 2022; Kementerian PPN/Bappenas, 2023).

In this sense, the development of infrastructure should not be measured solely by the economic activity it generates, but also by its ability to support green economic performance. This study aims to examine the strategic role of infrastructure, particularly green infrastructure, in advancing the transformation of Indonesia's agriculture and food sector toward a green economy.

It assesses the extent to which national and subnational infrastructure planning and implementation have internalised sustainability principles, and how infrastructure can strengthen the efficiency of agricultural distribution, support sustainable production, and accelerate adaptive and inclusive food security. Through an interdisciplinary approach at the nexus of development economics, infrastructure planning, and food sustainability, the study seeks to inform policy design for infrastructure-led acceleration of green economic growth with a specific focus on the strategic agri-food sector.

Infrastructure development is closely linked to conventional economic growth across many fields. A large number of studies found that public capital, the services provided by infrastructure, and the institutional framework determine regional productivity and output growth (Aschauer, 1989; World Bank, 1994; World bank, 2025; World Economic Forum, 2021; Munnell, 1992; Gramlich, 1994; Esfahani & Ramírez, 2003; Calderón & Servén, 2004, 2010; Dash & Sahoo, 2010; Foster, 2023).

They promote development by reducing transaction costs, improving market access for firms, and supporting private activity. So far, however, the majority of studies on this topic have sought to measure the effect of infrastructure using conventional indicators of growth, such as GDP, productivity, income, or aggregate output across regions.

However, this does not indicate whether infrastructure also increases resource efficiency, improves environmental conditions, supports a low-carbon growth path, or promotes sustainable development in an inclusive way.

Empirical analysis of Indonesia's green economic performance at the subnational level has just begun. A number of studies on green growth, low-carbon development, and indicators of green economy in Indonesia have been conducted.

These studies analyze national performance and a number of income-related indicators of the green economy, environmental indicators, and policy evaluation. A number of indicators of the green economy have been constructed from several dimensions. The analysis, however, has not yet been conducted on the structural relationships between enabling infrastructure, agricultural production-support capacity, socioeconomic performance, and Green Economy Index.

The fact is that an increase in output caused by infrastructure development does not necessarily lead to "greener" output. Such output can be generated only when infrastructure is accompanied by service quality, resource efficiency, environmental, and sustainability dimensions.

In addition, the role of socioeconomic performance as an intermediate variable between enabling infrastructure, agricultural production-support capacity, and green economic performance needs to be clarified. This study analyzes direct and indirect relationships between Enabling Infrastructure Capacity (EIC), Agricultural Production Support Capacity (APSC), Socioeconomic Performance (SEP), and the Green Economy Index (GEI) using fixed-effects panel regression for basic indicators of infrastructure services and regional GDP.

Based on this framework, the study operationalises green economic transformation through observable indicators that capture enabling infrastructure, agricultural production-support capacity, socioeconomic performance, and green economic outcomes. Enabling infrastructure comprises basic conditions that support production and distribution activities, such as access to electricity and road connectivity, as well as skilled construction capacity.

Agricultural production-support capacity is represented by irrigation rehabilitation and land optimisation, which reflect resource-based support for agricultural productivity. Socioeconomic performance captures broader macroeconomic and labor-market conditions, while the Green Economy Index represents economic, environmental, and social dimensions of green economic performance. This operationalization ensures that the empirical model remains connected to the study's theoretical argument while relying on consistent province-level secondary data.

RESEARCH METHODS

The research employs a quantitative multi-methods approach. It first employs Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze relationships among variables based on their corresponding latent constructs. In this respect, PLS-SEM is employed to analyze the empirical relationships among enabling infrastructure, agricultural production-support capacity, socioeconomic performance, and green economic performance in rural territories.

Thereafter, a panel regression is estimated to analyze the relationship between indicators of enabling infrastructure services and the economic output of rural territories, while controlling for unobserved province-specific variables that may influence the output (OECD & European Commission JRC, 2008).

This study uses secondary data from 33 provinces in Indonesia over the period 2011-2020, resulting in a total of 330 province-year observations. The data were retrieved from various Indonesian official sources, including Statistics Indonesia (BPS), the Ministry of Agriculture, the Ministry of Public Works and Housing (PUPR), and Bappenas/KLHK.

The targeted literature and policy review, including RPJMN, relevant sectoral plans, official green-economy documents, and international empirical studies, was used to establish the theoretical basis for selecting the observed indicators.

Table 1. PLS-SEM Latent Constructs and Indicators

Latent Variable	Variable Code	Indicator
Enabling Infrastructure Capacity (EIC)	EIC1	Households with electricity access (%)
	EIC2	Road Length (road length per 1000 km)
	EIC3	Number of Skilled Construction Workers (Number of Workers)
Agricultural Production Support Capacity (APSC)	APSC1	Irrigation Network Rehabilitation Development (irrigation rehabilitation per 1000 ha)
	APSC2	Land Optimization (Ha)
Socioeconomic Performance (SEP)	SEP1	Gross Regional Domestic Product (billion IDR)
	SEP2	Per Capita Income (Million/Year)
	SEP3	Unemployment Rate (%)
Green Economy Index (GEI)	GEI1	GEI Economic Dimension (Score)
	GEI2	GEI Environmental Dimension (Score)
	GEI3	GEI Social Dimension (Score)

Source: Dash & Sahoo, 2010; Lestari et al., 2022; Lumbanraja & Lumbanraja, 2023; World Bank, 2020; World Economic Forum, 2021.

To avoid a mismatch between the conceptual framework and the empirical model, the study focuses only on variables that are included in the dataset and consistently available at the provincial level. Accordingly, the operational framework covers four domains: enabling infrastructure, agricultural production-support capacity, socioeconomic performance, and green economic performance.

This approach ensures that the theoretical framework remains aligned with the variables presented in Table 1 and with the subsequent PLS-SEM and panel regression analyses.

The selection of indicators was based on prior empirical studies, official green economy frameworks, and the availability of consistent provincial data for Indonesia. The names of the latent constructs were refined to ensure consistency between the theoretical concepts and the observed indicators. Enabling Infrastructure Capacity (EIC) encompasses general infrastructure conditions that support production, distribution, and regional development, including electricity access, road length, and the availability of skilled construction workers.

Agricultural Production Support Capacity (APSC) captures agricultural resource and production-support inputs, represented by irrigation network rehabilitation and land optimisation. Socioeconomic Performance (SEP) reflects broader macroeconomic and labour market conditions, as reflected in GDP, per capita income, and unemployment.

The Green Economy Index comprises three dimensions: the economic dimension (GEI1), the environmental dimension (GEI2), and the social dimension (GEI3). The economic dimension captures the extent to which economic activities are aligned with green and resource-efficient growth. The environmental dimension reflects environmental quality and low-carbon development performance.

The social dimension captures the inclusiveness and welfare aspects of green economic transformation. These three dimensions are used to ensure that green economic performance is not reduced to conventional output growth alone.

Since unemployment represents an adverse labour market condition, the unemployment indicator was reverse-coded before inclusion in the Socioeconomic Performance construct. This transformation ensures that all indicators within the construct move in the same conceptual direction, where higher values indicate better socioeconomic performance.

In the two stages of PLS-SEM analysis, the measurement model was first evaluated using outer loadings, composite reliability, Cronbach's alpha, average variance extracted, and discriminant validity.

In the second stage, the structural model was evaluated using path coefficients and bootstrapped t-values and p-values. Furthermore, the coefficients of determination and the indirect effects were calculated to assess the mediating effect of the Structural Equation Partnerships (SEP).

As an additional analysis of the PLS-SEM model, we also ran a panel regression of the observed indicators of infrastructure and services on the respective regions' economic output, GRDP.

Unlike in the PLS-SEM model, where GRDP was used as a direct proxy for green economic growth, in this model, GRDP is used to measure the economic base of a region that can undergo green economic transformation.

The dependent variable of this study is Gross Regional Domestic Product (GRDP), measured in billion IDR. The independent variables are electricity access (Elec), road length (Road), access to safe drinking water (Water), and rehabilitation of irrigation networks (Irri).

The panel model includes Water as a basic infrastructure service indicator, as access to safe drinking water is a measure of service quality that can directly influence productivity, welfare, and regional economic activity. It is treated as an observed panel variable rather than an indicator in the EIC construct.

$$GRDPit = \alpha i + \beta 1Elecit + \beta 2Roadit + \beta 3Waterit + \beta 4Irriit + \varepsilon it$$

Where $\beta 1$-$\beta 4$ are estimated coefficients, Elecit stands for percentage of households with electricity (%) for province i and year t, Roadit stands for road length (road length per 1000 km) for province i and year t, Waterit stands for percentage of households with access to safe drinking water (%) for province i and year t.

Irriit stands for rehabilitation of irrigation networks (irrigation rehabilitation per 1000 ha) for province i and year t, GRDPit stands for Gross Regional Domestic Product (GRDP)(billion IDR) for province i and year t αi stands for captures province and εit stands for error terms.

This specification is used because the analysis aims to estimate marginal associations between infrastructure indicators and regional economic output in their original policy-relevant units, rather than elasticities. Therefore, the coefficients are interpreted in terms of each variable's unit.

Since the variables are measured in different units, the absolute magnitudes of the coefficients cannot be directly compared across variables. Instead, the analysis focuses on the direction, statistical significance, and substantive relevance of each indicator.

Estimate pooled, fixed-effects, and random-effects models; select the preferred specification via Chow, Hausman, and LM tests (α=5 %) (Baltagi, 2013; Greene, 2018; Wooldridge, 2010). Diagnostics include normality (Jarque–Bera), serial correlation (Durbin–Watson), multicollinearity (VIF<10), and heteroskedasticity (e.g., Glejser/White).

Inference relies on t-tests, F-tests, and adjusted R^2. Latent relations among green infrastructure, efficient distribution/production, income, and a composite green index are estimated.

This research assesses the outer model (indicator loadings, composite reliability, AVE, discriminant validity) and the inner model (path significance, indirect/mediation effects, predictive relevance) (Baltagi, 2013; Greene, 2018; Wooldridge, 2010; Hair et al., 2022b; Hair & Alamer, 2022a; Henseler et al, 2015).

The synthesis combines evidence from PLS-SEM and panel regression to formulate policy implications related to infrastructure service quality, agricultural production-support capacity, and green economic performance. Water, as a variable in panel regression, is included as an observed basic infrastructure service indicator.

However, this service indicator is not included in the EIC construct, as the PLS-SEM model includes only a selection of enabling infrastructure indicators consistent with production and distribution capacity, and the panel model can additionally include a range of basic service indicators associated with a region's output.

RESULTS AND DISCUSSION

This study analyzes 330 observations of 33 Indonesian provinces over the period from 2011 to 2020. Each observation is a single province in a single year; it is also possible to include time dynamics in the analysis of infrastructure, agricultural production-support capacity, socioeconomic performance, and the green economy of the provinces.

Before presenting the results of the PLS-SEM and panel regression analyses, this study also reports the descriptive statistics for the variables used (Table 2). The descriptive statistics indicate substantial variation across Indonesian provinces during the 2011–2020 period.

Basic enabling infrastructure indicators, such as electricity access and road length, show differences in both coverage and physical scale, reflecting uneven regional infrastructure endowments.

Agricultural production-support indicators, including irrigation rehabilitation and land optimisation, also vary across provinces and years, suggesting that production-support capacity is not evenly distributed across Indonesia's agricultural regions.

The socioeconomic indicators for Indonesia's 33 provinces show large differences in GRDP and per capita income. In addition to income, the Green Economy Index across the 64 dimensions also varies across individual observations.

Thus, a province's green economic performance cannot be inferred solely from GDP. The safe drinking water access indicator for the individual years provides information on the basic infrastructure services and, thus, on the economic base of regional development. Therefore, the pooled cross-section of all individual provinces across all years is an appropriate data basis for the application of PLS-SEM at the province–year level as well as for panel regression with unobserved provincial heterogeneity as an error component.

Table 2. Descriptive Statistics of Observed Variables

Latent Variable	Varia-ble Code	Mean	Median	Std. Dev.	Min	Max	Excess Kurto-sis	Skew-ness
Enabling Infrastructure Capacity (EIC)	EIC1	23532535.57	24765333.00	15869489.00	32504110.00	4480868.005	-0.422	0.087
	EIC2	54290026.857	54049000.00	53063650.00	57817699.00	1198910.375	4.537	1.934
	EIC3	450291.571	506775.00	122815.00	705301.00	200439.4	-1.535	-0.166
Agricultural Production Support Capacity (APSC)	APSC1	623715.571	688908.00	102298.00	958858.00	258142.812	-0.639	-0.554
	APSC2	450291.571	506775.000	122815.000	705301.00	200439.4	-1.535	-0.166
Socioeconomic Performance (SEP)	SEP1	1339885.00	1483740.00	742710.00	1944044.0	385018.529	-1.430	-0.016
	SEP2	5256.357	5600.000	3080.000	7407.000	1341.008	-1.105	-0.070
	SEP3	767.929	756.000	656.000	977.000	82.900	1.199	1.097
Green Economy Index (GEI)	GEI1	2476.929	2569.000	1948.000	2993.000	295.360	-0.520	-0.247
	GEI2	1567.500	1595.000	1377.000	1761.000	133.767	-1.680	0.067
	GEI3	1604.286	1578.000	1300.000	1905.000	173.273	-0.652	0.269

Note: SEP3 is presented as the original unemployment rate in the descriptive statistics. For the PLS-SEM analysis, this variable was reverse-coded so that higher values indicate better socioeconomic performance.
Source: Data processed, 2025

This study employs Structural Equation Modelling (SEM) using the Partial Least Squares (PLS) approach. Convergent validity is evaluated using item reliability, assessed by standardised factor loadings. The standardised loading reflects the degree of correlation between each measurement item and its latent construct. The outer-loading values for each indicator are shown in table 3.

Based on table 3, no indicator showed an outer loading below 0.60; therefore, all indicators are considered adequate/valid and were retained for subsequent analysis. The table presents standardised outer loadings for four latent constructs.

Green Economy Index (GEI1–GEI3), Agricultural Production Support Capacity (APSC1–APSC2), Enabling Infrastructure Capacity (EIC1–EIC3), and Socioeconomic Performance (SEP1–SEP3), and shows that all indicators exceed the conventional 0.70 threshold (0.762–0.976).

This confirms strong item construct correlations and that convergent validity is achieved. Loadings are especially high for EIC1 and GEI1–GEI2, as well as for APSC2, indicating very reliable measurement of the infrastructure and green-performance constructs.

Table 3. Convergent Validity Result

Latent Variable	Green Economy Index	Agricultural Production Support Capacity	Enabling Infrastructure Capacity	Socioeconomic Performance	Status (Standard = 0.70)
EIC1			0.976		Valid
EIC2			0.929		Valid
EIC3			0.897		Valid
APSC1		0.911			Valid
APSC2		0.877			Valid
SEP1				0.975	Valid
SEP2				0.963	Valid
SEP3				0.762	Valid
GEI1	0.945				Valid
GEI2	0.914				Valid
GEI3	0.965				Valid

Source: Data processed, 2025

Table 3 presents standardized outer loadings for four latent constructs: Enabling Infrastructure Capacity (EIC1–EIC3), Agricultural Production Support Capacity (APSC1–APSC2), Socioeconomic Performance (SEP1–SEP3), and Green Economy Index (GEI1–GEI3).

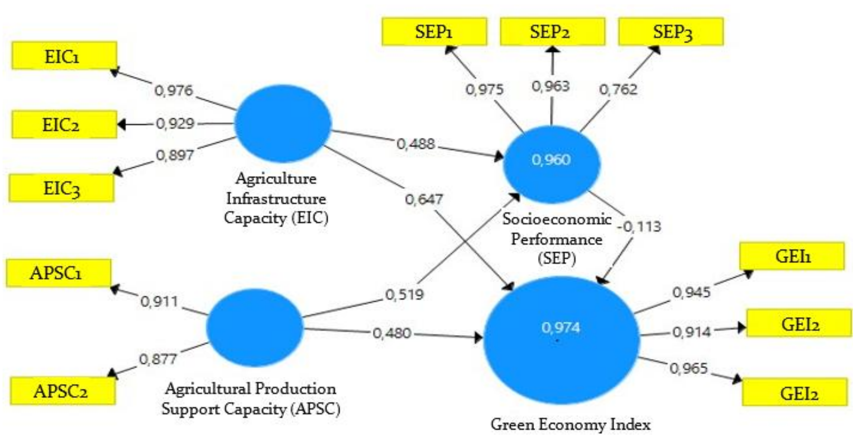

Figure 2. Outer Loading Result

Source: Data Processed, 2025

All indicators exceed the conventional 0.70 threshold, with loading values ranging from 0.762 to 0.976. The EIC construct shows strong loadings of 0.897-0.976, APSC ranges from 0.877 to 0.911, SEP ranges from 0.762 to 0.975, and GEI ranges from 0.914 to 0.965. Although SEP3 has the lowest loading value, it remains above the recommended threshold and is therefore retained in the model.

Table 4. Average Variance Extracted (AVE) Results

Variable	AVE	Status
Green Economy Index (GEI)	0.887	Valid
Agricultural Production Support Capacity (APSC)	0.800	Valid
Enabling Infrastructure Capacity (EIC)	0.873	Valid
Socioeconomic Performance (SEP)	0.819	Valid

Source: Data Processed, 2025

Discriminant validity is assessed by comparing the square root of the AVE (√AVE) of each construct with its correlations with other constructs in the model. A construct is considered to have adequate discriminant validity when its √AVE exceeds all inter-construct correlations, while the AVE itself is expected to be > 0.70. The evaluation results are presented in table 4.

AVE values for the Green Economy Index (0.887), Agricultural Production Support Capacity (0.800), Enabling Infrastructure Capacity (0.873), and Socioeconomic Performance (0.819) all exceed 0.70, confirming convergent validity and suitability for further analysis.

The AVE values for GEI, APSC, EIC, and SEP exceed the recommended threshold of 0.70, indicating that each construct explains a substantial proportion of the variance in its indicators. These results support the measurement model's convergent validity.

Table 5. Composite Reliability Result

Variable	CR	Status
Green Economy Index (GEI)	0.959	Valid
Agricultural Production Support Capacity (APSC)	0.889	Valid
Enabling Infrastructure Capacity (EIC)	0.954	Valid
Socioeconomic Performance (SEP)	0.931	Valid

Source: Data Processed, 2025

Composite reliability (CR) reflects the reliability level of a measurement instrument. Data with CR > 0.70 is categorised as having high reliability. A summary of the CR test results is presented in table 5.

Table 6. Cronbach's Alpha (CA) Result

Variable	CA	Status
Green Economy Index (GEI)	0.93	Valid
Agricultural Production Support Capacity (APSC)	0.75	Valid
Enabling Infrastructure Capacity (EIC)	0.92	Valid
Socioeconomic Performance (SEP)	0.88	Valid

Source: Data Processed, 2025

The internal consistency of each construct is relatively high, and the reflective measurement model meets the reliability criteria. These results indicate that all constructs exceed the recommended composite reliability threshold and therefore demonstrate adequate internal consistency. The reliability test based on table 5 can be confirmed by examining Cronbach's alpha. A variable is considered reliable if Cronbach's alpha > 0.70, as shown in table 6.

Table 7. Inner Model Path Coefficient (Significance Testing)

Variable	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
APSC -> GEI	0.480	0.489	0.195	2.464	0.014
APSC -> SEP	0.519	0.514	0.146	3.557	0.000
EIC -> GEI	0.647	0.725	0.251	2.578	0.010
EIC -> SEP	0.488	0.491	0.147	3.315	0.001
SEP -> GEI	-0.113	-0.205	0.367	0.307	0.759

Source: Data processed, 2025

In PLS-SEM, the measurement (outer) model assesses construct validity and reliability, while the structural (inner) model specifies regression links among latent variables to evaluate causal effects. Using SmartPLS, we estimate path coefficients to gauge the direction and strength of the independent variables' effects on the dependent variables and test their significance (via bootstrap t t-values and p p-values).

The coefficient of determination (R2) reports the proportion of variance in each endogenous construct explained by its predictors (optionally complemented by the adjusted R2). A summary of R2 values for all equations/figure 2 is presented in table 7.

Table 8. Inner Model (Significance Testing)

No	Variable (X)	Variable Z (Mediator)	Variable Y (Endogen)	Direct (L)	Undirect (TL)	Total (L+TL)	Proportion TL (TL/(L+TL))
1	APSC	SEP	GEI	0.48	-0.059	0.421	-0.139
2	EIC	SEP	GEI	0.647	-0.055	0.592	-0.093
		Socioeconomic Performance (Variable Z)				0.960	
		Green Economy Index (Variable Y)				0.974	

Source: Data processed, 2025

Based on Table 3 and the summary of effects, Agricultural Production Support Capacity (APSC) has a positive, significant effect on the Green Economy Index (GEI) (β = 0.480; t = 2.464; p = 0.014), as does Infrastructure Development (EIC) on GEI (β = 0.647; t = 2.578; p = 0.010).

Both APSC and EIC also exert positive and significant effects on Socioeconomic Performance (SEP) (β = 0.519; t = 3.557; p < 0.001; and β = 0.488; t = 3.315; p = 0.001, respectively). APSC and EIC both have clear, positive, and significant direct effects on GEI.

They also raise SEP, but SEP does not transmit those gains to GEI (the SEP to GEI path is not significant), so the indirect effects via SEP are negligible and slightly negative. As a result, the total impact on GEI is driven mainly by the direct channels from APSC and EIC. The model explains most of the variation in GEI and SEP, indicating a strong fit of APSC effects**.**

On SEP: positive, significant (β=0.519; t=3.557; p<0.001). On GEI: direct effect positive, significant (β=0.480; t=2.464; p=0.014); indirect via SEP small/negative and unsupported (−0.059). Total =0.421; VAF=−13.9% to no mediation.

EIC Effects On SEP: positive, significant (β=0.488; t=3.315; p=0.001). EIC Effects On GEI: direct effect positive, significant (β=0.647; t=2.578; p=0.010); indirect via SEP small/negative and unsupported (−0.055). Total = 0.592; VAF = −9.3%, there is no mediation.

SEP to GEI is negative and not significant (β=−0.113; t=0.307; p=0.759), indicating no mediation and a suppressor-like pattern via SEP. Effects on GEI are driven mainly by the direct paths from APSC and EIC. R^2(GEI) = 0.974 and R^2(SEP) = 0.960, indicating very high explained variance.

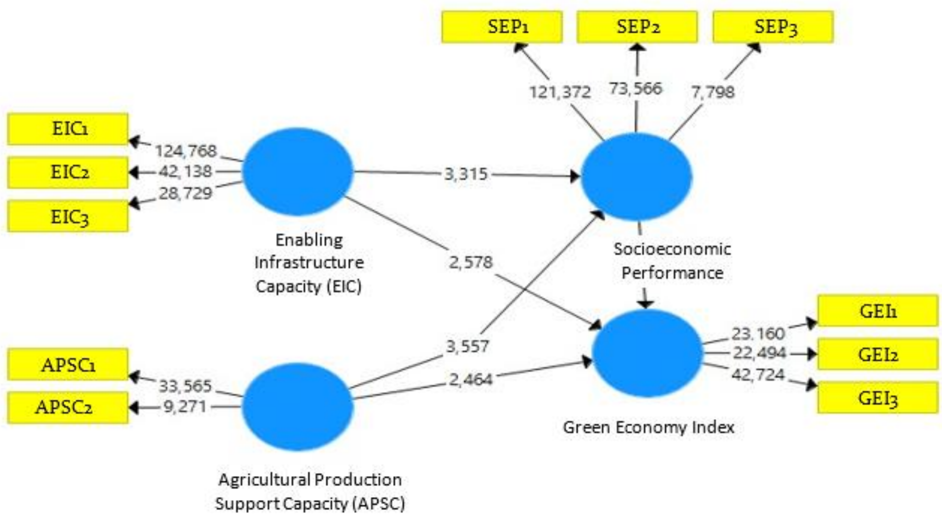

Figure 3. Hypothesis Testing Result

Source: Data processed, 2025

Using SEM-PLS, hypotheses were tested based on t-statistics and p-values from the bootstrapping procedure. Statistical significance was evaluated at the 0.05 level (two-tailed). A summary of the results is presented in figure 3.

Concise Hypothesis Test Summary (PLS-SEM) Abbreviations: APSC = Agricultural Production Support Capacity; EIC = Enabling Infrastructure Capacity; GEI = Green Economy Index; SEP = Socioeconomic Performance.

APSC to SEP (Ha1): Positive, significant (β=0.519, t=3.557, p<0.001; 95% CI [0.233, 0.805]).

EIC to SEP (Ha2): Positive, significant (β=0.488, t=3.315, p=0.001; 95% CI [0.199, 0.777]).

APSC to GEI (Ha3): Direct effect positive, significant (β=0.480, t=2.464, p=0.014; 95% CI [0.098, 0.862]); indirect via SEP = −0.059 (unsupported) the total = 0.421; VAF = −13.9%.

EIC to GEI (Ha4): Direct effect positive, significant (β=0.647, t=2.578, p=0.010; 95% CI [0.155, 1.139]*); indirect via SEP = −0.055 (unsupported) the total = 0.592; VAF= −9.3%.

SEP to GEI (Ha5): Not significant (β=−0.113, t=0.307, p=0.759; 95% CI [−0.834, 0.608]). *Upper bound >1 reflects normal approximation; percentile bootstrap CIs in SmartPLS are typically within a more plausible range.

APSC and EIC directly improve GEI and increase SEP, but SEP does not mediate their effects on GEI; policy should prioritise direct, resource-efficient agricultural development and infrastructure upgrades, while aligning SEP growth with green standards to translate income gains into greener outcomes.

Table 9. Mediating Testing (Indirect Effects)

First Track				
No	**Indrirect Effect Description**	**Indrirect Effect (TL)**	**Effect Total (L+TL)**	**Proportion TL (VAF) %**
1	APSC towards SEP to GEI	-0.059	0.421	-14.0%
Mean, STDEV, T-Values, P-Values: APSC towards SEP to GEI				
Original Sample (O)	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**
-0.059	-0.109	0.204	0.286	0.775
Track Second				
No	**Indrirect Effect Description**	**Indrirect Effect (TL)**	**Effect Total (L+TL)**	**Proportion TL (VAF) %**
2	EIC towards SEP to GEI	-0.055	0.592	-9.3%
Mean, STDEV, T-Values, P-Values EIC towards SEP to GEI				
Original Sample (O)	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**
-0.055	-0.096	0.192	0.286	0.775

Source: Data processed, 2025

The hypothesis testing results for the indirect (mediated) effects in the green-economy development model are summarised as shown in table 9.

The mediation tests indicate that Socioeconomic Performance (SEP) does not mediate the relationship between Agricultural Production Support Capacity (APSC) and GEI, nor between Enabling Infrastructure Capacity (EIC) and GEI. In both cases, the specific indirect effects are small, negative, and statistically unsupported because the SEP-to-GEI path is non-significant. Consequently, Variance Accounted For (VAF) values are negative, and the total effects of APSC and EIC on GEI are driven almost entirely by direct pathways rather than by transmission through SEP.

Taken together, the SEM-PLS results show that APSC and EIC both raise SEP and directly improve GEI, but SEP does not function as a conduit for translating those gains into greener outcomes in this sample. The model's explanatory power is high for both endogenous constructs, reinforcing the internal coherence of the specification.

Substantively, these findings suggest that accelerating green performance is most effectively achieved through direct interventions, resource-efficient agricultural upgrading, cleaner technologies, logistics efficiency, and supportive green infrastructure, while aggregate income growth must be explicitly aligned with sustainability instruments (standards, incentives, carbon/energy efficiency measures) if it is to contribute meaningfully to GEI.

This pattern is consistent with international green-growth frameworks that emphasise resource-efficient infrastructure, the adoption of clean technologies and enabling policy levers as primary drivers of green outcomes, with macroeconomic expansion contributing only when conditioned by sustainability criteria.

While the PLS-SEM model evaluates latent structural relationships, the fixed-effects panel regression examines the association between selected observed infrastructure-service indicators and regional economic output. This complementary analysis helps assess whether specific infrastructure services are associated with the regional economic base after controlling for province-specific heterogeneity.

The panel regression is used as a complementary analysis to the PLS-SEM model. While the PLS-SEM model examines structural relationships among Enabling Infrastructure Capacity (EIC), Agricultural Production Support Capacity (APSC), Socioeconomic Performance (SEP), and the Green Economy Index (GEI), the panel regression focuses on observed infrastructure-service indicators and their association with regional economic output.

Therefore, Gross Regional Domestic Product (GRDP) is not treated as a direct proxy for green growth, but as an indicator of the regional economic base within which green economic transformation may occur. The panel results are used to provide supporting evidence on how basic infrastructure services contribute to the regional economic base that may enable green economic transformation.

Following the model selection tests, the fixed-effects specification was retained as the preferred estimator. The results indicate that access to safe drinking water is the only infrastructure service indicator with a positive, statistically significant contemporaneous association with GRDP.

In contrast, electricity access, road length, and irrigation rehabilitation are not statistically significant after controlling for province-specific heterogeneity. These findings suggest that basic service quality may have a more immediate relationship with regional economic output than physical infrastructure quantity alone.

However, the non-significant coefficients should not be interpreted as evidence that electricity, road, and irrigation infrastructure are irrelevant. Rather, they may reflect measurement limitations, differences in service quality, and implementation lags that are not fully captured by contemporaneous quantity-based indicators.

Upon running the Hausman Test, it is found that REM is inconsistent, whereas FEM remains consistent; therefore, FEM is selected as the preferred specification for these data.

Substantively, the significant coefficient of Water suggests that basic service quality, particularly access to safe drinking water, has a more immediate association with regional economic output than physical infrastructure quantity alone.

By contrast, the non-significant coefficients of Elec, Road, and Irri should not be interpreted as evidence that electricity, road, and irrigation infrastructure are irrelevant.

Rather, these results indicate that quantity-based and contemporaneous indicators may not fully capture service reliability, infrastructure quality, road connectivity performance, irrigation functionality, or delayed infrastructure effects (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2024; Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2025).

Table 10. Fixed Effect Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	30544397	8917885	3.425072	0.0007
Elec	-16158.72	83490.49	-0.193540	0.8467
Road	-344.9772	291.2512	-1.184466	0.2372
Water	265223.9	39937.48	6.640977	0.000
Irri	-10.30168	26.09084	-0.394839	0.6932
R^2	0.984045			
Adjusted R^2	0.982085			
F-statistic	501.9864			
Prob(F-statistic)	0.000			
Observations	330			
Provinces	33			
Period	2011–2022 (10 years)			

Source: Data processed, 2025

The high R-squared value should also be interpreted cautiously because fixed-effects estimation absorbs time-invariant differences across provinces.

$$GRDPit = 30544397 - 16158.72Elec - 344.9772Road + 265223.98Water - 10.30168Irri$$

These panel findings complement the PLS-SEM results. The PLS-SEM model shows that Enabling Infrastructure Capacity (EIC) and Agricultural Production Support Capacity (APSC) have positive and significant direct relationships with the Green Economy Index (GEI). This finding is consistent with the broader infrastructure-growth literature, which emphasises that infrastructure supports economic performance through connectivity, lower transaction costs, improved service delivery, and stronger production capacity (Calderón & Servén, 2004, 2010; Dash & Sahoo, 2010).

However, the present study extends this argument by linking infrastructure not only to conventional output, but also to green economic performance through GEI. This distinction is important because green economic performance requires infrastructure to support resource efficiency, environmental quality, and inclusive development, not merely output expansion.

The positive role of APSC also aligns with the literature on agricultural infrastructure and production-support systems. Irrigation and land-related support are commonly associated with improved agricultural productivity, food security, and rural livelihoods, although the magnitude and timing of their effects vary across contexts.

Evidence from irrigation studies suggests that irrigation investment can improve productivity and livelihoods, but its contribution is often context-specific and depends on the quality of management, service reliability, and complementary inputs.

Therefore, the positive structural relationship between APSC and GEI should be interpreted as evidence that agricultural production-support capacity contributes to green performance when it is connected to resource efficiency and sustainable land-water management.

The finding that Socioeconomic Performance (SEP) does not significantly mediate the relationship between EIC/APSC and GEI provides an important theoretical contribution. It indicates that better socioeconomic performance does not automatically translate into green economic outcomes.

This is consistent with the logic of green economy measurement in Indonesia, where economic, environmental, and social dimensions must be assessed together rather than reducing green progress to income or output growth alone.

The Green Economy Index framework developed in Indonesia emphasises the need to measure progress in low-carbon and green economies using multidimensional indicators, not only conventional economic growth indicators. Accordingly, the insignificant mediation effect of SEP suggests that income-related improvements must be accompanied by environmental standards, resource-efficiency incentives, and low-carbon policy instruments to generate measurable green performance.

The panel-regression results complement the PLS-SEM findings, showing that access to safe drinking water is positively and significantly associated with GRDP. This result is consistent with evidence that water and sanitation services are closely related to socioeconomic development, health, productivity, and quality of life (World Bank Water and Sanitation Program, 2008; WHO/UNICEF Joint Monitoring Programme 2023; WHO/UNICEF Joint Monitoring Programme, 2025).

Studies on water, sanitation, and hygiene emphasise that improved water services generate broader welfare and productivity effects, while evidence from Indonesia shows that poor sanitation and hygiene impose significant economic costs and affect socioeconomic development (Kementerian PPN/Bappenas, & UNICEF, 2024; WHO/UNICEF Joint Monitoring Programme, 2025).

Thus, the significant coefficient of Water suggests that basic service quality may have a more immediate relationship with regional economic output than physical infrastructure quantity alone.

By contrast, electricity access, road length, and irrigation rehabilitation are not statistically significant in the contemporaneous fixed-effects panel model. This result differs from several studies showing that transport and infrastructure investment can improve agricultural productivity by reducing logistics costs, improving market access, and lowering post-harvest losses. For example, recent evidence from Asian economies suggests that transport infrastructure improves agricultural efficiency by enhancing market connectivity and reducing logistics costs, while analytical reviews of developing countries emphasise the importance of road infrastructure for agricultural trade and market integration.

The difference in the present study may be explained by measurement and timing issues: road length captures the quantity of road networks, but not road quality, logistics efficiency, travel time, or direct farm-to-market connectivity; irrigation rehabilitation may also require time before affecting output and may depend on service reliability, water availability, and local production systems (Purnomo et al., 2021; Sholihina & Salamah, 2015; Badan Pusat Statistik, 2022; Badan Pusat Statistik, 2023).

Therefore, the non-significant coefficients should not be interpreted as evidence that roads and irrigation are unimportant, but rather that quantity-based contemporaneous indicators may not fully capture the quality and delayed effects of infrastructure.

Overall, these findings refine the infrastructure–green economy argument in two ways. First, infrastructure and agricultural production-support capacity appear to matter more directly for green economic performance than through socioeconomic performance alone.

Second, in the panel model, basic service quality, particularly access to safe drinking water, shows a clearer short-run association with regional output than physical infrastructure quantity.

This suggests that future green infrastructure policy should move beyond expansion targets and place a stronger emphasis on service quality, resource efficiency, and sustainability-oriented performance indicators.

The policy implications of this study should be read in relation to both the empirical findings and Indonesia's current development-planning priorities. The PLS-SEM results show that Enabling Infrastructure Capacity (EIC) and Agricultural Production Support Capacity (APSC) have direct positive relationships with the Green Economy Index (GEI), while Socioeconomic Performance (SEP) does not significantly mediate these relationships.

This suggests that socioeconomic improvement alone is insufficient to achieve green economic performance unless it is supported by sustainability-oriented standards, incentives, and infrastructure governance.

The panel-regression results further show that access to safe drinking water has the clearest positive association with GRDP, whereas electricity access, road length, and irrigation rehabilitation are not significant in the contemporaneous specification. Therefore, policy should move beyond infrastructure expansion and place a stronger emphasis on service quality, resource efficiency, and green performance outcomes.

First, it is important to acknowledge the significant role of safe drinking water in the concept of green regional development. As basic, safe, and minimum-quality services, they should be considered the main components of green regional development. The recommendation here aligns with SDG 6 to ensure access to safe and sustainable drinking water and sanitation for all.

The roadmap for safe drinking water in Indonesia also reports that piped water service coverage and access to safe drinking water are major challenges in the country (WHO/UNICEF Joint Monitoring Programme, 2025). Therefore, infrastructure policy should focus on increasing safe drinking water services in provinces with low coverage. It also needs to be strengthened on water quality monitoring, reducing non-revenue water, and using performance-based grants for local water utilities. These measures are more specific than building infrastructure, as they link investment to service delivery outcomes.

Second, the non-significance of road length suggests that simply expanding the road network does not immediately increase regional production. Thus, road policy needs to shift from focusing on quantity to concentrating on improving road quality and making roads functional.

For agri-food regions, this could be implemented through performance-based contracting for road maintenance in agricultural corridors, prioritizing the road network connecting production locations with markets and processing plants, and incorporating indicators of road condition, travel time, and logistics costs when evaluating the added value of infrastructure for agriculture.

Third, irrigation rehabilitation should be designed around service reliability rather than solely on physical rehabilitation targets. Although the contemporaneous panel coefficient for Irri is not significant, APSC is positively associated with GEI in the PLS-SEM model, indicating that agricultural production-support capacity remains relevant for green economic performance.

Policy should therefore prioritise irrigation rehabilitation based on water-service reliability, command-area functionality, cropping intensity, and the performance of farmer water-user associations. Digital monitoring of irrigation service hours, water availability, and maintenance status can be introduced gradually, especially in regions where irrigation rehabilitation has not yet translated into measurable output gains.

Fourth, because SEP does not significantly mediate the relationship between EIC/APSC and GEI, income or output growth should be made green-conditional. This can be implemented through fiscal incentives for low-carbon agro-processing, energy- and water-efficiency standards for food-processing industries, renewable-energy adoption in agricultural value chains, and public procurement schemes that favour resource-efficient products.

These instruments are necessary to ensure that improvements in socioeconomic performance translate into measurable green economic outcomes rather than into conventional output expansion alone. Overall, the policy message is not simply to increase infrastructure spending, but to improve the way infrastructure is targeted, measured, and governed.

Safe drinking water requires service-quality expansion; roads require performance-based connectivity management; irrigation requires reliability-based rehabilitation; and economic growth requires green-conditional incentives. These measures align with Indonesia's development priorities in food, water, energy, infrastructure, and low-carbon economic transformation.

The policy direction aligns with RPJMN 2025–2029 and the long-term RPJPN 2045 emphasis on connectivity, economic transformation, and sustainability. Operationally, priorities include: (1) improving service quality and logistics (electricity reliability, non-revenue water, road/port quality, tariff affordability); (2) implementing green-conditional growth through standards, incentives, and renewable/circular requirements so that income gains translate into green outcomes; and (3) advancing value-added green agriculture (water-saving irrigation, low-emission agro-processing) (Indonesia. Presiden Republik Indonesia, 2025; Republic of Indonesia, 2021; Asian Development Bank, & PT PLN (Persero), 2025; PT PLN (Persero), 2025).

CONCLUSION

This study examined the relationships among infrastructure, agricultural production support, socioeconomic performance, and green economic performance in Indonesia using a quantitative, multi-method approach. The analysis combined Partial Least Squares Structural Equation Modelling (PLS-SEM) and fixed-effects panel regression.

The PLS-SEM model assessed the structural relationships among Enabling Infrastructure Capacity (EIC), Agricultural Production Support Capacity (APSC), Socioeconomic Performance (SEP), and the Green Economy Index (GEI).

The panel regression complemented this analysis by estimating the association between observed infrastructure-service indicators and regional economic output, measured by Gross Regional Domestic Product (GRDP). The study used secondary data from 33 Indonesian provinces over the 2011–2020 period. The PLS-SEM results indicate that EIC and APSC have positive, significant direct relationships with GEI, whereas SEP does not significantly mediate these relationships.

This finding suggests that infrastructure capacity and agricultural production-support capacity contribute more directly to green economic performance than through socioeconomic improvement alone. In other words, higher socioeconomic performance does not automatically translate into stronger green economic outcomes unless it is supported by sustainability-oriented standards, resource-efficiency policies, and environmental governance.

The panel regression results show that access to safe drinking water has the clearest positive association with GRDP, whereas electricity access, road length, and irrigation rehabilitation are not statistically significant in the contemporaneous fixed-effects specification.

These findings imply that policy should not simply prioritise infrastructure expansion, but should improve the quality, reliability, and green orientation of infrastructure services. The non-significant results for Road and Irri do not mean that road and irrigation infrastructure are irrelevant.

Rather, they indicate that physical quantity indicators may not fully capture road quality, logistics efficiency, irrigation service reliability, or the effects of delayed infrastructure. Therefore, policy should prioritise expanding safe drinking water services, improving quality-based road connectivity for agri-food distribution, and reliability-based irrigation rehabilitation.

Future research should examine infrastructure quality indicators, the lagged effects of road and irrigation investments, regional heterogeneity, and the role of environmental policy instruments in transforming SEP into measurable GEI improvements.

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