Interdependence Between Green Economic Growth And Digital Transformation In Indonesia

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Abstract.

This study investigates the effectiveness of policy controls on digital-based green economy indicators in Indonesia using the Forecast Error Variance Decomposition (FEVD) approach. The analysis centers on variables such as Employed Person, Green Credit, Exports of ICT Goods, Household Debt to GDP, Green Consumption, Green Trade, and Green Sustainable Development. The findings reveal that in the short term, most variables are predominantly influenced by their own past values, especially the Employed Person indicator. However, in the medium and long term, the interaction between Household Debt to GDP and other variables emerges as a pivotal factor in reinforcing sustainable development policies. This suggests that household financial stability plays a vital role in supporting green consumption, digital exports, and sustainability financing. These results align with previous studies highlighting the interconnected roles of labor, household finance, and green trade in driving inclusive green economic growth. Accordingly, development strategies should be tailored based on temporal horizons and the structural interlinkages among key variables. This research contributes empirically to the formulation of adaptive, digital-driven green policy frameworks in the post-pandemic era.

Keywords: *Green Economy; Digital Transformation; Green Consumption; Household Debt and Sustainable Development.*

I. INTRODUCTION

Modern economic development faces a dual challenge: fostering growth to enhance societal welfare while simultaneously preserving environmental sustainability. The concept of the green economy has emerged as a strategic response to this dilemma by integrating inclusive economic growth with ecological principles. A notable advancement in green economy efforts is the incorporation of digital technology, which enhances resource efficiency, expands access to green markets, and accelerates the transition toward sustainable consumption and production (OECD, 2020). In the era of global digital transformation, Indonesia has demonstrated encouraging trends in information technology adoption. Data from Harisman (n.d.) and Hazmin & Wijayanti (2022) reveal that Indonesian mobile users constitute approximately 39.57% of the global population, placing the country fourth among G20 members in mobile penetration. This indicates strong potential for integrating digital infrastructure into the national green economy agenda. Further, studies by Permana et al. (2021) and J. Ekonomi et al. (2023) highlight the crucial role of digital technology in boosting trade efficiency, labor productivity, and the global participation of developing countries. The trade of ICT goods has become a catalyst for environmentally friendly economic growth by minimizing emissions, improving business processes, and promoting sustainable digital consumption (Tu et al., 2021; Chien, 2022). To build a robust green-digital synergy, it is essential to understand the interaction among key variables such as mobile internet usage, employed persons, ICT goods exports, green consumption, green credit (households), GDP, and household debt to GDP. Liu et al.

(2021) emphasize that the success of a digital green transition hinges on household financial stability and the capacity of the digital labor force. This study, therefore, seeks to analyze the integration of green economic growth with digital transformation in Indonesia using the Vector Auto Regression (VAR) model. The primary focus is to identify the short-, medium-, and long-term effectiveness of interactions among strategic variables, with the ultimate goal of informing adaptive and competitive green policy formulation in the post-pandemic digital era. In the Indonesian context, maintaining climate-resilient economic sustainability for current and future welfare must be prioritized. Development strategies, at both micro and macro levels, should incorporate green economy principles to ensure inclusive and sustainable growth. One critical indicator of this is the equitable distribution of economic growth, reflecting improved living standards across demographics.With the rise of digital innovation, the global economic landscape is undergoing a major

transformation. Technological advancements such as smartphones, satellite navigation systems, and digital platforms (e.g., Uber, TikTok, Instagram, Amazon, and Google) have significantly reshaped production and consumption patterns. Digitalization reduces transaction costs, accelerates distribution, and eliminates geographical barriers thereby broadening developing countries' access to global markets and improving labor productivity and capital efficiency (Nurdiana et al., 2023; J. Ekonomi et al., 2023; Permana et al., 2021). Indonesia's mobile phone user growth, despite global saturation, continues to rise. Representing 39.57% of the global population, Indonesia ranks fourth in mobile user penetration among G20 nations, following China (222.58%), India (144.26%), and the United States (46.59%).

This mobile dominance serves as a critical enabler of digital economy development, facilitating greater access to information networks and communication infrastructure, thus improving national productivity and per capita income especially in emerging economies like Indonesia (Harisman, n.d.; Hazmin & Wijayanti, 2022). Accordingly, this study makes two significant contributions: Theoretical Contribution: It enriches development economics literature by proposing an integrative macroeconomic model linking the green and digital economies through a multivariate time-series (VAR) framework a rarely explored approach in similar research. Practical and Policy Contribution: It offers evidence-based recommendations to policymakers on designing sustainable development strategies rooted in digital transformation, with a focus on variable interactions across temporal horizons. Research Objectives : To examine the dynamic relationships among mobile internet users, employed persons, ICT goods exports, GDP, green consumption, household green credit, and household debt to GDP in the context of digital green growth in Indonesia. To identify which variables most significantly influence green economic growth across short, medium, and long-term time horizons. To develop policy recommendations that promote synergy between sustainable development and digital transformation. By utilizing the Vector Auto Regression (VAR) approach, this research aims to construct a comprehensive map of causal relationships and dynamic responses among key variables, serving as a foundation for the formulation of inclusive, adaptive, and sustainable green economic policies in Indonesia.

II. METHODS

This study employs a quantitative data analysis approach using the Vector Auto Regression (VAR) model with the support of EViews 10 software. The VAR method is particularly suitable for examining the dynamic and simultaneous relationships among multiple time-series variables. According to Sims, as cited in Manurung (2005), when simultaneity among variables is present, it becomes inappropriate to strictly distinguish between dependent and independent variables, as all variables may mutually influence one another over time. The VAR model is therefore utilized to explore intertemporal interactions, capturing both the causal linkages and the degree of integration among the variables under study. This method allows for the analysis of how exogenous and endogenous variables interact across various time lags, providing a comprehensive understanding of the short-run and long-run dynamics within the system. Moreover, the VAR framework helps identify feedback effects, persistence, and delayed responses between variables, offering robust empirical insights for policy formulation and forecasting in macroeconomic and development contexts.

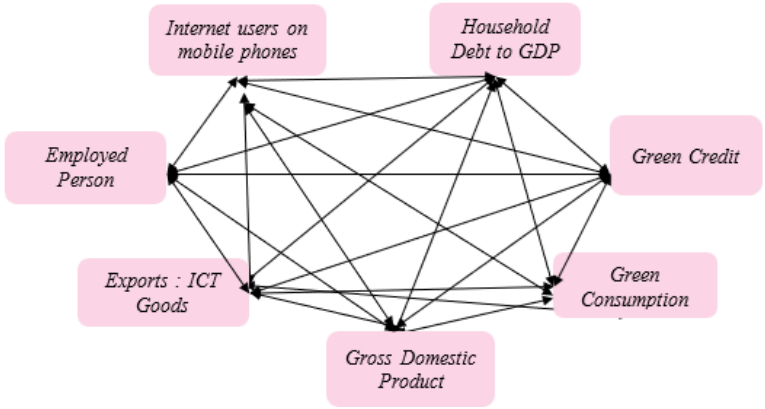


Fig 3. Kerangka Konseptual VAR

Based on the constructed Vector Auto Regression (VAR) framework, the following system of equations can be formulated to represent the dynamic interactions among the variables:

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + B\varepsilon_t$$

Alternatively, the equation can be reformulated as follows:

$$Y_t = A_0^{-1} A_1 Y_{t-1} + A_0^{-1} A_2 Y_{t-2} + \cdots + A_0^{-1} A_p Y_{t-p} + A_0^{-1} B\varepsilon_t$$

Where :

$$Y_t = \begin{bmatrix} IUMP_t \\ EMP_t \\ EXP_t \\ GDP_t \\ GCN_t \\ GCH_t \\ DGD_t \end{bmatrix}, \quad \varepsilon_t = \begin{bmatrix} \varepsilon_{IUMP,t} \\ \varepsilon_{EMP,t} \\ \varepsilon_{EXP,t} \\ \varepsilon_{GDP,t} \\ \varepsilon_{GCN,t} \\ \varepsilon_{GCH,t} \\ \varepsilon_{DGD,t} \end{bmatrix}$$

Matriks Kontemporer (Contemporaneous Structure) A0A_0A0:

$$A_0 = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & a_{37} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & a_{47} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix}$$

The structural matrix captures the contemporaneous interdependencies among the variables. Specifically, the element a_{12} reflects the direct contemporaneous effect of EMP on IUMP at time t."

"Final Structural Vector Autoregression (SVAR) Model Specification

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & a_{37} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & a_{47} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} \cdot \begin{bmatrix} IUMP_t \\ EMP_t \\ EXP_t \\ GDP_t \\ GCN_t \\ GCH_t \\ DGD_t \end{bmatrix} = \sum_{i=1}^{p} A_i \cdot \begin{bmatrix} IUMP_{t-i} \\ EMP_{t-i} \\ EXP_{t-i} \\ GDP_{t-i} \\ GCN_{t-i} \\ GCH_{t-i} \\ DGD_{t-i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{IUMP,t} \\ \varepsilon_{EMP,t} \\ \varepsilon_{EXP,t} \\ \varepsilon_{GDP,t} \\ \varepsilon_{GCN,t} \\ \varepsilon_{GCH,t} \\ \varepsilon_{DGD,t} \end{bmatrix}$$

Reduce form :

1. $IUMP_t = \varepsilon_{1t}$
2. $GDP_t = \alpha_1 * IUMP_t + \varepsilon_{2t}$
3. $EXP_t = \beta_1 * IUMP_t + \beta_2 * GDP_t + \varepsilon_{3t}$
4. $EMP_t = \gamma_1 * IUMP_t + \gamma_2 * GDP_t + \gamma_3 * EXP_t + \varepsilon_{4t}$
5. $GCH_t = \delta_1 * IUMP_t + \delta_2 * GDP_t + \delta_3 * EXP_t + \delta_4 * EMP_t + \varepsilon_{5t}$
6. $DGD_t = \varphi_1 * IUMP_t + \varphi_2 * GDP_t + \varphi_3 * EXP_t + \varphi_4 * EMP_t + \varphi_5 * GCH_t + \varepsilon_{6t}$
7. $GCN_t = \theta_1 * IUMP_t + \theta_2 * GDP_t + \theta_3 * EXP_t + \theta_4 * EMP_t + \theta_5 * GCH_t + \theta_6 * DGD_t + \varepsilon_{7t}$

III. RESULT AND DISCUSSION

The results of the Augmented Dickey-Fuller (ADF) test indicate that the stationarity levels of the variables differ. The variables Employed Person and Green Consumption are stationary at the level form, whereas Green Credit, Exports of ICT Goods, Green Trade, Macroprudential Policy, and Employed Person become stationary at the first difference. Meanwhile, Green Sustainable Development achieves stationarity only at the second difference. This is evidenced by the Dickey-Fuller test statistics being lower than the MacKinnon critical values at the 1% significance level. These findings imply that all variables are stationary at their respective forms, allowing for the continuation of the analysis to the next stage:

Variable	Augmented Dickey Fuller	Nilai Kritis Mc Kinnon pada Tingkat Signifikansi 1%	Prob	Information
GDP	-8.815251	-3.646342	0.0000	Stasioner
GCON	-8.815251	-3.646342	0.0000	Stasioner

GC	-9.284608	-3.646342	0.0000	Stasioner
HDGDP	-9.189977	-3.646342	0.0000	Stasioner
IMP	-4.939205	-3.679322	0.0004	Stasioner
EP	-9.552784	-3.646342	0.0000	Stasioner
EICTG	-9.643223	-3.453434	0.0000	Stasioner

Result SVAR Test

Estimated A matrix:					
1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
-3.637135	1.000000	0.000000	0.000000	0.000000	0.000000
0.275382	-0.029319	1.000000	0.000000	0.000000	0.000000
8.066823	-2.304038	0.239801	1.000000	0.000000	0.000000
-0.016060	-0.004890	-0.117420	-0.001562	1.000000	0.000000
0.129483	-0.430756	0.319985	0.009054	0.059579	1.000000
Estimated B matrix:					
0.103706	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.241253	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.062528	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.087977	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.044246	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	0.107826

$e_{y1} = 0.103706u_{y1}$

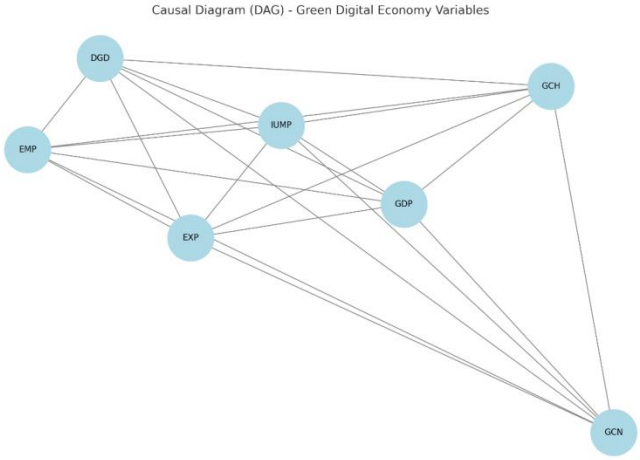
$e_{y2} = -3.637135e_{y1} + 0.241253u_{y2}$

$e_{y3} = 0.275382e_{y1} - 0.029319e_{y2} + 0.062528u_{y3}$

$e_{y4} = 8.066823e_{y1} - 2.304038y2 + 0.239801y3 + 1.087977u_{y4}$

$e_{y5} = -0.016060e_{y1} - 0.004890e_{y2} - 0.117420e_{y3} - 0.001562e_{y4} + 0.044246u_{y5}$

$e_{y6} = 0.129483e_{y1} - 0.430756\ e_{y2} + 0.319985e_{y3} + 0.009054e_{y4} + 0.059579u_{y5} + 0.107826uy6$



The following is a Directed Acyclic Graph (DAG) illustrating the causal relationships among the seven main variables in the study titled “Integration of Green Economic Growth Based on Green Digital Transformation in Indonesia.” The variable Internet Users on Mobile Phones (IUMP) acts as an exogenous factor that directly influences nearly all endogenous variables, including Gross Domestic Product (GDP), ICT goods exports (EXP), Employed Person (EMP), Green Credit Household (GCH), Household Debt to GDP (DGD), and Green Consumption (GCN). GDP significantly impacts digital exports, employment, green credit, and green consumption. Meanwhile, EMP plays a pivotal role in promoting green credit, green consumption, and household financial stability (represented by DGD). GCH and DGD represent financial variables that simultaneously influence green consumption (GCN). All causal pathways ultimately converge on the key target outcome variable Green Consumption (GCN) which serves as the final node of this green digital growth framework

SIRF Test

Variable	Time	GDP	GCON	GC	HDGDP	IMP	EP	EICTG
GDP	Short	+	+	+	+	+	+	+
	Middle	+	+	-	-	-	+	-
	Long term	+	+	-	-	-	+	-
GCON	Short	-						
	Middle	-	+	-	-	-	+	-
	Long term	-	+	-	-	-	-	-
GC	Short	+	-	+				
	Middle	+	-	+	+	+	-	+
	Long term	+	-	+	+	+	-	+
HDGDP	Short	+	+	+	+			+
	Middle	+	+	-	+	+	+	+
	Long term	+	-	-	+	+	+	+
IMP	Short	+	-	-	-	+		-
	Middle	+	+	-	-	+	+	-
	Long term	+	+	-	-	+	-	-
EP	Short	+	+	+	+	+	+	+
	Middle	+	-	-	+	-	+	+
	Long term	+	-	+	+	+	+	+
EICTG	Short	+	+	+	+	+	+	+
	Middle	+	-	-	+	-	+	+
	Long term	+	-	+	+	+	+	+

Based on the results of the Forecast Error Variance Decomposition (FEVD) analysis, insights were gained regarding the effectiveness of control and the role of key variables influencing green economy indicators based on digital transformation in Indonesia. The following section outlines the main findings for each of the studied variables:

Employed Person

FEVD results indicate that in the short term, the Employed Person variable is primarily self-driven, meaning fluctuations in labor force numbers are largely influenced by the variable itself. However, in the medium and long term, policy efforts to boost employment should consider the synergy between Employed Person and Household Debt to GDP. This suggests that sustainable household financing can expand the labor sector's capacity in a green economy. Zhang et al. (2020) support this, showing that inclusive household financing enhances labor force participation, particularly in green and digital sectors.

Green Credit

For improving Green Credit, FEVD indicates that short-term control lies with Green Credit itself and Employed Person. In the medium and long term, influence shifts to Green Credit and Household Debt to GDP. This highlights that the penetration of green credit is more effective when supported by a sound and productive household debt structure. Wang & Zhi (2016) reinforce this by stating that controlled household leverage strengthens the impact of green investments in fostering sustainable economic development.

Exports: ICT Goods

FEVD shows that in the short term, ICT goods exports are influenced by the variable itself and Employed Person. In the medium and long term, effective policies to promote green digital exports involve strengthening ICT exports and leveraging Household Debt to GDP. This emphasizes that the success of digital-based exports depends on domestic consumption conditions and adaptable household financing. Liu et al. (2021) found that ICT export sectors are significantly influenced by stable domestic demand and household financing.

Household Debt to GDP

FEVD results reveal that across all time horizons short, medium, and long Household Debt to GDP is heavily influenced by itself and Exports: ICT Goods. This indicates that the synergy between digital exports and household debt management plays a crucial role in economic resilience. Tu et al. (2021) and Chien (2022) support this, suggesting that financial stability and eco-friendly exports increase national economic value.

Green Consumption

Green Consumption control in the short term is mainly influenced by the variable itself and Employed Person. For the medium and long term, recommended policies should strengthen Green Consumption and Household Debt to GDP. This implies that green consumption capacity depends on stable income and healthy household financing. Huang et al. (2020) argue that incentives for eco-friendly consumption are more effective when backed by stable purchasing power and a microcredit ecosystem.

Green Trade

FEVD shows that short-term green trade is driven by the variable itself and Employed Person. In the medium and long term, influence transitions to Green Trade and Household Debt to GDP. Sandberg et al. (2019) argue that the relationship between green trade and natural resources is highly influenced by domestic fiscal policies and consumption capacity. Qureshi & Yusuf (2022) also state that green trade expansion needs household financial stability to ensure sustainable demand for green goods.

Green Sustainable Development

he most consistent results are observed in the Green Sustainable Development variable, which is dominantly influenced by itself and Employed Person across all time horizons. This underlines the strong connection between green development and labor force capacity. Borodin et al. (2023) highlight that green bonds effectively finance sustainability projects, while Kim & Park (2019) emphasize the role of labor force participation in strengthening the socio-economic foundation of sustainable development.Hence, these FEVD findings provide empirical evidence that green economic development policies in Indonesia must align with the unique interaction patterns of each variable across time horizons. Short-term strategies should focus on strengthening internal sectoral dynamics, while long-term approaches must prioritize structural synergies between the labor force and green household finance.

IV. CONCLUSION

Based on the results of the FEVD analysis, this study demonstrates that the effectiveness of controlling key variables in digital-based green economic development in Indonesia strongly depends on the characteristics of each variable and the policy time horizon. Overall, Employed Person and Household Debt to GDP consistently emerge as critical variables across both short- and long-term periods. These findings underscore the central role of labor as a driver of sustainable development and highlight the need to strengthen household financing to support green consumption, digital exports, and environmentally friendly credit growth. Furthermore, the results emphasize that policy effectiveness cannot be uniformly applied, but must instead be adapted to the dynamics and interlinkages of variables at each time horizon. Short-term interventions are more effective when focused on reinforcing the internal strength of individual variables, while long-term strategies require cross-sectoral integration particularly between green finance and the labor market. Therefore, the findings of this study are expected to serve as a valuable reference in formulating policies that are responsive to the needs of green economy development and Indonesia’s ongoing digital transformation.

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