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-RESEARCH ARTICLE-

ESG AND DIGITAL TRANSFORMATION IN VIETNAM: IMPLICATIONS FOR SUSTAINABLE GROWTH IN THE DIGITAL ECONOMY

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─Abstract─

The current research investigates the evolving influence of digital transformation and environmental, social, and governance (ESG) dimensions on sustainable growth in Vietnam. Employing data spanning from 1996 to 2023 and utilising the ARDL Bounds testing methodology, the analysis indicates that digital transformation exerts a significant positive effect on sustainable growth in the short term, whereas its long-term influence is negative and statistically insignificant, suggesting that initial gains are temporary and do not translate into enduring benefits. Regarding ESG components, governance demonstrates a consistently significant negative impact in both the short and long term, reflecting inefficiencies within Vietnam's institutional framework. The social dimension exhibits a negative effect in the short term but contributes significantly and positively to sustainable growth over the long term. In contrast, the environmental factor positively influences growth in the short term but adversely affects long-term sustainability, highlighting the trade-off between immediate efficiency improvements and long-term structural and regulatory limitations. Collectively, these findings underscore the critical role of ESG considerations and digital transformation in achieving sustainable growth objectives in Vietnam. Based on this evidence, the study provides policy recommendations, including the enhancement of human capital, improvement of governance quality, and encouragement of digital innovation to foster sustained economic development.

Keywords: Digital Transformation; ESG; Sustainable Growth; Vietnam; ARDL Bounds Test.

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Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

INTRODUCTION

The rapid pace of industrialisation has generated substantial environmental challenges, prompting the United Nations to establish 17 Sustainable Development Goals (SDGs), a globally recognised initiative designed to protect the environment, eradicate poverty, and ensure that all individuals can enjoy prosperous and peaceful lives by 2030. Sustainable development, or sustainable growth (SG), denotes the capacity of the present generation to meet its needs without compromising the ability of future generations to fulfil theirs. SG embodies a framework that integrates social problem resolution, economic advancement, and environmental stewardship (Hoang et al., 2024). It encompasses multiple interconnected processes—social, environmental, and economic—all aimed at enhancing overall well-being. Contemporary interpretations of SG place particular emphasis on achieving environmental and social objectives, which are essential for safeguarding the welfare of all economic actors.

Among the key drivers of SG, digital transformation (DT), reflecting the extensive incorporation of digital technologies across markets, public administration, and production processes, has emerged as a central pillar. Digitalisation or DT involves the adoption of digital technologies within businesses (Naseem et al., 2023), accelerating change and enabling structural transformations across industries by generating novel technological paradigms. Empirical evidence increasingly indicates that expanded DT, broader internet access, and improved ICT infrastructure contribute to elevated economic growth, particularly in emerging and developing economies. By lowering transaction and administrative costs, enhancing transparency, and improving coordination between public and private sectors, higher levels of DT promote productivity gains and support both national competitiveness and SG.

In addition to DT, ESG factors play a crucial role in advancing SG (Naseem et al., 2023). These factors serve as performance indicators: environmental factors include carbon emissions, natural resource utilisation, and energy efficiency; social factors cover workforce diversity, labour practices, and supply chain management; while governance encompasses board composition, shareholder rights, independence, and corporate ethics (Boffo & Patalano, 2020). ESG criteria establish standards for assessing the responsibility and performance of organisations across environmental, social, and economic dimensions (Sadiq et al., 2023). The importance of ESG has intensified as stakeholders and citizens increasingly demand environmental accountability. Effective integration of ESG practices in businesses aligns with national progress in SG, as strong ESG performance supports a country's trajectory towards sustainable development (Chipalkatti et al., 2021).

Within this context, the present study seeks to empirically examine the influence of ESG factors and DT on SG in Vietnam over the 1996–2023 period. Analysing these relationships is particularly pertinent given Vietnam's rapid development in Southeast

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

Asia, where substantial economic growth has been achieved in recent years. The nation aspires to sustain high growth rates to become an industrialised economy and achieve high-middle income status by 2035. However, this expansion has coincided with rising emissions, demonstrating the trade-off between economic growth and environmental degradation (Nguyen & Le, 2022), as illustrated in Figure 1. In response, the Vietnamese government has outlined national strategies to advance DT for 2025–2030. Despite these policy initiatives, empirical studies examining the combined effects of DT and ESG on SG in Vietnam remain scarce, particularly at the macroeconomic level. This gap is pronounced in developing economies, where financial channels, government investment, and private sector financing are critical for translating structural reforms into economic outcomes.

Accordingly, the study addresses the following research questions: a) How does DT influence SG in Vietnam? b) How do ESG factors affect SG in Vietnam? By addressing these queries, this research contributes to the existing literature, as prior studies have predominantly explored the relationship between DT, ESG, and SG at the corporate or firm level across various countries, with limited macro-level evidence in Vietnam. The findings of this study offer policymakers actionable insights for designing effective strategies that integrate DT and ESG factors to advance SG.

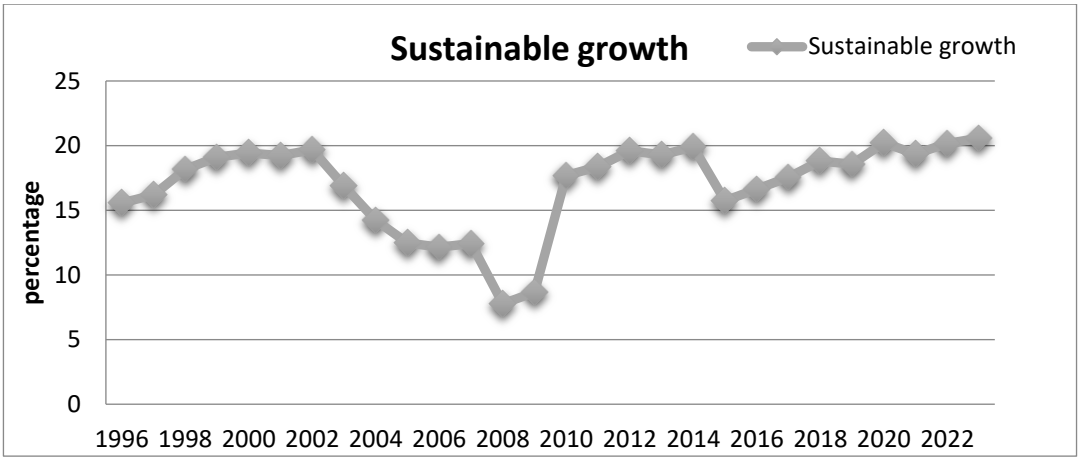

Figure 1: Sustainable Growth in Vietnam 1996 to 2023 Period

The structure of this study is organised as follows: Section 2 presents a review of the existing literature. Section 3 outlines the theoretical framework, data, and estimation methods. Section 4 reports the empirical findings, while Section 5 concludes the study and offers policy recommendations.

REVIEW OF EXISTING LITERATURE

This section examines previous research concerning the interplay between ESG, DT, and SG. The first sub-section focuses on studies addressing the DT–SG relationship,

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

while the second sub-section considers research investigating the association between ESG and SG.

DT and SG

Digitalization encompasses a broad array of resources that facilitate personal and collective interactions, as it can be utilised and shared across large populations. It generates diverse opportunities for development and strategic planning by offering innovative and intelligent solutions (Hussain et al., 2022). In recent years, the nexus between DT and SG has attracted considerable scholarly attention. In this context, Su and Wu (2024) investigated the impact of green transformation and DT on SG in Vietnam over the period 1995–2023. Employing the Bayer-Hanck cointegration test and the ARDL model, their study revealed that both DT and green transformation positively influenced SG. Alojail and Khan (2023) examined the effects of DT on organisational sustainability outcomes using data from 760 stakeholders, finding that DT enhanced economic, environmental, and social sustainability. Hussain et al. (2022) analysed the role of DT in SG through the mediating effect of innovation, drawing on data from Kuwait, Bahrain, Qatar, Oman, UAE, and Saudi Arabia over 2008–2021. Their results from GMM, Fixed Effects, and Quantile Regression models demonstrated a positive influence of DT on SG in these countries. Similarly, Su and Wu (2024), analysing Chinese listed companies from 2012 to 2022, found that enterprise DT strengthened firms' innovative capabilities, thereby promoting sustainable development, with enterprise core competence serving as a mediating factor.

In a comparable study in China, Chen et al. (2025) examined corporate DT and its impact on ESG performance, concluding that DT enhanced environmental, social, and governance outcomes. Safi et al. (2024) assessed the influence of DT on environmental quality in OECD economies between 1995 and 2020, reporting that DT contributed positively to reducing carbon emissions. Using data from China A-share listed companies, Su and Wu (2024) further explored the environmental consequences of corporate DT via the System GMM method, indicating that DT improved environmental performance through corporate governance and green innovation mechanisms. Drawing from this body of literature, the following research hypothesis is proposed:

H1: *There is a significant impact of ESG on SG in Vietnam.*

ESG and SG

As global challenges such as climate change, environmental deterioration, and social inequality intensify, ESG has gained prominence for promoting environmentally responsible practices and long-term sustainability. The literature indicates that ESG practices play a critical role in advancing SG, with numerous studies examining the link between ESG and SG outcomes across both developing and developed nations. For

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

example, Sadiq et al. (2023) investigated the influence of ESG components on economic growth in Western Balkan countries between 2013 and 2022, employing a Fixed Effects regression model. Their results showed that ESG had no statistically significant effect on economic growth. Gidage and Bhide (2025) analysed data from 12 developing economies spanning 2010–2022 to evaluate the role of ESG in sustainable development, applying instrumental variable regression and 2SLS methodology, and found that ESG dimensions positively contributed to sustainable development.

Lin (2024) also assessed ESG performance in ASEAN countries from 2000 to 2023 using the Driscoll-Kraay Standard Error approach, reporting that ESG positively influenced sustainable development. Similarly, Sadiq et al. (2023) examined the relationship between ESG scores and SDGs in ASEAN countries for 1986–2020, employing a Panel ARDL model, and observed a positive association. Işık et al. (2024) explored ESG factors' contributions to SDGs in BRICS-11 countries, identifying heterogeneity across nations, with ESG having positive effects in some countries and negative effects in others. In another study on BRICS nations, Lin (2024) investigated the impact of ESG performance on economic growth for 2000–2020 using a Panel ARDL-PMG approach and found a negative effect in the selected countries.

Namoog and Abubakari (2025) examined ESG variables' influence on long-term economic growth in Ghana via partial least squares structural equation modelling, reporting that governance factors alone significantly affected economic growth, while social and environmental factors had minimal direct effects. Using data from Chinese listed companies between 2009 and 2021, Lin (2024) studied ESG performance and its effect on sustainable growth rates, finding through baseline regression and instrumental variable analysis that ESG positively influenced sustainable growth. Based on this body of evidence, the second hypothesis is proposed as follows:

H2: *There is a significant impact of ESG on SG in Vietnam.*

Research Gaps

Although interest in the influence of digitalization on SG has been increasing, prior research has predominantly treated ESG and DT as separate determinants of SG, with only a limited number of studies considering their combined effect. Additionally, most existing studies have assessed ESG's role in SG using aggregate ESG indices or scores, and, to the best of our knowledge, few have examined the distinct contributions of environmental, social, and governance factors individually. Furthermore, the majority of research has focused on other emerging and developed economies, leaving empirical evidence from Vietnam relatively limited. This study addresses these gaps by investigating the effects of ESG and DT on SG in Vietnam, providing novel empirical insights into the role of these factors in promoting sustainability within the country.

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

DATA AND METHODOLOGY

Theoretical Framework and Data

This study utilises the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework, originally proposed by Dietz and Rosa (1997), to investigate the influence of DT and ESG factors on SG in Vietnam. The STIRPAT model has been extensively applied in the literature to assess how various socio-economic factors affect environmental quality and sustainable development. It posits that environmental impacts are primarily driven by three key determinants: population, affluence, and technology. The STIRPAT model is represented mathematically in the following equation.

$$I_i = \alpha P_i^{\beta} A_i^{\gamma} T_i^{\delta} \varepsilon_i \quad (1)$$

Where,
I= Environmental Impacts,
A= Affluence,
P= Population,
T= Technology.

Building on the STIRPAT model presented in Equation (1), the study's specific model is formulated as follows:

$$SG_t = \beta_0 + \beta_1 DT_t + \beta_2 EG_t + \beta_3 URBG_t + \mu_t \quad (2)$$

In Equation (2), SG, DT, ESG, and URBG correspond to the I, T, A, and P components of the STIRPAT model. Furthermore, following the approach adopted in prior studies (Işık et al., 2024; Lin, 2024; Sadiq et al., 2023), the model is further elaborated as follows:

$$SG_t = \beta_0 + \beta_1 DT_t + \beta_2 GOV_t + \beta_3 SOC_t + \beta_4 ENV_t + \beta_5 EG_t + \beta_6 URBG_t + \beta_7 IND_t + \mu_t \quad (3)$$

Where GOV, SOC, ENV, and IND represent governance, social, environmental factors, and industrialization, respectively.

This study utilises time series data from Vietnam spanning 1996 to 2023 to empirically investigate the relationships outlined above. The data for all variables were obtained from various secondary sources. To quantify DT, as well as the GOV, SOC, and ENV components of ESG, separate indices were constructed for each variable employing the Principal Component Analysis (PCA) method. A comprehensive description of all variables, along with their data sources, is provided in Table 1.

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

Table 1: Detailed Description of Variables and Data Sources

Variables	Measurement	Data Source
Sustainable Growth	Adjusted net savings excluding particulate emissions (% of GNI)	WDI
Digital Transformation	Index consisting of Fixed Broadband subscription, Mobile cellular subscriptions (both per 100 people) and percentage of individuals using internet in population	WDI
Urbanization	Urban population growth (annual percentage)	WDI
Economic Growth	GDP per capita growth (annual percentage)	WDI
Industrialization	Industrial value-added including construction (% of GDP)	WDI
Governance Factor	Index consisting of rule of law, political stability and absence of violence, control of corruption, government effectiveness, regulatory quality and voice and accountability (each measured in estimate)	World Governance Indicators
Social Factor	Index consisting of access to clean technologies and fuel for cooking as percentage of population), access to electricity (as percentage of population), participation rate in labour force (percentage of population between 15-64 ages), prevalence of undernourishment (as percentage of population), people having services of safely managed drinking water (as percentage of population), people having services of safely managed sanitation as percentage of population), Prevalence of overweight (% of adults), school enrolment, primary (% gross) and Unemployment, total (as percentage of total labour force), population at the age of 65 and above (as percentage of total population).	WDI
Environment Factor	Agricultural land (as percentage of total land) Agriculture, fishing and forestry value added (percentage of GDP), total freshwater withdrawals annual (percentage of internal resources), Fossil fuel energy consumption (percentage of total), net energy imports (% of energy use), electricity generation from coal sources (% of total), forest area (percentage of land area), renewable electricity production (percentage of total electricity production), Renewable energy consumption (percentage of total final energy consumption)	WDI

Research Methods

To examine the relationship between DT, ESG, and SG in Vietnam, the stationarity of the variables is first assessed using the Phillips-Perron (PP) test (Phillips & Perron, 1988)) and the Augmented Dickey-Fuller (ADF) unit root test (Dickey & Fuller, 1979) to determine their orders of integration. These tests ensure that none of the series is integrated of order two, I(2), which is a critical requirement for applying subsequent econometric procedures. Following the determination of integration orders, the study employs the Autoregressive Distributed Lag (ARDL) approach developed by Pesaran et al. (2001). The ARDL methodology is preferred for several econometric reasons: first, it accommodates regressors integrated of different orders, I(0) or I(1), but not I(2); second, it is suitable for time series datasets with a limited number of observations;

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

third, it allows the simultaneous estimation of short-run and long-run relationships within a single modelling framework. The ARDL model thus facilitates the analysis of both short-run dynamics and long-run equilibrium effects. The long-run ARDL specification is formulated as follows:

$$\Delta SG_t = \alpha_0 + \sum_{i=1}^{r} \alpha_{1k}\Delta SG_{t-j} + \sum_{i=0}^{r} \alpha_{2k}\Delta DT_{t-j} + \sum_{i=0}^{r} \alpha_{3k}\Delta GOV_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta SOC_{t-j} + \sum_{i=0}^{r} \alpha_{5k}\Delta ENV_{t-j} + \sum_{i=0}^{r} \alpha_{6k}\Delta EG_{t-j} + \sum_{i=0}^{r} \alpha_{7k}\Delta IND_{t-j} + \sum_{i=0}^{r} \alpha_{8k}\Delta URBG_{t-j} + \beta_1 SG_{t-1} + \beta_2 DT_{t-1} + \beta_3 GOV_{t-1} + \beta_4 SOC_{t-1} + \beta_5 ENV_{t-1} + \beta_6 EG_{t-1} + \beta_7 IND_{t-1} + \beta_8 URBG_{t-1} + \varepsilon_t \quad (4)$$

In Equation (3), Δ, ε, and α₀ denote the first difference, the error term, and the intercept, respectively. The corresponding short-run ARDL model is specified as follows:

$$\Delta SG_t = \alpha_0 + \sum_{i=1}^{r} \alpha_{1k}\Delta SG_{t-j} + \sum_{i=0}^{r} \alpha_{2k}\Delta DT_{t-j} + \sum_{i=0}^{r} \alpha_{3k}\Delta GOV_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta SOC_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta ENV_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta EG_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta IND_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta URBG_{t-j} + \alpha ECM_{t-1} + \varepsilon_t \quad (5)$$

RESULTS AND DISCUSSION

Table 2 presents the summary statistics for the study variables. These statistics offer a basic overview of the data, including the mean, standard deviation, minimum, and maximum values for each variable. Among the series, IND exhibits the highest mean, while SG displays the largest standard deviation, indicating that SG shows the greatest variation across all variables. Furthermore, the results of the Jarque-Bera (J-B) test suggest that all variables, except SG, follow a normal distribution.

Table 2: Descriptive or Summary Statistics

Variables	Mean	Standard Deviation	Minimum Value	Maximum Value	J-B Stat
SG	16.946	3.7457	7.7690	20. 574	8.200**
DT	2.86e-08	1.000	-1.2360	1.0728	4.106
URBG	3.237	0.5713	2.209	4.3669	1.030
EG	5.1502	1.4294	1.666	7.7256	1.707
GOV	-1.79e-08	1.000	-1.279	1.9714	2.483
SOC	1.07e-08	1.000	-1.490	1.4235	2.4544
ENV	5.00e-08	1.000	-1.4500	1.9215	2.5056
IND	36.184	2.438	29.729	40.208	2.3730

Where, ** shows significance at 5%.

Table 3 presents the correlation matrix, which illustrates the linear relationships among the study variables and serves as a preliminary assessment prior to model estimation. The correlation coefficients reflect both the strength and direction of pairwise

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

associations, indicating whether these relationships are statistically significant or not. This initial analysis is useful for detecting potential associations and specification issues among the variables. The coefficients reveal that none of the variables exhibit a significant correlation with SG. Additionally, the correlation matrix confirms that severe multicollinearity is not present in the dataset (Norocel & Vierescu, 2024).

Table 3: Correlation Matrix

Variables	SG	DT	ENV	SOC	GOV	EG	URBG	IND
SG	1.000							
DT	0.230	1.000						
ENV	0.4819	0.7915	1.000					
SOC	0.3184	0.9047	0.9036	1.000				
GOV	0.2365	0.5722	0.7846	0.7750	1.000			
EG	-0.0829	-0.2666	-0.1864	-0.2167	-0.0168	1.000		
URBG	-0.3475	-0.6697	-0.4003	-0.6126	-0.3469	-0.026**	1.000	
IND	-0.1418	-0.039**	-0.0720*	0.1670	-0.006**	-0.0877*	-0.1209	1.000

Where *** and ** shows significance at 1% and 5%, respectively.

Following the descriptive statistics and correlation analysis, the stationarity of the variables was assessed using the ADF and PP tests, with the results presented in Table 4. The findings indicate that most variables become stationary after first differencing, whereas only EG and IND are stationary at levels. This pattern demonstrates that the variables exhibit mixed orders of integration, I(0) and I(1), confirming the suitability of the ARDL Bounds testing approach for estimating both long-run and short-run relationships.

Table 4: Stationarity or Unit Root Tests

Variables	ADF		PP	
	I(0)	I(1)	I(0)	I(1)
SG	-1.7242	-4.415**	-1.886	-4.391
GOV	-1.6345	-7.967***	-1.5055	-7.766***
ENV	-0.2571	-4.2851**	-0.3785	-4.2758**
SOC	1.5203	-3.758**	-0.4602	-2.792**
DT	-1.7098	-2.896**	-1.0301	-2.9555**
EG	-2.367	-7.847***	-5.456***	--------
IND	-2.991**	---------	-2.978**	--------
URBG	-2.0265	-4.583**	-1.7331	-3.201**

Where, *** and ** shows significance at 1% and 5%, respectively.

Subsequently, the ARDL Bounds test was employed to assess the existence of long-run cointegration among the variables. The results, reported in Table 5, show that the calculated F-statistic exceeds the upper bound critical values at all significance levels, confirming the presence of long-run cointegration among the variables.

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

Table 5: ARDL Bound Test Results

Statistics	Value	K
F-Stat	354.00	7
Significance Level	I(0)	I(1)
10%	1.92	2.89
5%	2.17	3.21
2.5%	2.43	3.51
1%	2.73	3.9

Following the ARDL Bounds test, the relationships between the dependent and independent variables were estimated. Tables 6 and 7 present the short-run and long-run results, respectively. The analysis reveals that DT exerts a significant positive effect on SG in the short run, whereas its long-run impact is negative and statistically insignificant. This indicates that while DT generates immediate benefits for SG, these effects are not sustained over time and may even diminish.

Table 6: ARDL Short Run Results

Variables	Coefficient	T-Stat	P-Value
Error Correction Model (ECM)	-1.241***		0.000
D(GOV)	-1.904***	29.218	0.000
D(SOC)	-136.68***	-84.473	0.0007
D(ENV)	0.5527**	5.495	0.0119
D(DT)	0.560**	4.287	0.0233
D(URBG)	-3.115***	-37.207	0.000
D(IND)	-1.0656***	-53.909	0.000
D(EG)	0.6144***	37.163	0.000

Where, ***, ** & * show significance at 1, 5 and 10 %.

Table 7: ARDL Long Run Results

Variables	Coefficient	T-Stat	Prob-Value
GOV	-3.145**	-12.388	0.0011
SOC	5.095**	6.431	0.0076
ENV	-4.064**	-6.105	0.0088
DT	-1.247	-2.156	0.1200
URBG	-9.276***	-16.414	0.000
IND	-1.738**	-12.079	0.0012
EG	0.0104	0.1013	0.925

***=p<0.05 and **=p>0.05.

The short-term gains can be attributed to digitalization fostering new business models and innovations that support green economic growth. These findings are consistent with Norocel and Vierescu (2024) and Alojail and Khan (2023), who reported a positive influence of DT on SG. Conversely, the negative and insignificant long-run effect aligns

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

with the observations of Li et al. (2024) and Ionescu-Feleagă et al. (2023), who suggested that inadequate government and policymaker attention can limit the long-term sustainability benefits of digitalization. In addition, Salahuddin et al. (2016) highlighted that DT's substantial energy requirements may increase CO_2 emissions, thereby reducing the rate of sustainable growth.

Regarding ESG factors, the results indicate that GOV exerts a negative and statistically significant effect on SG in both the short and long run. This suggests that governance structures in developing countries are often underdeveloped and inefficient, particularly in implementing policies and regulations related to energy transition and environmental innovations necessary to promote sustainability and SG. Similar outcomes have been reported in prior studies by Teng et al. (2021) and Norocel and Vierescu (2024), which also observed a negative influence of GOV on SG. The SOC component exhibits a negative and significant effect on SG in the short run, while its long-run effect turns positive. This pattern implies that although short-term social investments may divert resources from production, over time, policies targeting healthcare and education strengthen human capital, thereby enhancing SG. The short-run negative impact aligns with the findings of Leung and Wang (2010) and Voumik and Sultana (2022), whereas the long-run positive effect is consistent with Gidage and Bhide (2025) and Jain et al. (2024).

Similarly, ENV demonstrates a positive and significant short-run effect on SG but a negative and significant long-run impact. This apparent contradiction can be explained by the fact that long-term investments in environmental sustainability often do not yield direct economic benefits and increase costs. Firms incur substantial expenditures on environmental compliance and sustainability initiatives, primarily to meet regulatory standards and enhance reputation, which does not necessarily improve profitability. While a strong environmental reputation may facilitate access to capital, it does not expand domestic growth potential (Lin, 2024). These findings are in agreement with (Shahbaz et al., 2017) and Lin (2024). Furthermore, IND has a pronounced negative effect on SG in both the short and long run, indicating that industrial expansion contributes to higher emissions. This result is supported by Voumik and Sultana (2022) and Akram et al. (2024), who observed that industrialization increases environmental degradation and diminishes SG. In contrast, EG positively and significantly affects SG in the short run, demonstrating that economic growth enhances SG, consistent with Anwar et al. (2020) and Castro and Lopes (2021). However, its long-run effect is statistically insignificant, aligning with the findings of Bieth (2021) and Islami et al. (2022), who reported a negligible impact of EG on emissions levels.

URBG exhibits a strong negative and significant impact on SG in both the short and long term, reflecting the environmental pressures associated with urbanisation, such as increased food demand, transportation, deforestation, and energy consumption, which contribute to waste, sanitation, and traffic issues, ultimately hindering SG (Shahbaz et

Vol: 17 **No:** 02 **Year:** 2025 **ISSN:** 2146-0744 (Online) (**pp.** 128-143) **Doi:** 10.34109/ijebeg.2025170207

al., 2017). These results are supported by prior studies including Li et al. (2024) and Anwar et al. (2020). The error correction term has a negative and highly significant coefficient of 1.24, indicating that SG in Vietnam adjusts towards its long-run equilibrium following short-term shocks, with an adjustment speed of 12.4% per year.

To ensure the validity and reliability of the ARDL estimates, a series of diagnostic tests were conducted. These include the Breusch-Godfrey LM test for autocorrelation, the Breusch-Pagan test for heteroskedasticity, the Jarque-Bera test for residual normality, the Ramsey RESET test for functional form adequacy, and the CUSUM and CUSUM-squared tests for parameter stability. Failing any of these tests could bias the estimates and compromise the robustness of policy inferences.

The results presented in Table 8 confirm that the model does not suffer from autocorrelation, heteroskedasticity, omitted variable bias, or non-normality of errors.

Table 8: Diagnostic Tests for Model Stability

Tests	Statistics	P-Value	Decision
Normality	0.290	0.865	Residuals are Normally Distributed
Ramsey RESET	2.644	0.245	Correct Functional Form
Heteroskedasticity	1.113	0.542	No Heteroskedasticty
Serial Correlation	2.035	0.289	No Serial Correlation

Additionally, the CUSUM and CUSUM-squared tests, illustrated in Figure 2, confirm the stability of the model parameters.

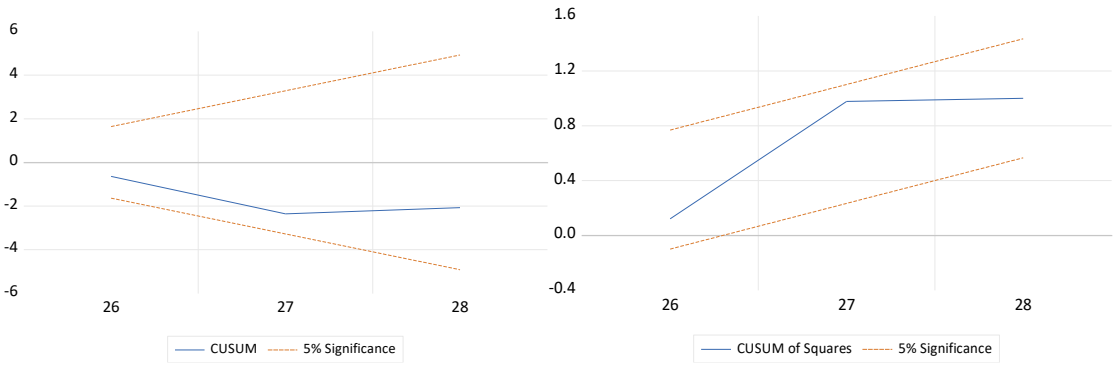

Figure 2: Graphical Representation Model Stability Diagnostics

CONCLUSION AND RECOMMENDATIONS

This study examines the influence of DT and ESG factors on SG in Vietnam over the 1996–2023 period, utilising the STIRPAT framework and the ARDL approach. The findings confirm the presence of a long-run stable cointegrating relationship among the variables. In the short run, DT and the ENV component exert a positive and statistically significant effect on SG, whereas SOC and GOV display significant negative impacts,

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emphasising the critical role of DT and environmental sustainability in promoting SG. Additionally, IND, EG, and URBG contribute positively to SG in the short term. In contrast, DT demonstrates a negative and statistically insignificant impact on SG in the long run. Among ESG factors, ENV and GOV effects turn negative in the long run, while SOC shows a positive effect. Similarly, EG, which is significant in the short term, becomes insignificant over the long term. Post-estimation diagnostics confirm the stability of the model parameters and the reliability and efficiency of the estimates.

Based on these results, several policy recommendations emerge. First, the government should integrate DT with long-term environmental strategies and green growth initiatives to ensure that short-term efficiency gains translate into sustainable development outcomes. Investments in low-carbon and energy-efficient digital infrastructure, such as renewable energy-based ICT systems and green data centres, are essential to mitigate the environmental costs associated with rapid digital expansion. Enhancing governance quality, regulatory frameworks, and data protection mechanisms will strengthen the effectiveness of DT and its contribution to SG. Furthermore, the adoption of market-based instruments and environmental regulations, such as carbon pricing, can mitigate rebound effects and offset potential long-run negative consequences of DT. Collectively, these measures would enable Vietnam to leverage ESG factors and DT to achieve sustained SG.

Second, the persistent negative impact of GOV on SG highlights inefficiencies within existing institutional and regulatory frameworks. Policymakers should prioritise improving governance quality by reducing bureaucratic obstacles, enhancing transparency, and ensuring effective policy implementation. Strengthening institutional capacity and aligning governance mechanisms with sustainability objectives can transform GOV into a driver of long-term SG. Third, the findings indicate that investments in social factors incur short-term costs but generate long-term benefits by fostering social stability and human capital development. Targeted investments in healthcare, education, and social protection, supported by efficient allocation of resources, can convert the short-term negative effects of SOC into long-term positive outcomes. Finally, to secure the long-term benefits of ENV initiatives, policymakers should promote innovation-based environmental strategies, including renewable energy adoption and green technologies. Simultaneously, balancing economic growth with environmental regulations will facilitate the transition of industries to cleaner production methods, reducing the negative long-term impacts while sustaining SG.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH STUDIES

This study utilises single-country time series data, which restricts the generalizability of the findings and limits their applicability for broader cross-country or global comparisons. Future research could address this limitation by employing panel data from multiple emerging and developed economies to capture more comprehensive and

comparative insights. Additionally, the current analysis assumes linear relationships between the variables, leaving scope for future studies to investigate potential non-linear or asymmetric effects of ESG and DT on SG through methodologies such as NARDL and QARDL. Furthermore, subsequent research could explore the moderating or mediating roles of key factors, including institutional quality, digital finance, and green transformation, as channels through which ESG and DT influence SG.

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