



Original Article

Green Initiative and Digital Technology: Unraveling the Impact on Environmental Quality in Developing Countries

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ABSTRACT

Environmental quality in emerging countries is examined in this research in relation to eco-friendly initiatives, digital innovation, financial growth, economic expansion, and trade liberalization. The World Development Indicators provide a panel dataset of developing economies that spans the years 1990–2022. Dynamic panel data analysis makes use of the System Generalized Method of Moments (SYS-GMM) to account for possible dynamics in the dependent variable, unobservable heterogeneity, and endogeneity. Economic growth, green initiatives, and digital technology all have negative effects on environmental quality, whereas financial development, trade liberalization, and digital technology all have positive effects. This emphasizes the importance of replacing fossil fuels with renewable energy sources, implementing digital tools for managing resources and keeping an eye on the environment, and encouraging green investment via the banking system. Among the policy consequences is the need for low-income governments to promote green technology adoption, increase financing options for environmentally responsible investments, and ensure that international climate commitments and sustainable development goals are consistent with one another. In order to achieve long-term economic development, this research stresses the need of digitization and financial advances in enhancing environmental quality growth.

Introduction

Due to the persistent degradation of environmental quality caused by human use of natural resources, digitization, and the Green Initiative have emerged as crucial components for enhancing environmental quality (Weimin et al., 2022). As a result, the study looks at how environmental quality changes when green initiative sources are a part of the overall energy mix. Specifically, it examines how well green initiatives can both maintain economic development paths and lessen the effects of climate change (Iram et al., 2024; Asghar et al., 2024a).

Furthermore, fostering economic development is impossible without communication and information technology. These days, advancements in society, new ideas, and innovations are mostly spurred by ICTs, including the Internet, smartphones, cellular phones, computer systems, and related applications. Information and communication technologies, on the other hand, boost productivity when used extensively (Qadri et al., 2023; Ameer et al., 2024, Ji et al., 2024). More importantly, ICT has played a major role in the evolution of the world economy during the last several decades. Zhai and An (2020) state that it has facilitated the development of smart cities, better healthcare systems, and more efficient transportation networks.

Growth in industrial production and other forms of economic activity raises energy consumption (Asghar et al., 2024b), which in turn raises carbon emissions and worsens environmental quality. Based on what we've learned so far, it's clear that ICT is crucial for a nation's environmental initiatives, economic growth, and trade liberalization. Environmental quality in Belt and Road Initiative countries is the focus of this research, which aims to examine the impact of environmental programs, sustainable practices, FDI, trade liberalization, and information and communication technology (C. Wang et al., 2021). In addition to the impacts of internet users in other sectors pertaining to CO₂ emissions, the purpose is to provide substantial policy implications about the role of ICT in improving environmental quality. Since ICT equipment requires energy to function, advancements in this field lead to greater energy efficiency. Carbon dioxide emissions are intimately related to both economic growth and environmentally beneficial activities, which are both supported and encouraged by information and communication technology (ICT). Financial literacy programs, energy sector integration, economic expansion, and easier trade access are all part of these endeavors. The financial sector has propelled the expansion and interconnection of the information and communication technology domain. At the same time, it's linked to various initiatives where monetary advancement might greatly enhance ecological integrity.

This research looked at developing-world contexts to see how environmental efforts, digital technology, financial innovation, economic development, and trade interact with one another. Developing nations are putting a strain on the world's resources, which is causing global warming and diminishing environmental quality. In order to achieve sustainable economic development and environmental quality, this study aims to determine the effect of green initiatives, digital tools, foreign direct investment (FDI), GDP, and trade on the reduction of CO₂ emissions (Sampene et al., 2023).

The major impact of green initiatives, digital technology, and economic growth on ecological sustainability is the focus of this research. This research highlights the relevance of emerging countries' efforts to attain environmental sustainability and quality, offering crucial insights into this pressing global economic issue. In order to better understand the relationship between relevant elements and their effect on environmental quality, this research delves into the Environmental Kuznets Curve (EKC) hypothesis. To improve productivity, encourage economic growth, and advance environmental quality, green initiatives, digital technologies, and resources for financial development are crucial. As the paper continues to analyze the policy implications, it stresses how important it is for laws and fiscal policies to adapt to the evolving economy (Agaton et al., 2022).

This research focuses on sustainability programs, technological developments, financial breakthroughs, economic growth, and trade. According to this research, digital technology affects environmental quality. The impact of economic expansion on ecological sustainability might be positive or negative. According to Aimon et al. (2021), emerging economies show the Environmental Kuznets curve.

Indirectly linking environmental quality with green initiatives, digital technology, financial development, economic growth, and commerce, this essay finds a gap. Examining data from developing nations from 1990 to 2022, this study delves deeply into the interplay between green initiatives, digital technologies, financial development, commerce, economic growth, and environmental quality. Previous research has ignored some important questions about these variations, which this work seeks to resolve investigation.

Literature Review

A study was performed to examine the relationship between green initiatives and environmental quality, using examples from both specific regions and individual countries. Most of these studies demonstrate that the adoption of green initiatives contributes to the reduction of carbon emissions. In their study, (Wang, 2021) employed various panel data approaches to investigate the impact of green initiatives on environmental quality in 39 developing countries from 1995 to 2017. They found that green initiatives had a significant and lasting influence in reducing carbon emissions. Furthermore, the study highlights the need of improving the caliber of institutions and advocating for the implementation of green initiatives sources to enhance environmental quality.

(Mishra & Alavi, 2023) investigates the proposition of whether renewable energy can successfully replace fossil fuels in 25 African countries between 1980 and 2012. While the study does not support the existence of the Environmental Kuznets Curve in African countries, it does demonstrate that green initiatives have a significant and harmful effect on environmental quality. The research undertaken by (Woon et al., 2023) examines the relationship between renewable energy, GDP growth, and carbon emissions in 22 countries in Central and South America from 1995 to 2010. The study utilizes the cointegration estimator and Granger causality test. The analysis revealed a unidirectional causal link between renewable energy and financial development and environmental quality. The study highlights the significance of advocating for the utilization of renewable energy to mitigate the impacts of climate change.

The study by (Xu et al., 2023) investigates the determinants of carbon emissions in European Union member countries between 1980 and 2012. The authors utilize the dynamic ordinary least squares regression technique to establish that renewable energy is indeed beneficial in reducing carbon dioxide emissions. In addition, they note that there is a link between GDP and air pollution that follows the pattern of an environmental Kuznets curve. The study also reveals a reciprocal cause-and-effect relationship between renewable energy and carbon emissions. (Wang et al., 2021) utilized the generalized spatial two-stage least squares (GS2SLS) technique and identified a one-way causal connection from renewable energy to carbon emissions.

(Wan & Sheng, 2022) provide evidence that trade, tourism, and renewable energy help reduce the impact of climate change in European Union member states. They use advanced statistical methods such as FMOLS, DOLS, and GMM estimators to support their findings. The study found a strong association between economic growth and environmental decline. (Albaker et al., 2023) explicitly investigates the relationship between renewable energy and carbon emissions in major energy-consuming economies throughout the period of 2000 to 2015. The authors use a two-step GMM estimator to show that the renewable energy sector can significantly reduce the effects of climate change in countries with high energy consumption.

(Shan et al., 2021) examine the relationship between industrialization, the utilization of renewable energy, and the levels of carbon emissions in 48 nations situated in Europe and Central Asia in their research. The study, utilizing a two-step Generalized Method of Moments estimator, uncovers the following results: Renewable energy decreases carbon emissions; Renewable energy mitigates the positive influence of industrialization on carbon emissions; The EKC hypothesis is confirmed for nations in the Eastern and Central Asia economies. The importance of renewable energy in lowering carbon emissions has been validated by individual research undertaken in Ecuador, Thailand, China, India, Portugal, and other countries.

The current research on the relationship between financial development, information and communication technology, green initiative, and environmental quality produces uncertain findings. Past studies have thoroughly investigated a wide range of samples, data sets, econometric methods, and time spans. Nevertheless, this research has produced divergent findings. For example, (Zhao et al., 2023) examined how the level of financial growth and the use of information and communication technology, internet influenced the amount of carbon emissions in group of seven countries between nineteen ninety two to two thousand fourteen. The researcher utilized pooled mean group model to ascertain the persistent optimistic consequences of internet users on environmental quality. They observed that the factors affecting FDI have little influence, but the interaction between internet users and financial development has a detrimental impact. Moreover, they argue that is an inverse association between FDI, information and communication technology, internet users and economic growth.

(Fakher et al., 2022) inspected the connection between natural contamination, financial development, and budgetary advancement in 24 move countries. They employed panel data from the time frame spanning 1993 to 2004. They found evidence that supports the Environmental Kuznets Curve (EKC) hypothesis, which proposes that financial development might have detrimental impacts on environmental quality if it is not carried out within a strong institutional framework. In a study conducted by (Fakher et al., 2021), the impact of financial development on the growth of gross domestic product and environmental degradation in India between 1980 and 2003 was analyzed.

In their study, (Ofori et al., 2023) examined the non-linear relationship between money related improvement and natural weakening. The analysts utilized board information from 110 industrialized and creating countries, covering the period from 1986 to 2005. The creators have confirmed the precision of the Natural Kuznets Bend and illustrated that budgetary improvement is causally connected to the increment in natural contamination. In 2006, he concocted a set of five conditions and utilized them to surmise the SO₂ emanations of 29 Chinese territories crossing from 1994 to 2001. The creator found that the effect of FDI on mechanical sulfur

dioxide emanations is unimportant. A 1% increment in FDI leads to a corresponding increment of 0.098% in sulfur dioxide emanations.

Methodology and Data Description

This research primarily intends to analyze developing countries member states' responses to changes in green initiatives and environmental quality. To assess the impact of silicified components on the environmental quality, this research utilized a panel dataset that included data for developing countries member nations from 1990 to 2022.

Table 1: Variables Description

Variables	Code	Measurement	Source
Environmental Quality	EQ	CO ₂ emissions (metric tons per capita)	WDI
Green Initiative	GI	Renewable energy consumption (% of total final energy consumption)	WDI
Digital Technology	DT	Individuals using the Internet (% of population)	WDI
FDI	FD	Financial development index	IMF
Economic growth	EG	GDP growth (annual %)	WDI
Trade	TD	% of GDP	WDI

Estimation in mathematical form

Considering the above discussion, the basic EKC can be reported as:

$$EQ = f(EG) \quad (1)$$

While incorporating additional parameters, the model can be rewritten as

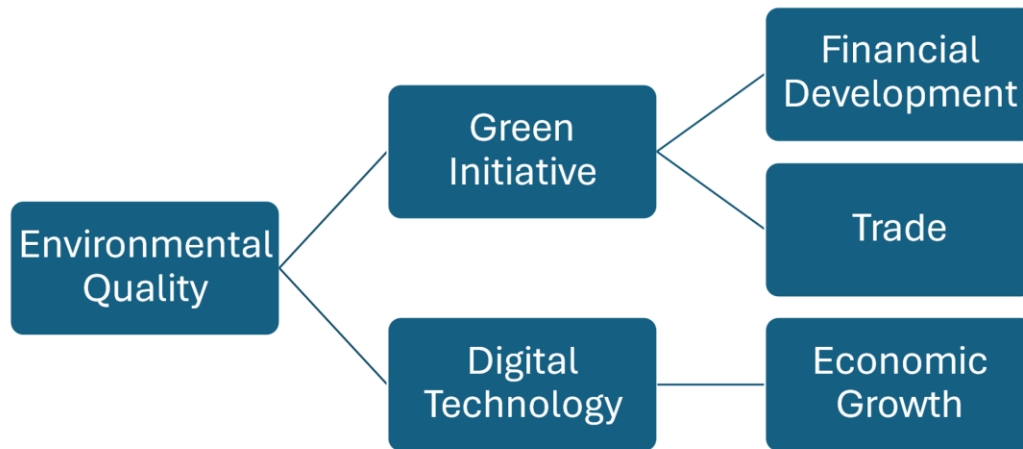
$$EQ = f(GI, DT, FD, EG, TD) \quad (2)$$

Which can be outlined mathematically as

$$EQ_{it} = \lambda_0 + \rho_1 GI_{it} + \rho_2 DT_{it} + \rho_3 FD_{it} + \rho_4 EG_{it} + \rho_5 TD_{it} + \mu_t \quad (3)$$

Where EQ denotes environmental quality, GI indicates green initiative, and DT refers to digital technology. FD symbolizes financial development, EG implies economic expansion, and TD indicates trade. The coefficients are shown, t represents the period, and the error term is delineated.

Figure 1: Conceptual Model



World Development Indicator (WDI) and International Monetary Fund (IMF) data, covering 1990–2022, are used. Since emerging economies are making great use of their resources to achieve sustainability, the study's findings corroborate the connection between green efforts, digital technology, financial development indices, economic growth, trade, and the impact on environmental quality in these regions. In this scenario, environmental quality is declining due in large part to expanding economies. The impact of developing-world GI, DT, FD, EF, and TD on environmental quality was assessed in this research.

The research found the predictors by evaluating the stability of the parameter's slope using slope homogeneity. Subgroups in panel datasets could influence one another, which might result in too generalized conclusions. In order to achieve this aim, the methods described quantitatively in Rashid Khan et al. (2021) and Z. Lin et al. (2023) are used as:

$$\tilde{\Delta} = (N)^2 (2k)^{-\frac{1}{2}} \left(\frac{1}{N} \tilde{S} - k \right) \quad (4)$$

$$\tilde{\Delta} = \left(\frac{2k \setminus (T - k - 1)}{T + 1} \right) \left(\frac{1}{N} \tilde{S} - k \right) \quad (5)$$

When data from different groups show signs of being dependent on one another, this is called cross-sectional dependency for a number of reasons, such as shared traits with developing countries, increased economic integration, and more social and geographical cooperation. So, to quantify the effect of spillovers between series, Lange et al. (2021) developed a cross-sectional dependence (CSD), as shown in the equation 6.

$$CD = \sqrt{\frac{2M}{S(S-1)}} \left(\sum_{z=1}^{S-1} \sum_{x=z+1}^S \hat{\rho}_{zx} \right) \square S(0,1) \quad (6)$$

According to Ng et al. (2021), second-generation unit root tests, such as CIPS and PASDF, are better than first-generation tests when there is cross-sectional dependence (CSD) in a series. This is because these tests assess the unit root well within the context of CSD as:

$$CIPS = \frac{1}{S} \sum_{z=1}^S m_z(S, M) \quad (7)$$

$$\Delta B_{zm} = \varphi_z + \zeta_z B_{z,m-1} + \delta_z \bar{B}_{m-1} + \sum_{x=0}^q \delta_{zx} \bar{B}_{m-1} + \sum_{x=1}^q \lambda_{zx} \Delta B_{z,m-1} + \varepsilon_{zm} \quad (8)$$

However, for the extended relationship in the series analysis, the Pedroni and Westerlund cointegration tests were used. The Pedroni test incorporates individual-specific dynamics and fixed effects to evaluate cointegration in the presence of cross-sectional dependency (CSD). Westerlund used error correction estimates to evaluate the long-term connection between parameters and EQ within the framework of CSD, as outlined by Shi and Lai (2013) as

$$E_a = \frac{1}{S} \sum_{z=1}^S \frac{a'_z}{FR(a'_z)} \quad (9)$$

$$E_m = \frac{1}{S} \sum_{z=1}^S \frac{Ma'_z}{a'_z(1)} \quad (10)$$

$$Q_m = \frac{a'}{FR(a')} \quad (11)$$

$$Q_a = Ma' \quad (12)$$

Endogeneity may impact predictors, but the One-step Generalized Method of Moments (GMM) can handle it. While error terms are not affected by the moment's condition, endogenous variables are. In dynamic modeling, it emphasizes the similarities and differences between the population and the sample. Instruments that are correlated with the endogenous variables but uncorrelated with the error term are often used to construct moment conditions for GMM. repressors.

$$E[Z_{it}(\mu_{it})] = 0 \quad (13)$$

Z_{it} denotes the instrumental factor.

$$\hat{\lambda} = \arg \min_{\lambda} \left(\frac{1}{N} \sum_{i=1}^N z_i (EQ_i - \alpha_0 + \alpha_1 EQ_{1i} + \alpha_2 DT_{2i} + \alpha_3 FD_{3i} + \alpha_4 EG_{4i} + \alpha_5 TD_{5i})' \right) \quad (14)$$

$$W \left(\frac{1}{N} \sum_{i=1}^N z_i (EQ_i - \alpha_0 + \alpha_1 EQ_{1i} + \alpha_2 DT_{2i} + \alpha_3 FD_{3i} + \alpha_4 EG_{4i} + \alpha_5 TD_{5i}) \right)$$

Fully Modified Ordinary Least Squares (FM-OLS) significantly measures the relation while incorporating endogeneity and serial correlation. It significantly validates the findings of 1-step GMM.

Results and Discussion

Descriptive analysis was formerly used to highlight potential problems, such as outliers and extreme skewness, which might significantly affect the estimate. Measures of central tendency, deviation from the mean, and data dispersion are all included in descriptive statistics. While skewness and kurtosis assess the data's dispersion, the mean, minimum, and maximum are indicators of central tendency. The mean values of each parameter are found to be within the specified minimum and maximum range in Table 2. By quantifying the variation from the mean, the standard deviation shows that every parameter is within the range of threshold values (± 2).

Table 2: Summary statistics

Parameters	Mean	Min	Max	SD	Skewness	Kurtosis
EQ	-0.382	-3.826	2.751	1.398	-0.226	2.228
GI	3.463	-2.813	4.597	1.235	-1.781	6.117
DT	1.237	-10.953	4.579	2.098	-1.168	4.092
FD	-1.942	-4.737	-0.210	0.698	-0.106	3.181
EG	1.454	-4.414	5.010	0.844	-1.277	7.850
TD	4.178	0.993	6.191	0.542	0.089	4.140

Using the Pearson correlation coefficient, we may determine the degree of association between two variables; the result can take on a value between -1 and 1. How these two series are linearly related, and how much even small changes in one affect the other. Coefficients may take on values between -1 (completely negative linear connection) and +1 (completely positive linear relationship), with 0 (no linear linkage) serving as the default. The results of the pairwise correlation analysis are documented in Table 3.

Table 3: Pairwise Correlation and Variance of Inflation Factors

Variables	(1)	(2)	(3)	(4)	(5)	(6)	VIF	1/VIF
(1) EQ	1.000							
(2) GI	-0.666* (0.000)	1.000					1.252	0.799
(3) DT	0.354* (0.000)	-0.388* (0.000)	1.000				1.167	0.857
(4) FD	0.515* (0.000)	-0.543* (0.000)	0.476* (0.000)	1.000			1.328	0.753
(5) EG	-0.015 (0.380)	0.015 (0.370)	-0.078* (0.000)	-0.004 (0.824)	1.000		1.019	0.981
(6) TD	0.031 (0.071)	-0.194* (0.000)	0.012 (0.474)	0.066* (0.000)	0.104* (0.000)	1.000	1.045	0.957
Mean VIF							1.162	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The information in Table 3 discloses that weak and moderate relation is prevailing among the predictors. However, EG showing strong affiliation with FD, which may lead towards multicollinearity. Therefore, to ensure the presence of multicollinearity, the study employed the Variance Inflation Factor (VIF) which is commonly used to detect the strong affiliation among the predictors. The VIF values indicate that there is no problem of multicollinearity because coefficient values of each parameter are within threshold value range (± 10).

It is worth noting that when dealing panel data set, we must ensure some characteristics before finalizing the suitable approach to measure the cointegration between predictor and dependent factor i.e., EQ. That's why study employ the slope heterogeneity tests (Feng et al., 2022) and (Xu et al., 2023), as reported in Table 4. Both tests declared that slope of coefficients are heterogeneous, indicating that slope is not consistent across the subgroup.

Serial correlation, also known as autocorrelation, refers to the relationship between a variable and its own past values in time series data - residuals from a regression model will be correlated over different periods; This type of dependency among violates the assumption of independence for linear regression specifies estimates are inefficient and standard errors unreliable, which affects hypothesis testing yet also the fortification of confidence intervals. The information in Table 4 unveils that serial correlation is prevailing among the datasets.

Heteroscedasticity refers to the situation when the variance of response errors in a regression analysis is different at different levels of independent variable values. The unequal spreading of these errors is contrary to one of the premises for linear regression errors, that are constant error variation. The information in Table 4 exposes that heteroscedasticity is also prevailing in the data. Furthermore, the explanatory variables are likely correlated with the error term, which violates an assumption of linear regression models, indicating the presence of endogeneity, as reported in Table 4.

Table 4: Pre-Diagnostic tests

	Slope homogeneity	Prob	Slope homogeneity(adj)	Prob
(Blomquist & Westerlund, 2013)	58.980	0.000	68.332	0.000
(Pesaran & Yamagata, 2008)	43.982	0.000	49.550	0.000
Wooldridge autocorrelation	F (1, 103)	46.131	Prob > F	0.000
Heteroskedasticity	chi2	58.79	Prob > chi2	0.000
Endogeneity	Durban-- chi2(1) 166.362	0.000	Wu-Hausman- F(1,3428) 174.634	0.000

So, it may conclude that slopes are heterogeneous, serial and heteroskedasticity are also prevailing. Further study employed the cross-sectional dependency (CSD), arises when residuals

or observations of units in panel data are correlated with each other, therefore violating the independence assumption. This dependence might come from the common shocks, spillover impacts or unobservable typical elements which would eventually make our estimations and inferences biased. The CSD are portrayed in Table 5.

Table 5: CSD

Variables	CD-test	P-value	Average joint T	Mean p	Mean abs(p)
EQ	117.989	0.000	33.00	0.28	0.53
GI	132.629	0.000	33.00	0.32	0.53
DT	390.461	0.000	33.00	0.93	0.93
FD	113.027	0.000	33.00	0.27	0.51
EG	58.385	0.000	33.00	0.14	0.22
TD	23.621	0.000	33.00	0.06	0.32

The CD-test statistics and p-values for all variables (EQ, GI, DT, FD, EG) in Table 5 show the presence of significant CSD, being equal to zero. This implies all variables indeed exhibit CSD. However, in the presence of CSD, second generation unit root such as CIPS and PSADF are more suitable to measure stationery. The outcomes of unit roots are portrayed in Table 6.

Table 6: Second Generation Unit Root test

Pictogram	Pesaran CIPS		Pesaran PSADF	
	@ level	@ diff	@ level	@ diff
EQ	-1.787	-4.989***	-1.970**	-3.725***
GI	-1.900	-5.169***	-1.871	-3.581***
DT	-0.583	-3.824***	-1.314	-2.604***
FD	-2.793***	-5.284***	-2.626***	-4.222***
EG	-4.127***	-6.061***	-3.298***	-5.424***
TD	-1.520	-4.471***	-1.330	-3.427***

The information in Table 6 exposes that FD and EG have unit root at level in the case of CIPS, while all parameters appeared as stationery at first difference denoting significance at 1% level. Whereas EQ, FD and EG have a unit root in case of PASADF while at first difference all factors appeared statistically stationery at 1% level of significance (B. Lin & Ma, 2022a).

However, for the long-term affiliation in the presence of CSD, Pedroni and Westerlund cointegration are employed. Table 7 discloses that all the parameters such as GI, DT, FD, EG and TD are cointegrated in the long run with EQ, indicating that these factors influence environmental quality of developing economies in the long run.(R. Wang et al., 2023)

Table 7: Cointegration test

Pedroni test for cointegration		
	Statistics	Prob-Value
Modified Phillips–Perron t	8.3952	0.0000
Phillips–Perron t	1.4422	0.0746
Augmented Dickey–Fuller t	1.9437	0.0260
Westerlund test for cointegration		
Variance ratio	2.3681	0.0089

System GMM (SYS-GMM) is an advanced econometric technique, that works the same as other estimator techniques but many suitable in dynamic panel data models where each unit subject to multiple observations over time. This was developed in the 1990s by Arellano, Blundell since they merged exactly this approach with bond's difference first and second procedures which most likely created confusion about who is borrowing from whom) extending Difference GMM because of the estimated efficiency gain due to using both differenced and level equations at once they help reduce bias. SYS-GMM is most suited to the treatment of endogeneity, unobservable heterogeneity and in dynamic models where the dependent variable depends on its earlier values (Wang et al., 2022). Estimation of the accommodates some additional steps, first specifying a dynamic panel model and then transforming it to handle fixed effects with endogeneity as well. Appropriate instruments—are usually lagged values of them & test variables—selected moment conditions between these instrumented are solved errors using GMM. The system generalized method of moments (SYS-GMM) significantly incorporated the serial, auto, hetero and endogeneity to capture a significant relation between the parameters and independent factor such as environmental quality. The outcomes of GMM are reported in Table 8.

Table 8: SYS-GMM

LNEQ	Coef.	St. Err.	t-value	p-value	[95% Conf Interval]	Sig
L	0.871	0.014	62.31	0.000	0.843 0.898	***
GI	-0.457	.0786	-7.01	0.000	-0.005 -0.003	***
DT	0.024	.0042	-2.41	0.016	-0.001 0.000	**
FD	0.795	.1384	-1.77	0.077	-0.052 0.003	*
EG	-0.028	.0123	13.38	0.000	0.004 0.006	***
TD	0.508	.1580	4.70	0.000	0.001 0.002	***
Mean dependent var			-0.356	SD dependent var		1.398
Number of obs			3177	Chi-square		11199.868

*** $p < .01$, ** $p < .05$, * $p < .1$

The information in Table 8 discloses that GI, DT, FD, EG and TD are significantly influencing the environmental quality. The findings disclose that GI are negatively integrated with environmental quality, indicating that emerging economies are adopting and installing green initiatives to mitigate the carbon emission but their adoption is below the potential level.

(Rahimirad & Sadabadi, 2023) reported that in developing economies adoption ratio is below the potential level, and there is very low, or zero incentive are provided to switch from fossil fuel energy to renewable energy. That’s why the findings of the current study illustrate a negative affiliation of green initiatives with environmental quality.

While digital technology improves our environment such as advanced sensors and IoT devices for real-time environmental monitoring, satellite imagery can be used to track changes like deforestation or urban expansion. The energy efficacy is optimized and more effectively managed with Smart grids, building; resources are used efficiently saved utilizing new agricultural technologies like precision agriculture solutions or water management. Transport-Electric vehicles and intelligent traffic systems to cut emissions. Efficient recycling with the help of AI and robotics, platforms that promote circular economy: for waste management. Carbon footprints are also monitored, and sustainable energy sources connected to through Eco literacy tools (Feng et al., 2022). The findings disclose that digitalization is assisting developing economies to improve environmental quality.

Fully modified ordinary least squares (FMOLS) is used to examine long run association in integrated in data- series and deal with endogeneity problem as well as serial correlation. Regarding the relationships between variables during short-term estimation, FMOLS can serve as a robustness check such that any spurious correlations analyzed in this way are confirmed to be valid long-run associations. The result of FMOLS is reported in Table 9, to validate the findings of SYS-GMM.

Table 9: Robust Analysis

EQ	Coeff	Std. errs.	Z	P>z	[95% conf	Interval]
GI	-0.458	0.079	-5.820	0.000	-0.612	-0.304
DT	0.024	0.004	5.730	0.000	0.016	0.033
FD	0.796	0.138	5.750	0.000	0.525	1.067
EG	-0.029	0.012	-2.330	0.020	-0.053	-0.005
TD	0.508	0.158	3.220	0.001	0.199	0.818

The information in Table 9 declares the findings of SYS-GMM, because SYS-GMM finds out a negative affiliation of GI and EG with environmental quality, as reported in Table 8.

Conclusion and Implications

The research relied on sustainable efforts, technological advancements, financial progress, economic growth, and trade liberalization to measure the state of the environment in developing countries. The outcome is that the IMF and the World Development Indicators (WDI) provide a panel dataset of developing countries. According to the first diagnostics, the following models are ready for empirical testing: Westerlund, SYS-GMM, and FMOLS.

In emerging countries, environmental quality is greatly impacted by all aspects, as shown by the SYS-GMM. The data shows that the green initiative has a major impact on ecological balance. Digital technology may help develop sustainable solutions to reduce carbon emissions and enhance environmental quality. On the other hand, more access to finance, better use of resources, and more investment in environmentally friendly endeavors are all results of a flourishing financial sector.

Carbon emissions in emerging markets have been falling sharply as a result of rising investment in environmentally friendly projects. It is also the responsibility of governments in developing countries to ease the transition away from fossil fuels and toward renewable energy for households and businesses. The economy, the environment, smart grid technology, investment in renewable energy, and climate resilience will all see improvements as a result of this shift. The Sustainable Development Goals (SDGs) and the outcomes of COP 28 should guide national policymaking. It is imperative that the government raises public awareness, establishes a strong financial framework to encourage the use of environmentally friendly technology, and provides incentives for countries to engage in green energy initiatives and research.

In order to improve environmental quality, digital technology is essential since it is now reshaping the world in significant ways. Digital technologies are being embraced and used by emerging and developing nations in an effort to attain both economic success and environmental sustainability. The expansion of digitization has led to an increase in transparency and efficiency in the use of resources. In an effort to lower carbon emissions, policymakers are seeking to link digitalization—which includes smart grid and carbon storage technology—with improved environmental quality. Promoting understanding of digital technology usage for both domestic and business purposes is also important for advancing digitalization. Digital technology is expanding in Indian and Chinese households and businesses, leading to better resource allocation, transparency, and efficiency.

On the flip side, financial development encourages cooperation among countries to strengthen the financial sector, connects local and international markets, and increases access to finance. To improve the environment, we need more green investment and stronger climate action, both of which are encouraged by increased economic development. Green businesses, renewable energy, and biofuels could get a boost from changes made to the banking system by the legislative body. In line with global environmental objectives, these mitigation strategies increase economic growth and resilience to combat environmental deterioration. Green finance, stronger laws, the introduction of CSR programs, and climate engagement activities are all ways to bolster financial growth, which is crucial for bettering environmental quality. Sustainable efforts, such as investments in renewable energy growth and soil conservation, may be made possible via well-regulated financial institutions in developing nations. This might be a powerful weapon for global environmental stewardship. Adhering to worldwide environmental standards,

these solutions promote economic development and resilience while simultaneously reducing environmental degradation. As a result, sustainable growth is made possible values.

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