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Advancing Environmental Sustainability in D-8 Economies: A Comprehensive Analysis of the Efficacy of Natural Resource Utilization and Green Energy Technologies towards Sustainable Development Goals

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The escalating global environmental challenges have brought the effectiveness of environmental regulations into sharp focus. Responding to this urgency, various international initiatives such as the Kyoto Protocol, the Paris Agreement, and the Sustainable Development Goals (SDGs) have been introduced to combat environmental degradation. This study meticulously examines the pivotal environmental factors influencing the sustainability of D-8 economies spanning from 1984 to 2021, encompassing natural resources, green technology, financial development, institutional quality, and corruption. Utilizing advanced estimation techniques, the study delves into these objectives with precision. The findings underscore the positive impact of natural resources and green technology on environmental quality. However, financial development, the rule of law, and corruption are identified as significant contributors to environmental degradation within D-8 economies. Furthermore, a cross-country analysis is conducted for selected economies, enriching the study's scope and depth. Ultimately, this research provides crucial insights and policy implications for realizing a cleaner and greener future by 2030 in alignment with the SDGs. Highlights of the study include a unique examination of D-8 economies within the framework of the SDG targets, the identification of natural resources and green energy as eco-friendly indicators, the acknowledgment of the detrimental effects of financial development, institutional quality, and corruption on environmental quality, and the provision of policy recommendations based on empirical outcomes.
Keywords: Ecological footprint, green energy technology, institutional quality, SDGs. Environmental regulations, sustainability, Natural resources, financial development.

INTRODUCTION

In recent years, there has been increasing global attention on the degradation of the environment and the need for sustainable solutions. Researchers have conducted extensive studies to understand the relationships between economic growth and environmental stress. They have also explored the influence of social factors such as population growth and urbanization on the environment. However, despite numerous efforts, finding effective solutions to environmental problems remains a challenge, highlighting the need for proper channels and solutions within the framework of the Sustainable Development Goals (SDGs). Additionally, the financial sector, while facilitating human beings through lower-interest loans, indirectly contributes to carbon emissions through increased purchasing power and energy-intensive business activities. Ensuring access to financial services and improving institutional quality are key factors in achieving sustainability goals and addressing environmental stress.

The role of the rule of law and corruption in environmental studies has been a subject of critical debate. It is widely recognized that unbiased and robust institutions play a crucial role in effectively managing environmental degradation through the implementation of strict environmental laws. A

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strong economy with zero corruption is more likely to adhere to environmental standards, and stringent regulations can aid in their enforcement. Without adequate regulations, the production and consumption sector can contribute significantly to pollution. Developing economies with fewer regulations not only impact the environment domestically but also have spillover effects on neighboring economies. The institutional factors of corruption and the rule of law are considered key environmental factors that can contribute to environmental degradation in the long run. These factors are directly linked to the Sustainable Development Goals (SDGs), specifically Goal 16 and its targets 16.3 and 16.5.

Additionally, addressing the environmental challenges faced by D-8 economies requires not only identifying the problems but also offering viable solutions. This study focuses on the efficient allocation of natural resources to promote sustainable growth. While nations rely on their natural resources to generate revenue for development, the utilization of these resources can have both positive and negative impacts on sustainability. Some countries prioritize protecting the environment by investing revenue in efficient ways, while others prioritize rapid progress at the expense of environmental deterioration. The study considers this issue as a solution to mitigate environmental degradation within the framework of the SDGs. This eco-factor is also aligned with SDG 1, specifically target 12.2, which aims to ensure the sustainable utilization of natural resources at the domestic level. Furthermore, renewable energy has become increasingly crucial in safeguarding the environment for present and future generations. Policymakers have recognized the significance of green energy in achieving sustainability, making it a viable solution for a greener environment. The research highlights green energy as a secondary alternative to address environmental harm, aligning with Goal 7 and its target 7.2 of affordable and accessible green energy. In conclusion, the efficient utilization of natural resources and the adoption of green energy technologies offer promising solutions to mitigate environmental harm.

The selection of D-8 economies as the focus of this study raises the question of its significance. However, there are several reasons behind this choice. Firstly, these economies possess significant growth potential but often face inefficiencies in their governance systems, allowing corrupt practices to persist. Consequently, they are unable to fully capitalize on potential growth opportunities, hindered by corruption and illegal economic activities that impede the implementation of environmental protection laws and the adoption of green technology initiatives. Surprisingly, previous research has largely overlooked the examination of these crucial factors, namely corruption and green technology, in the context of sustainability within the framework of the SDGs, specifically within the D-8 economies (as shown in Table 1). Therefore, recognizing this research gap, this study aims to empirically assess the effects of corruption on ecological footprint (ED) from 1984 to 2017. Additionally, the study investigates the impact of green technology on renewable energy intensity with regard to ED. Furthermore, the study recognizes the significant role of institutional quality (IQ) in environmental quality, as it not only affects a country's own environment but also transcends borders through spatial institutional spillovers. A weak institutional system poses another obstacle to efficiently utilizing technological innovations and reaping the benefits of green growth. Thus, by addressing the debates raised in previous studies, this research contributes to the literature by incorporating modern aspects of ED, including corruption, institutional quality, natural resources, financial development, and green technology. In essence, this study presents four major contributions to the existing literature. Firstly, the relationship between financial development and environmental degradation is investigated for the D-8 countries. Secondly, natural resource abundance and clean technology are included as determinants of environmental degradation. Thirdly, we analyzed the role of institutional quality in environmental degradation. Lastly, we also incorporated corruption, which may cause to influence the environmental quality in the selected panel. This study has adopted advanced econometric techniques to obtain robust outcomes: cross-sectional dependency test (CDs), the slope of homogeneity test, and second-generation panel unit root tests (CADF & CIPS). Furthermore, the Westerlund co-integration test has been employed to find long-term co-integration among selected variables. Cross-Sectional-ARDL has been employed on behalf of co-integration to obtain robust outcomes; in the last D-H panel, causality has been used to find the causal association among selected variables.

LITERATURE REVIEW

This study provides an overview of past studies that have made efforts to deal with specified environmental factors across the different regions. More interestingly, this study divided past empirical studies into two phases; firstly, it describes the attention researchers gave to D-8 economies. Moreover, the second phase provides a review of Table 1 that further divides into four sub-sections, i.e., i) environment degradation (ED) and FD, ii) environment degradation (ED) and natural resources (NRs), iii) environment degradation (ED) and institutional quality (IQ), iv) environment degradation (ED) and corruption (CR).

In the first phase, this section briefly summarizes the selected economies and different arguments regarding variable associations. For example, Shah *et al.* (2020) reviewed the relationship between RE, IQ, and economic growth for D-8 economies and concluded that IQ enhances GDP and sustainability. Dwumfour and Ntow-Gyamfi, 2018 Investigated the linkages between NRs, FD, and IQ for Africa. Shahbaz *et al.* (2018) revealed the long-run association among FD, institutions, and government stability for India and China. Ojeka *et al.* (2019) investigated the long-run relationship between CR perceptions, IQ, and the Nigerian economy's preference for listed companies. Zallé (2019) elaborated the association of NR with economic growth in the light of IQ. Das and Mahalik, 2020 have discussed the Indian economy by investigating the association of international subsidy with IQ, corruption, and investment regime.

Table 1. A Brief Survey of Past Studies.

Author	Country	Method	Findings
Environmental degradation and FD			
(Dagar *et al.*, 2022)	OECD	GMM Series	RE, NRs decline emissions, while FD increases emissions
(Saud *et al.*, 2020)	BRI Economies	PMG	FD found supportive instruments for three different proxies of ED. Moreover, there was a feedback hypothesis between FD & ED.
(Pata and Yilanci, 2020)	G-7 economies	MTAR model	FD has made a significant contribution to EQ in Japan.
(Godil *et al.*, 2020)	Turkey	Q-ARDL	FD is found to be a supportive instrument for ED.
(Khan *et al.*, 2022)	Canada	D-ARDL	FD, EI, REP, and NRs increase environmental degradation.
(Naqvi *et al.*, 2023)	14 Asia Pacific economies	D-KSE	FD increase the level of emissions.
(Durani *et al.*, 2023)	BRICST	P-QR	FD increase emissions
Environmental degradation and Natural Resources			
(Zameer *et al.*, 2020)	China	Entropy Weight method	The utilization of NRs is very high in the eastern region while low in the western region.
(Li *et al.*, 2019)	China	Panel threshold model, STIRPAT model	Environmental degradation can be reduced, depending on the country's resources.
(Zafar *et al.*, 2019)	USA	ARDL	NRs have found eco-friendly indicators in the USA. Also, EC ↔ EF and GDP ↔ EF, NR → EF.
(Shen *et al.*, 2021)	China	AMG & CCE-MG	NRs are harmful to environmental quality.
(Kongbuamai *et al.*, 2020)	ASEAN economies	D-KSE	NRs have a negative relation with ED.
(Kwakwa *et al.*, 2020)	Ghana	ARDL, STRIPAT model	NRs have seen eco-friendly indicators.
(Nathaniel *et al.*, 2021)	BRICS Economies	FMOLS	NRs cause an increase in the level of environmental damage.
(Naqvi *et al.*, 2023)	14 Asia Pacific economies	D-KSE	NRs increase the level of emissions.
(Durani *et al.*, 2023)	BRICST	PQR	NRs decrease emissions
(Ulucak and Khan, 2020)	BRICS	FMOLS	NRs reducing ED.
Environmental Degradation and institutional quality			
(Mehmood, 2022)	G11 Nations	CS-ARDL	IQ improves ED
(Anwar *et al.*, 2023)	E-7 Countries	FGLS	IQ reduce ED
(Wei *et al.*, 2022)	Emerging 7 countries	PQR	IQ improves ED
(Akbar *et al.*, 2022)	BRI countries	PQR-FE	IQ increase ED
(Warsame *et al.*, 2022)	Somalia	ARDL, FMOLS	IQ reduce ED
(Salman *et al.*, 2019)	Indonesia, South Korea and Thailand	FMOLS	A significant contribution towards the environment quality by IQ. Likewise, IQ granger causes environmental quality.
(Hussain and Dogan, 2021)	BRICS	CS-ARDL	IQ decreases emissions
(Le and Ozturk, 2020)	47 emerging and developing economies	CCE-MG, AMG, D-CCE	Institutional quality has been the main contributor to environmental damage.
Environmental Degradation and Corruption			
(Akhbari and Nejati, 2019)	Developing and Developed economies	N/A	They found the insignificant impact of corruption on ED.
(Sinha *et al.*, 2019)	BRICS & Next 1 countries	LSDV, Cup-Fm, Bai-FM and Cup-BC	The negative influence of corruption on environment quality.
(Wang *et al.*, 2020)	China	OLS, FE, and GMM	Corruption harms ecological conditions.
(Yang *et al.*, 2020)	30 provinces of China	Spatial Durbin Model	Corruption increases the level of environmental pollution.
(Haseeb and Azam, 2020)	Lower and Higher income countries	FMOLS	Likewise, corruption also contributed to ED.
(Sulemana and Kpienbaareh, 2020)	OECD Countries	OLS & 2SLS	Corruption is negatively related to environmental quality.
(Kumar *et al.*, 2021)	33 Developing economies	Dynamic GMM	Corruption increases environmental stress
(Usman *et al.*, 2022)	African Economies	Q-GMM	Corruption increases emissions
(Asif *et al.*, 2023)	South Asia	P-ARDL	Corruption & Political Instability increase emissions

Q-GMM: Quantile Generalized Method of Moments, OLS: Ordinary Least Squares, GMM: Generalized Method of Moments, ARDL: Autoregressive Distributive Lag Model, FE: Fixed-Effect, FMOLS: Fully Modified Ordinary Least Squares, FE-IV: Fixed effects-instrumental variables, CUP-FM: Continuously Updated Fully Modified method, CUP-BC: Continuously Updated Bias-Corrected, PQR: Panel Quantile Regression, PCA: Principal Component Analysis, D-KSE: Driscoll and Kraay standard errors, 2SLS: Two-Stage least squares, ED: Environmental Degradation, IQ: Institutional Quality, Later on, Shoaib *et al.* (2020) investigated the crucial role of financial development in environmental sustainability over the period of 1993-2013. They employed the Principal Component Analysis to create a composite financial index and found the positive connection with rising emissions in the D-8 economies.

Shortly, many studies have overlooked differences in the patterns and growth level changes while ignoring some essential and modern aspects of ED to study in selected economies. Especially in D-8 economies, this study responding to this deficiency empirically explores the long-run association between the mentioned variables.

However, by having a perfect summary of past studies, this study is differentiated in the following ways. Firstly, the past studies voluntarily ignored the key importance of D-8 economies in the existing literature. Therefore, the present study focuses on the D-8 economies, particularly considering the most environmentally influential factors. Moreover, in the existing literature, numerous studies have described the importance of the importance of financial, institutional and natural resources in environmental sustainability. However, the existing literature has not focused on specified factors to check out their response in D-8 economies; thus, the present study tries to reduce such ambiguity. Likewise, the current study directly derives the study variables from the Sustainable Development Goals, an emerging trend that forthcoming studies may follow to bring more clarity to their research theme.

Model Construction and Theoretical Background

***Data Collection*:** This empirical study introduces the key factors of environmental degradation (ecological footprint) for the D-8 economies over the annual period of 1984-2021. However, these determinants are natural resource consumption, green technology, financial development, institutional quality, and corruption. However, the countries' selection has been made based on the mentioned characteristics and data availability. Similarly, the panel group of D-8 economies comprises Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan, and Turkey. This study uses the ecological footprint (EF) as a proxy that represents the environmental degradation in these economies. Furthermore, the natural resources and financial development data have been taken from World Bank open data. The data on the rule of law and corruption is extracted from the International Country Guide Risk (ICRG). In the same context, the data on green technology is retrieved from the Knoema data bank, while the author's calculation calculates it as following previous studies (Hao *et al.*, 2020) and (Xin and Zhang, 2020). Similarly, the data description is given in the Table 2.

***Conceptual Framework and Model Specification*:** The countries considered in this study are characterized in terms of high levels of corruption and moderate institutional quality. Adopting green technology and this growing tendency to corruption is vastly correlated with illegal activities, ultimately increasing environmental damage in D-8 economies. Moreover, lower adoption of green technology, lower institutional performance, and a high corruption rate enhance environmental degradation due to economic activities. Thus, well-organized and local institutions are essential to control the adverse environmental situation (Lau *et al.*, 2014).

However, this study's variable selection is strange in selecting environmental determinants, while past studies have focused on the EKC hypothesis by ignoring the kinds of environmental indicators together. In addition, to fill this gap, we have developed an exciting and robust model to estimate an unseen behavior of the following indicators on ecological footprint.

$$EF_{i,t} = f(\beta_0, NRs^{\beta_1}, GT^{\beta_2}, FD^{\beta_3}, RL^{\beta_4}, CR^{\beta_5}, \varepsilon^{\mu_{i,t}}) \quad \ldots\ldots\ldots (1)$$

The given model implies that environmental deprivation is the function of natural assets, green technology, financial development, institutional quality, and corruption. Similarly, this model can be transformed into a log-log model.

$$lnEF_{i,t} = \beta_0 + \beta_1\ lnNRs_{i,t} + \beta_2\ lnGT_{i,t} + \beta_3\ lnFD_{i,t} + \beta_4\ lnRL_{i,t} + \beta_5\ lnCR_{i,t} + \mu_{i,t} \ldots\ldots (2)$$

Similarly, by following (Hao *et al.*, 2020) and (Xin and Zhang, 2020), we incorporated the green technology variable among other innovative indicators of ED to validate the assumption that effective and impartial selected indicators may or may not help simultaneously improve the environment quality. Furthermore, we add the financial progress and natural resources variable that captures the impact of selected economies' environment quality. Where i and t indicate country and time dimension individually. EF shows the ecological footprint, NRs represent natural resources, GT represents green technology, FD denotes financial development, IQ resents institutional quality, and BR represents corruption. This study utilizes two different measures of institutional quality: (i) the rule of law, and (ii) corruption for the selected economies. However, RL is based on two different components such as "Law and Order" (Lau *et al.*, 2014). Simply put, Law refers to the efficacy and objectivity of institutions in legislation. Finally, order refers to the strength of law and its implementation to deal with populace issues at the domestic level.

To comprehensively understand the impact of human activities on the environment, it is important to consider multiple dimensions of degradation. Previous studies emphasize the need to examine the overall human influence. However, most research has primarily used emissions as a proxy for environmental degradation (ED), which only captures a fraction of the concept. This study incorporates the ecological footprint (EFP) as an additional indicator, introduced by which provides a comprehensive measure of the environment, including factors like forestland, carbon

Table 2. Description of Variables

Variable	Symbol	Unit of measurement	Source
Ecological footprint	EF	GHA per person	Knoema
Total natural resource rents	NR	As % of GDP	WDI
Green Technology	GT	Renewable energy as % of total energy / GDP	WDI
Financial development	FD	Domestic Credit to private sector as % of GDP	WDI
Law and order	RL	Index	ICRG
corruption	CR	Index	ICRG

footprint, and built-up land. Previous studies, as summarized in Table 1, have employed various quantitative methods to explore the relationship between development and EFP, investigating associations with natural resource rents, green technology, financial development, law and order, and corruption in relation to emissions and EFP as dependent variable.

***Estimation strategy*:** Because the study used countries in close economic cooperation, we first conducted the cross-sectional dependency tests. For this concern, we have used three CD tests developed by (Pesaran, 2004; Friedman, 1937; Frees, 1995). Similarly, this study uses the advanced series of data integration tests that can deal with CSD problems, and these are Covariate-Augmented Dickey-Fuller (CADF) and cross-sectionally augmented IPS (CIPS) proposed by (Pesaran, 2007). According to the data integration properties, this study utilizes the advanced co-integration test (Westerlund, 2007), and its general form can be expressed as,

$$\Delta Y_{it} = \delta'_i d_t + \eta_i\left(Y_{i,t-1} - \beta'_i x_{i,t-1}\right) + \sum_{j=1}^{p_i} \eta_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + \mu_{it} \ldots\ldots (3)$$

However, under the specified characteristics of study data integration tests, this study performs the advanced form of the Pooled Mean Group (PMG), which is known as the cross-sectionally Augmented Autoregressive Distributive Lag (CS-ARDL) (Chudik and Pesaran, 2015). However, this estimator can perform well without pre-testing of the data integration properties. Therefore, it is compulsory to have valid co-integration amid the selected variables. However, the mathematical notation can explain well the entire features of this estimator, as given below,

$$y_{i,t} = \phi_i + \sum_{l=1}^{p} \varphi_{il} y_{i,t-l} + \sum_{l=0}^{q} \varpi_{il} \bar{X}_{i,t-l} + \varepsilon_{i,t} \ldots\ldots (4)$$

More interestingly, this study utilizes the D-H panel causality test to investigate the causal association among the selected variables proposed by (Dumitrescu and Hurlin, 2012).

RESULTS

Descriptive statistics analysis was conducted to gain insights into the data characteristics, as presented in Table 3. Furthermore, there is no substantial difference stuck between the mean and median values of the selected variables.

Table 4 represents the correlation outcomes, revealing the associations between variables. However, under the obtained results, not even a single variable has a correlation value more than 0.80%. Thus, there is no chance for multicollinearity in the selected panel. Additionally, a VIF test was conducted to detect multicollinearity, and the outcomes are provided in Appendix A.

Table 4. Results of Pairwise Correlations.

	LNEF	LNNR	LNGT	LNFD	LNIQ	LNCRP
LNEF	1.000					
LNNR	0.288*	1.000				
LNGT	-0.612*	-0.266*	1.000			
LNFD	0.578*	0.070	-0.577*	1.000		
LNIQ	0.653*	0.120***	-0.603*	0.359*	1.000	
LNCRP	0.360*	-0.078	-0.329*	0.338*	0.398*	1.000

Table 5 describes the outcomes of CSDs and the slope of homogeneity tests. Similarly, the outcomes regarding the CSDs and slope of homogeneity strongly support the prior expectations of the study.

Table 5. CD and Homogeneity Tests.

Table 3. Results of Descriptive Statistics

	LEF	LNR	LGT	LFD	LIQ	LCRP
Mean	0.460524	1.424009	-23.00312	3.364817	1.09510	0.74789
Median	0.408827	1.938165	-22.71705	3.251217	1.09861	0.69314
Maximum	1.528397	3.550478	-19.58838	5.065789	1.60944	1.38629
Minimum	-0.766321	2.093879	-27.18629	1.600906	0.00000	2.48490
Std. Dev.	0.614092	1.492165	1.83410	0.750925	0.36190	0.43053
Skewness	0.066670	0.515732	0.31420	0.290249	1.06020	2.19624
Kurtosis	1.954138	1.923627	2.40614	2.724728	4.02788	16.55022
Jarque-Bera	10.745540	21.484130	7.22645	3.989942	53.67543	1961.38900
Probability	0.004641	0.000022	0.02696	0.000602	0.00000	0.00000

	Value		P-value
Pearson (CD)	-4.453*		0.003
Frees (Q)	1.758		0.147
Friedman (CD)	20.566*		0.004
	Delta	**adj.**	
Statistics (P- value)	12.125 (0.000)	13.679 (0.000)	
Dependent Variable	**LM**	**LM adj***	**LM CD***
Statistics (P-value)	45.67 (0.018)	4.09 (0.000)	1.555 (0.120)

Table 6 describes the outcomes of the CADF & CIPS data integration tests. In summary, the magnitudes of both the CADF and CIPS tests confirm the rejection of the null hypothesis of non-3stationarity, indicating that the selected variables in the panel exhibit stationary behavior to a certain extent.

Table 6. CADF & CIPS Unit Root Tests.

Tests	**CIPS**		**CADF**	
Variables	**At I(0)**	**At I(1)**	**At I(0)**	**At I(1)**
LEF	-----	-5.511***	-----	-3.491***
LNR	-----	-5.049***	-----	-3.808***
LGT	-2.382**	-----	-2.357**	-----
LFD	-----	-4.333***	-2.527**	-2.953***
LIQ	-2.870***	-----	-2.694***	-----
LCR	-2.869***	-----	-2.357**	-----

"Note***represents 1% level of significance, and **represents 5% level of significance."

Similarly, Table 7 shows the long-term co-integration results for the selected panel, and it negates the null hypothesis for no co-integration among the variables.

Table 7. Westerlund Cointegration Test

Statistics	**Value**	**Z-value**	**P-value**	**Robust P-value**
Gt	-7.994	-4.000	0.000	0.000
Ga	-1.847	4.505	1.000	0.840
Pt	-5.616	1.014	0.978	0.005
Pa	-1.303	3.398	1.000	0.790

In Table 8, the cross-sectional dependence and country-specific heterogeneity of the D-8 economies were tested. The results of the CS-ARDL estimation are presented in the table. Regarding the impact of natural resources (NR) on environmental degradation (ED), it was found that an increase in NR would lead to an increase in ED in Bangladesh, Egypt, and Pakistan. However, it would cause a reduction in ED in Malaysia, Iran, and Turkey. Specifically, a 1% rise in NR would result in a 0.07% increase in ED for Bangladesh, a 0.114% increase for Egypt, and a 0.112% increase for Pakistan. Conversely, it would lead to a 0.023% decrease in ED for Malaysia, a 0.148% decrease for Iran, and a 0.085% decrease for Turkey. No significant impact of NR on ED was found in the case of Nigeria and Indonesia.

Regarding the influence of green technology (GT) on environmental damages, it was observed that GT has a positive effect on ED in Bangladesh, Malaysia, Iran, Nigeria, and Pakistan. However, it has a negative impact on ED in Egypt, Indonesia, and Turkey. A 1% increase in GT would result in a 0.143% increase in ED for Bangladesh, a 0.080% increase for Malaysia, a 0.085% increase for Iran, a 0.036% increase for Nigeria, and a 0.115% increase for Pakistan. On the other hand, it would lead to a 0.197% decrease in ED for Egypt, a 0.037% decrease for Indonesia, and a 0.093% decrease for Turkey.

Regarding the variable of financial development (FD), a 1% increase in FD would cause a 0.327% increase in ED for Egypt, a 0.204% increase for Indonesia, a 0.214% increase for Iran, and a 0.071% increase for Nigeria. Conversely, a 1% rise in FD would result in a 0.208% decrease in ED for Malaysia and a 0.098% decrease for Pakistan.

Similarly, for the variable of institutional quality (IQ), an increase in IQ would lead to an increase in ED for Bangladesh, Iran, Nigeria, and Pakistan. On the other hand, a 1% rise in IQ would result in a 0.036% decrease in ED for Indonesia and a 0.257% decrease for Turkey.

Finally, in terms of corruption, higher corruption levels would lead to an increase in ecological footprint (ED) in Bangladesh, Egypt, Indonesia, Nigeria, and Pakistan. Conversely, increased corruption would result in a decrease in ED for Malaysia, Iran, and Turkey.

***Long and Short Run Results of CS-ARDL Estimator*:** Table 9 provides the outcomes of the CS-ARDL estimate for the panel, indicating significant long-run coefficients for all analyzed indicators of environmental degradation at 1% and 5% levels of significance. The long-run coefficient's estimated parameters are displayed in Table 9.

Regarding the indicators of environmental degradation, natural resource rents are considered a determinant of the explained variable. The estimated coefficient of NR shows an adverse association with the green footprint. This means that a 1% growth in NR would lead to a 0.985% decrease in environmental damages, according to the CS-ARDL specification at a 1% significance level. Concerning another factor influencing the ecological footprint, we consider a variable called green technology. The estimated coefficient value of green technology reveals an adverse relationship with environmental damage. This suggests that a decrease in ED of 0.052% can be observed with a 1% increase in this factor. In a similar vein, institutional quality is considered another factor influencing environmental degradation. Based on the coefficient value of 0.013, it shows a positive correlation with the explained variable. This suggests that a 1% enhancement in institutional quality would result in a 0.013% rise in environmental degradation within the chosen economies. Lastly, an exciting variable, corruption, is utilized

Table 8. Cross-Country Analysis of D-8 Economics

Country	LNR	LGT	LFD	LIQ	LCR
Bangladesh	0.0742 (0.004)	0.1439 (0.024)	-0.1221 (0.297)	0.0854 (0.027)	0.0704 (0.001)
Egypt	0.1142 (0.006)	-0.1970 (0.005)	0.3272 (0.008)	-0.0428 (0.760)	0.1861 (0.051)
Malaysia	-0.1958 (0.000)	0.0801 (0.091)	-0.2082 (0.062)	0.1003 (0.476)	-0.6608 (0.000)
Indonesia	- 0.0233 (0.305)	-0.0371 (0.052)	0.2044 (0.025)	-0.0362 (0.002)	0.0735 (0.025)
Iran	-0.1486 (0.001)	0.0852 (0.008)	0.2149 (0.022)	0.2361 (0.007)	-0.1408 (0.015)
Nigeria	-0.0113 (0.714)	0.0361 (0.041)	0.0711 (0.002)	0.1397 (0.003)	0.3533 (0.002)
Pakistan	0.1128 (0.000)	0.1155 (0.000)	-0.0988 (0.098)	0.0722 (0.009)	0.9603 (0.000)
Turkey	-0.0854 (0.032)	-0.0931 (0.002)	0.0657 (0.567)	-0.2571 (0.004)	-0.1462 (0.020)

as the determinant of the ecological footprint. In light of the obtained findings, it can be observed that there exists a direct correlation between corruption and the degradation of the environment. It can be implied that an increase in corruption by 1% leads to a 0.027% rise in environmental damages, assuming all other factors remain constant. Our results show that the coefficient of financial development in relation to environmental degradation is positive and significant at a 5% level of significance. This suggests that a 1% increase in this factor would result in a 0.027% increase in ED in D-8 economies.

These short-run estimated coefficients provide insights into the relationships between different factors and environmental degradation. The results indicate that green technology has a substantial adverse association with EF, while institutional excellence and corruption exhibit positive associations with environmental damages (ED). Additionally, a 1% rise in natural resources corresponds to a 0.014% increase in environmental degradation, whereas a 1% increase in financial development would result in a 0.026% decrease in ED. The error correction term's coefficient (-0.238) suggests a 23.8% adjustment towards equilibrium following a temporary shock to the long-run relationship between these variables.

Table 9. Short Run & Long Run Results of CS-ARDL Estimator.

Variables	Coefficient.	St. Error.	Z	Sig.
		Long Run Results		
LNR	-0.9853	0.0140	-70.28	0.000
LGT	-0.0528	0.0309	-1.71	0.007
LFD	0.0279	0.0157	1.78	0.035
LIQ	0.0130	0.0353	0.37	0.003
LCRP	0.0273	0.0146	1.86	0.053
Short Run Results				
LNNR	0.0146	0.0140	1.04	0.007
LNGT	-0.0528	0.0310	-1.70	0.000
LNFD	-0.0266	0.0156	-1.70	0.089
LNIQ	0.0130	0.0352	0.37	0.001
LNCRP	0.0275	0.0146	1.88	0.060
ECM (-1)	-0.2380	0.0876	-2.72	0.007
		Stability Results		
R^2 = 0.68	CD Statistic = 1.90		R^2 (MG) = 0.93	

The pairwise D-H test examines heterogeneity in panel data and represents an enhanced version of the Granger non-causality test introduced by Dumitrescu and Hurlin (2012). This method employs W-bar and Z-bar statistics to analyze the data. The outcomes of the D-H causality test are shown in Table 10. It is observed that there is bidirectional causality between green technology and the ecological footprint, thus confirming the feedback hypothesis. The issue of environmental degradation in D-8 economies leads to a growth in the share of green technology in terms of renewable energy intensity. However, inefficient usage reduces the bio-capacity of the environment, further contributing to the rise in environmental deprivation. Nevertheless, integrating maintainable and managing options into production and consumption can alleviate environmental degradation and allow green technology to flourish.

There is also bidirectional causality between environmental degradation and financial development. This implies that changes in financial development can impact environmental quality and vice versa. This result proves that financial development contributes to environmental degradation in D-8 economies. The increased environmental degradation caused by financial development in these economies is unsurprising, as they rely heavily on non-renewable energies in their production and consumption processes. The financial sector consumes significant energy from fossil fuels to support its economic activities. Additionally, financial institutions may provide more loans for projects that harm the environment. Outdated technology in the financial sector can also contribute to environmental degradation. This finding aligns with the findings of Zafar *et al.* (2019).

Likewise, a feedback hypothesis is observed between green technology and institutional quality. This implies that fluctuations in institutional quality can influence human behavior to maximize the usage of green technology through the introduction of eco-friendly policies and tax structures. In simple terms, policies related to institutional quality and green technology work together. Furthermore, a two-way causality is found between green technology and corruption. It suggests that in the context of green technology, there is a growing trend of corruption in D-8 economies. Financial development also exhibits a feedback hypothesis with institutional quality, indicating that institutions support financial development to provide loans for developing countries. Additionally, a two-way causal association is found between financial development and corruption, as well as between institutional quality and corruption.

A one-way causal relationship is observed regarding the relationship among institutional quality and ecological footprint (ED). It suggests that institutions do not prioritize minimizing environmental damage. Similarly, a one-way causal relationship exists among green technology and financial growth. Furthermore, empirical evidence contradicts the neutrality hypothesis, which states that specific indicators do not affect each other. Specifically, there is an impact from green technology to natural resources, natural resources to financial growth, institutional quality, and corruption. A graphical representation of these relationships can be found in Appendix B.

Table 10. Results of D-H Panel Causality.

Variable	W-bar	Z-bar	P-value
LEF >> LNR	1.5287	1.0575	0.290
LNR >> LEF	0.5411	-0.9170	0.358
LEF >> LGT	3.3816	4.7632	0.000
LGT >> LEF	3.6337	5.2675	0.000
LEF >> LFD	2.9305	3.8610	0.000
LFD >> LEF	4.2294	6.4588	0.000
LEF >> LIQ	7.3873	12.7746	0.000
LIQ >> LEF	1.4593	0.9187	0.358
LEF >> LCR	1.6257	1.2513	0.201
LCR >> LEF	5.5391	9.0783	0.000
LNR >> LGT	1.3832	0.7665	0.443
LGT >> LNR	1.2798	0.5596	0.575
LNR >> LFD	1.0524	0.1048	0.916
LFD >> LNR	1.4541	0.9081	0.363
LNR >> LIQ	0.9732	-0.0537	0.957
LIQ >> LNR	0.8060	-0.3860	0.699
LNR >> LCR	1.4523	0.9046	0.365
LCR >> LNR	0.4540	-1.0920	0.274
LGT >> LFD	4.9031	7.8063	0.000
LFD >> LGT	1.0318	0.0636	0.949
LGT >> LIQ	7.4957	12.9910	0.000
LIQ >> LGT	1.8288	1.6575	0.005
LGT >> LCR	3.6476	5.2951	0.000
LCR >> LGT	2.6132	3.2265	0.001
LFD >> LIQ	5.4958	8.9916	0.000
LIQ >> LFD	2.4309	2.8618	0.004
LFD >> LCR	3.9688	5.9375	0.000
LCR >> LFD	2.5547	3.1094	0.001
LIQ >> LCR	2.8212	3.6424	0.000
LCR >> LIQ	5.8956	9.7912	0.000

DISCUSSION

These findings suggest that NR has improved environmental quality in the D-8 economies over the study period 1984-2021. The positive role of natural resources in enhancing environmental quality is linked to sustainable management options, combining consumption and production practices, reducing natural resource depletion rates and environmental stress, and allowing for natural resource regeneration. Additionally, the potential for stimulating economic development and enhancing environmental quality lies in the shift from obsolete technologies to advanced technologies that incorporate recycling, reprocessing, innovation, value addition, and artificial resources as substitutes for natural resources (Bekun *et al.*, 2019). Additionally, the reliance on imported fossil fuels can be reduced through the utilization of abundant natural resources, as these resources have the capability to meet the energy requirements, resulting in a decrease in environmental damage (Ulucak and Khan, 2020). The explanation for this negative association can be attributed to the regenerative capacity of natural resources, which contributes to the improvement of environmental quality and the mitigation of the drawbacks associated with traditional fossil fuel energy, to some extent. As a consequence, there is a reduced dependence on imported and polluting fossil fuels by countries. These earlier findings by Shahbaz *et al.* (2018) further validate these results.

It emphasizes the importance of green energy cooperation in establishing a more environmentally sustainable energy system and put emphasis on the significance of green financial support in fostering sustainable development.t. Energy efficiency, particularly low energy efficiency, is a key concern across the panel. Therefore, green energy intensity (GT) may serve as a crucial indicator for understanding the study's findings and guiding appropriate policies for a cleaner environment in the D-8 economies. Empirical results indicate that both green technology and the current energy structure in the sampled countries alleviate the pressure on the environment. Although there has been a significant decrease in energy intensity in recent years, the panel countries need to transition from traditional energy sources to modern ones in their production processes. One of the main advantages of green technology is its ability to reduce the proportion of traditional energy sources per unit of output. Consequently, policymakers should prioritize using clean technology and improving energy efficiency to enhance environmental quality. In this context, the implementation of renewable energy-based green technology can offer an alternative approach to gradually decrease reliance on conventional energy sources within the energy structure of D-8 countries. The formulation of green energy regulations and policies aims to incentivize the adoption of sustainable energy sources and foster energy innovations, thereby mitigating the detrimental impacts of traditional energy sources on the quality of the environment. Furthermore, policymakers in the selected economies should prioritize providing support to researchers and scientific institutions to attain higher levels of energy efficiency. Encouragement of the utilization and promotion of energy-efficient and clean technologies should be emphasized across diverse sectors, particularly within industries related to energy. These findings are consistent with previous research conducted by Lin et al. (2016) and Ulucak and khan (2020). It is evident from this result that financial development plays a significant and substantial role as a determinant of environmental degradation in newly developing countries (Tamazian and Rao, 2010). Similarly, the same outcomes were reported in a study conducted in Qatar (Charfeddine, 2017). During the process of financial development, a robust financial sector stimulates financial markets, resulting in the provision of low-interest credits. This, in turn, encourages investment activities and boosts the purchasing power of the public. As a consequence, there is an increase in the acquisition of energy-intensive high-value items, leading to a higher demand for energy and contributing to environmental degradation. The insufficient allocation of financial resources towards environmentally friendly projects and the expansion of high-energy consumption initiatives further worsens the environmental degradation (Saud *et al.*, 2019). Moreover, extending financial assistance to long-term projects can intensify the demand for natural resources, accompanied by a significant upsurge in industrialization and transportation activities. These findings are consistent with the studies conducted by Mukhtarov et al. (2024), Saud *et al.* (2020), and Shah *et al.* (2020), but they differ from the findings of the study conducted by (Destek and Sarkodie, 2019).

The question arises as to why the indicator of institutional quality has a detrimental impact on ED. One possible explanation for the positive link between the institutional quality variable and the explained variable is the political environment in the concerned economies. It is plausible that a higher institutional quality provides greater civil rights and political independence to the general public (Lau *et al.*, 2014). Additionally, these findings may indicate that the political environment in the selected panel of countries pays less attention to public issues, such as a polluted environment resulting from high emissions levels. Although the political and institutional system in these nations may have initiated certain measures to prioritize environmental quality, it may still take time to shift the approach of higher authorities and place greater emphasis on environmental concerns. The results observed in these countries indicate that economic advancement and industrialization take precedence, consequently resulting in a negative impact on environmental degradation despite improvements in institutional quality. Similarly, institutional quality does not appear to be a supportive mechanism for developing eco-friendly policies in D-8 economies. Therefore, there is a need for higher authorities to place more focus on environment-friendly energies and technologies, taking into account institutional quality. Likewise, our findings align with the case studies conducted by Liu *et al*. (2020), Le and Ozturk (2020) , but they contrast with the findings of a case study by (Sarkodie and Adams, 2018).

Four different logics can explain this outcome. One plausible explanation is that corruption can disrupt trade protection levels or other subsidies that may impact the composition of an economy (Cole, 2007). Another explainable reason is that as the economic condition expands over time, there is an inconsistency between economic progress and environmental excellence, resulting in a more significant deterioration of the environment (Zhang *et al.*, 2016). Consequently, rapid growth may generate increased environmental degradation. Furthermore, in the initial phases of economic growth, when an economy is weaker, and regular market competition is not firm, corruption may quickly impede immature economic development, ultimately leading to increased environmental degradation. Other inefficiencies in institutional performance, besides corruption, are also emphasized, as significantly distressing factors for a country's total factor production and government fears about environmental control. Thus, there is a need to focus more on addressing illegal earnings in terms of corruption, as corruption is a crucial factor intertwined with environmental degradation. This result is in link with previous studies such as Sahli and Rejeb, (2015), and Wang *et al*. (2022), while contrasting with the findings of Ozturk and Al-Mulali, (2015).

Conclusion: The key findings of the empirical study on D-8 economies for the period 1984-2017 highlight the significance of natural resources, green technology, institutional quality (specifically the rule of law and corruption), and financial development in environmental sustainability. The study employs advanced estimators and cross-country analysis to obtain robust outcomes and determine causal associations among the variables.

The implications of the findings suggest specific policy recommendations for the D-8 economies. Firstly, these economies should focus on the financial sector and promote clean and green investments. Discouraging loans for energy and pollution-intensive industries would facilitate an energy transition aligned with the SDGs. Additionally, institutions should reconsider their implementations and regulations, particularly regarding the rule of law, to strengthen their positions on environmental quality. Addressing corruption is crucial, and online transactions for economic and human activities can help curb its negative externalities in terms of pollution.

Natural resources play a vital role in economic growth while potentially reducing emissions, but efficient utilization is key. Higher authorities should be involved in extraction and consumption activities to ensure the efficient utilization of natural resources. Similarly, green energy technologies should be maximally utilized in economic activities to foster sustainable growth.

The study also provides specific policy recommendations for individual economies based on the cross-country analysis. For example, countries like Bangladesh, Egypt, and Pakistan should reshape their natural resource consumption policies to mitigate environmental harm and ensure sustainable development. In cases where the response to green technology remains uncertain, providing perfect information about its advantages and compatibility with green environments is essential. Furthermore, countries with harmful responses from financial development should distribute their capital to green energy projects while ensuring competent institutions monitor the allocation of loans for such projects. Strengthening environmental regulations and effectively implementing them is crucial where the influence of the rule of law is limited. Addressing corruption practices through introducing digital currency at the domestic level is recommended.

In conclusion, the study's key findings contribute to the existing knowledge by highlighting the importance of natural resources, green technology, institutional quality, and financial development in environmental sustainability for D-8 economies. The policy recommendations derived from the findings offer guidance on reshaping resource consumption policies, promoting green investments, strengthening institutions, combating corruption, and maximizing the utilization of natural resources and green technology.

Future research can build upon the current study's limitations and gaps by exploring several potential avenues. These include conducting a longitudinal analysis to capture recent trends, engaging in comparative analysis to explore specific country comparisons within the D-8 economies, employing qualitative research methods to gain deeper insights into the factors influencing environmental sustainability, conducting policy analysis to evaluate the effectiveness of environmental policies and identify best practices, conducting sector-specific analysis to understand the contribution of different sectors to environmental degradation or sustainability, undertaking spatial analysis to explore cross-border influences and the spatial dimension of sustainability, and investigating the role of specific green technologies and emerging technologies in promoting environmental sustainability in D-8 economies. Pursuing these avenues would contribute to a more comprehensive understanding of environmental sustainability in the D-8 economies and inform the development of effective policies and strategies for a sustainable future.

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Table. A Appendix 1

Variable	VIF	1/VIF
LGT	1.91	0.522456
LIQ	1.72	0.580889
LFD	1.48	0.674486
LCRP	1.35	0.743197
LNR	1.12	0.894742

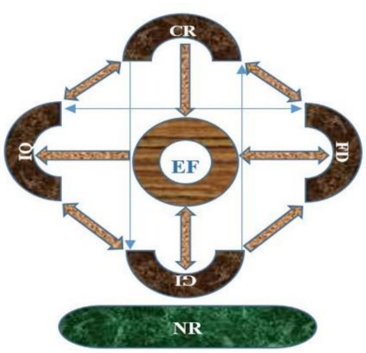

Figure A. Appendix 2: Graphical Abstract of D-H Panel Causality Test

Standard measurement units and their abbreviations

ED	Environmental degradation.
NR	Natural resources.
GR	Green technology
FD	Financial development
IQ	Institutional quality.
CR	Corruption.
CS-ARDL	Cross Sectional Augmented Regressive Distributive Lag model.
D-8	Eight developing economies
EF	Ecological Footprint
CADF	Covariate-Augmented Dickey-Fuller
CIPS	Cross-sectionally augmented Im, Pesaran and Shin.
CD	Cross sectional dependence.