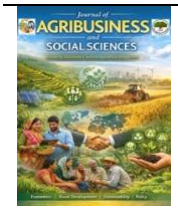

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Impact of Growth Factors on Greenhouse Gas Emissions in 12 Environmentally Vulnerable Countries: The Moderating Role of Governance.

Mansoor Ahmed Golo [a, *], Sahar Qabool [b], Syed Safdar Ali Shah [c], Ayesha Sattar [d]

[a] *School of Management, Harbin Institute of Technology, Harbin, P. R. China.*
[b] *Faculty of Management Sciences, Hamdard University, Karachi, Pakistan*
[c] *Department of Management Sciences, Isra University, Hyderabad, Pakistan*
[d] *Indus University, Karachi, Pakistan.*

A R T I C L E I N F O

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This study examines the moderating role of governance in alleviating the causes of environmental degradation, proxied by total greenhouse gas emissions. At first, this study examines the influence of growth measures, including GDP, domestic credit, and savings, on emissions, using energy use as a control variable. At the next step, it identifies the variable that has the higher worsening impact on the environment. Later, the high impact factor of environmental degradation is moderated by governance factors. This helps to develop a climate action strategy. Panel data from twelve environmentally vulnerable countries from 1996 to 2020 are examined by employing the Panel Autoregressive Distributed Lag-PMG model. The findings show that GDP and savings positively influence emissions. The influence of domestic credit in this regard is negative. However, the control variable shows the least positive influence on greenhouse gas emissions compared to GDP and Savings. GDP influences the most among all the other factors. Therefore, the study moderates its influence with good governance factors. The study finds that governance indicators, including regulatory quality, control of corruption, and the rule of law, significantly weaken the main positive effect of GDP on greenhouse gas emissions. It is therefore recommended that strengthening the government's operational structure in these public areas could be an effective climate action strategy for the examined countries.

Introduction

In the current era of a shared future, the importance of natural settings is gaining global attention. People from every walk of life are calling for action to stop the "apocalyptic" impact of the worsening environment . However, development-driven desires have created a phase of economic growth competition among countries, paving the way for environmental degradation (Adebayo et al., 2023). Any undesirable change in natural settings caused by reduced air quality, water resources, and soil health, as well as damage to ecosystems, is called environmental degradation (Singh et al., 2022). Concerns about environmental degradation provide countries with a basis for climate action (Peisker, 2023). In light of this, the current study examines the impact of growth factors on environmental degradation and seeks to identify a solution to this challenge. Dai et al., (2023) revealed that ecological collapse is a byproduct of economic growth. Though it improves undeveloped infrastructure, eliminates scarcity, enhances living standards, and secures residents' food through higher production and consumption, it also results in environmental degradation by intensifying greenhouse gas emissions. Such gases severely affect the Earth's surface as a result of global temperature rises, which creates climatic instability (Zhou et al., 2023). Ultimately, devastating events due to climate change occur in various regions of the world. For example, China experienced severe flooding in 2021 due to heavy rainfall, driven by unusual rainfall patterns. The reason could be rising global temperatures due to hazardous emissions. China's flood caused over 4,000 deaths and left 14 million citizens homeless. In Pakistan, the 2010 and 2022 floods similarly damaged infrastructure worth 14 billion dollars (Government of Pakistan, 2021). Apart from that, environmental degradation has reduced the natural resilience of ecological systems. It also causes sea levels to rise; thus, coastal floods occur (Mayo & Lin, 2022).

* Corresponding author. *E-mail address* ahmed.mansoor@hit.edu.cn (Mansoor Ahmed Golo).

Unforeseeable monsoon patterns, volcanic outbursts, glacier melt, and tornado occurrences are also the after-effects of poor environmental quality. Due to poor air quality, millions of people die each year. The death toll includes lung issues, brain damage, heart diseases, and lung cancer resulting from hazardous emissions (McDuffie et al., 2021). The European Commission's report on Science for Environment Policy estimated that health-related costs will reach up to 176 billion dollars globally by 2060 (Commission & Environment, 2018). The challenge of environmental degradation cannot be abandoned. Many researchers present economic growth as a solution. According to them, when economies start growing, citizens can pay more for ecological causes. The Environment Kuznets Curve (EKC) hypothesis advocates this assertion. To confirm the validity of EKC, researchers conducted several studies. In some regions, EKC was proved valid, and in some places it wasn't. For example, in G-7 countries, the EKC was valid when biomass fuel consumption and GDP were analyzed in a single model (Z. Wang et al., 2020). Whereas, in another G-7 countries' study, the results were different when the fossil fuel consumption and economic growth nexus were taken into account (Balcilar et al., 2020). The EKC hypothesis validity resulted in mixed outcomes in OECD countries (Isik et al., 2021). The EKC was valid in emerging countries, while the influence of foreign trade, financial development, agriculture, and energy consumption on emissions was examined (Koshta et al., 2021). The regional study of Latin America, the Caribbean, East Asia, the Pacific, Europe, Central Asia, South Asia, the Middle East, North Africa, and Sub-Saharan Africa indicated that the regions have different estimates of the economic growth and CO2 emissions nexus (Bibi & Jamil, 2021).

The existing literature on resolving the environmental degradation problem has yielded inconsistent results, underscoring that economic growth alone cannot effectively reverse environmental degradation. Inconsistencies in the outcomes of existing literature signify research gaps. The current study fills this gap and examines the moderating impact of good governance as an innovative strategy to improve environmental quality. The study establishes specific objectives aligned with its rationale.

(1) To analyze the impact of growth factors, including real GDP, domestic credit to the private sector, and gross domestic savings, on total greenhouse gas emissions.

(2) To ascertain whether good governance factors, government effectiveness, regulatory quality, control of corruption, and rule of law moderate the primary impact of the leading growth factor on greenhouse gas emissions intensity.

Review of Literature

Environmental Degradation

The environment is a natural canvas of our only home; every material we produce, consume, or waste within this confined space lingers and echoes its presence for generations. The environment is degraded when water, soil, and air are polluted (Singh et al., 2022). This degradation of environmental quality can be assessed through various indicators such as CO2, CH4, N2O, and F-gases, including HFCs, PFCs, and SF6 that contribute to air pollution (Razzaq et al., 2023). The rise in air pollution could lead to a rise in temperature, which can result in melting glaciers, rising sea levels, and abrupt precipitation. In a 2020 report, the National Oceanic and Atmospheric Administration highlighted a consistent increase of 0.08 degrees Celsius per decade in heatwaves on land and ocean surfaces since 1980 due to hazardous emissions into the Earth's surface. Alarmingly, the average temperature rise in 1981 was reported as 0.18 degrees Celsius, reflecting a more than 100% increase from 1880 to 1981. The environment is also degraded when the industrial sector emits carbon dioxide into the air (Hodžić et al., 2023). Over the past three decades, an increased volume of harmful gases has significantly impacted the Earth's surface, leading to a rise in global temperatures and the presence of toxic pollutants, contributing to climate unpredictability (Zhou et al., 2023). That instability in the weather patterns causes liquid and solid water to fall from the atmosphere and reach the Earth's surface. It is a crucial component of the Earth's water cycle. But abrupt rainfall has severe consequences, such as floods (Nanditha et al., 2023). Existing studies have utilized various indicators to assess environmental degradation, with the majority focusing on CO2 emissions. However, only a few studies have adopted total greenhouse gas emissions as an indicator of environmental degradation. Total greenhouse gas emissions comprise carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), fluorinated gases, and water vapor. The present study incorporates total greenhouse gas emissions (TGHG) as a metric for environmental degradation.

Growth Factors and Environmental Degradation

Growth factors include economic growth indicators, indicating monetary expansion of an economy's capacity to utilize loans and produce goods and services (Kures & Deller, 2023). These indicators are often associated with increased employment opportunities and higher income levels. This general development comes at the cost of environmental degradation (Sohag et al., 2021). In many developing countries, ecological challenges associated with growth factors are becoming increasingly apparent, primarily due to the nature of their growth patterns that heavily rely on burning fossil fuels (Arayssi, 2020).

Nowadays, explaining the relationship between growth and nature is more complex than ever before. In the current development structure, nature frequently provides essential inputs like water, timber, and minerals, and valuable services such as water purification, flood management, and nutrient cycling to nations (Tallis et al., 2008). However, countries often excessively utilize nature's resources to fuel economic growth, leading to environmental degradation (Kumari et al., 2023). In this context, a study conducted from 1971 to 2011 found trade openness, income, and energy consumption to be the chief causes of carbon emissions in Thailand, Turkey, India, Brazil, China, Indonesia, and Korea (Ertugrul et al., 2016). Likewise, from 1971 to 2013, trade also caused CO2 emissions in the USA, Japan, Canada, Iran, Saudi Arabia, the UK, Australia, Italy, France, and Spain (M. A. Ansari et al., 2019). (Tiba & Belaid, 2020) found a two-way causal relationship between hazardous emissions, trade openness, GDP, and foreign direct investment in 27 African countries from 1990 to 2013. Trade openness worsened environmental quality in China after joining the WTO in 2001 (Jun et al., 2020). In Australia, from 1980 to 2014, trade openness, financial development, and energy consumption were found to be

harmful to the environment (Nasir et al., 2021). A worldwide investigation revealed a persistent correlation between environmental degradation, trade openness, and economic growth across the global sample. However, the impact of trade openness on the environment differs based on a country's income level, as it has a favorable influence in high-income nations but is unfavorable in middle and low-income countries(Le et al., 2016). Similarly, the varying effects of trade openness were reported in a study conducted across 142 countries from 1990 to 2003, which found that increased trade openness increased deforestation in non-OECD countries while slowing deforestation in OECD countries (Tsurumi & Managi, 2014).

Besides the above reasons, per capita income, energy consumption, gross capital formation, foreign direct investment, and gross domestic product also harm the environment(Liu et al., 2022). However, the direction and magnitude of the impact depend on the methodological differences and the countries' development categories (Khan et al., 2021). In Indonesia, gross capital formation was negatively associated with environmental degradation, whereas trade openness showed a positive relationship between 1965 and 2018 (Anwar & Elfaki, 2021). In the Balkan countries, from 1996 to 2017, industry caused CO2 emissions in the short run, whereas gross fixed capital formation caused them in the long and short run (Mitić et al., 2020). Countries often rely on increased industrial production to accomplish fiscal progress, which leads to excessive use of natural resources, energy, and financial resources and causes hazardous emissions (Ozcan et al., 2020). Offering loans on easy terms boosts economic growth but degrades the environment (Shen et al., 2021). If countries provide credit on soft terms for environment-friendly projects, this could improve environmental quality (Gokmenoglu et al., 2021). Energy-induced economic growth through easy financial access can lead to environmental collapse (Zeqiraj et al., 2020). A study of 184 countries between 1990 and 2017 indicated that energy-induced economic growth positively affects CO2 emissions, whereas financial development can reduce emissions (Khan et al., 2021). From 1980 to 2014, a study found that economic growth, financial development, and energy consumption increased CO2 emissions, whereas foreign direct investment curbed emissions in India, Pakistan, Bangladesh, Sri Lanka, and Malaysia (Rajpurohit & Sharma, 2021).

The reviewed literature reported numerous growth aspects that influence the environment. However, the detrimental and beneficial impacts depend on countries' income levels and geographic classifications. Given the diverse outcomes reported in the existing literature, the factors causing environmental degradation mentioned above remain subject to debate and require empirical verification across regions. The current study examines the environmental impact of growth variables, including real GDP, gross domestic savings, and domestic credit to the private sector, by taking energy use as a control variable.

Good Governance and Environmental Degradation

Good governance can be assessed by analyzing how well the institutions in a country are operational. That can be done by considering certain factors such as transparency, accountability, citizen participation, rule of law, stable political system, and openness of civil services (Pomeranz & Stedman, 2020). According to (Fukuyama, 2016), the term "governance" does not have a universally agreed-upon definition, but it can be understood in three different ways. One of those ways is the effective implementation of state policies. It reveals the significance of institutional compliance. This reflects the public concerns regarding institutional management and its relationships with society. Thus, governance is the ability of governments to formulate and execute rules for delivering better services to the public (Peters et al., 2022). Academicians emphasized the significance of good governance in enhancing environmental quality (Sou & Vinnicombe, 2023). By decreeing possible ecological policies, governments can control the causes of environmental degradation (Kulin & Johansson Sevä, 2019).

Irreversible anthropogenic causes of environmental harm require urgent and collective responses (Boasson & Tatham, 2022). Indeed, the environmental sector alone won't be able to attain the ecological goals. Therefore, all stakeholders must be on board (Lafferty & Hovden, 2003). The Paris Agreement has already called upon all countries to identify and communicate their post-2020 climate actions to mitigate national greenhouse gas emissions, and the goals are referred to as Nationally Determined Contributions.

Sound and effective operational institutions help countries reduce environmental degradation (Yasmeen et al., 2018). The robust enforcement of eco-friendly laws ensures sustainable growth, while their presence moderates unregulated emissions (Haseeb & Azam, 2021). In this context, the current study also emphasizes the need for efficient legislation and execution. As a result, growth activities would adapt their operational processes according to legal requirements, ultimately leading to sustainable growth (Stef & Ben Jabeur, 2020). Hence, the current study incorporates selected good governance indicators acquired from World Governance Indicators (WGI). The decision to choose specific indicators for the current study from the database of WGI is based on the necessity of prioritizing dimensions that are most pertinent to the current research's context. The selected indicators include government effectiveness, which refers to the efficiency of a government in performing its functions. Regulatory quality assesses the quality of governance within a country. Control of corruption refers to the effectiveness of a country's efforts to prevent corruption in public and private sectors. The rule of law means that laws are applied consistently, fairly, and impartially in a society.

Hypotheses Development

General growth is a crucial factor in improving living standards, and countries often aim to increase industrial output by allocating resources effectively (Kures & Deller, 2023). However, theorists usually link such growth factors to environmental degradation (Mtar & Belazreg, 2023; J. Wang et al., 2023). For example, Limits to Growth (LTG) theory highlights the connection between growth-associated factors, such as the use of fossil fuels as inputs to industrial production, which often causes pollution (Ozcan et al., 2020). The Environmental Kuznets Curve (EKC) theory also argues that monetary growth harms the environment. However, it happens at the initial stage of the country's development. The EKC theory has resulted in mixed outcomes at its turning point (Caviglia-Harris et al., 2009). Similar arguments are reported in the studies conducted by (Chen & You, 2021) and (Dai et al., 2023) those revealed that pursuing economic growth drives nations to consume more financial and energy resources, leading to prolonged environmental instability.

There are various studies that have clearly incorporated particular factors in this regard. For example, studies by (Hamdan et al., 2018), (Ben Abdeljelil et al., 2023), and (Khalfaoui et al., 2023) hypothesized a GDP-emissions link. (Shen et al., 2021) and (Gokmenoglu et al., 2021) linked domestic credit and hazardous emissions.

(Zeqiraj et al., 2020) and (Shah et al., 2022) linked savings and emissions. Moreover, savings can influence investments that provide sufficient funds, thereby affecting emission intensity. Based on the facts discussed above, the current study also hypothesizes that growth factors, including GDP, domestic credit, and savings, may intensify the total greenhouse gas emissions in the countries under observation. Thus, the hypotheses on direct impacts are developed as follows.

Hypothesis 1: An increase in Gross Domestic Product will positively influence greenhouse gas emissions in 12 high-risk countries.

Hypothesis 2: An increase in Domestic Credit to the Private Sector will positively affect greenhouse gas emissions in 12 high-risk countries.

Hypothesis 3: An increase in Gross Domestic Savings will positively influence greenhouse gas emissions in 12 high-risk countries.

The aforementioned theories explain the relationships between growth factors and emissions. None of the underlying theories explicitly provided any insights into under which conditions the power of these relationships weakens. Therefore, the current study complements these relationships and examines good governance factors, including government effectiveness, regulatory quality, the rule of law, and control of corruption as moderating variables. Available literature presents insights that the selected governance factors have the ability to weaken the main effect of highly impacting growth variables on greenhouse gas emissions. Thus, these factors can perform similarly in the 12 examined high-risk countries. In this regard, existing studies, such as those by (Bouchoucha, 2021), examined World Governance Indicators as moderating variables in the environment and health relationship. (Yasmeen et al., 2018) examined the role of good governance indicators by creating a composite index, employed as a moderating variable in the trade-environment relationship. Results were promising in lessening the harmful influence of trade on environmental degradation. Similarly, (Ibrahim & Law, 2016), in a sub-Saharan African study, discovered that good governance can weaken the ecological impacts of trade when employed as a moderating variable in trade-environment relationships. Moreover, the theorists (Glasbergen et al., 2013), (Gunderson, 2018), and (Poole, 2012) emphasized the significance of global governance in mitigating environmental degradation. Therefore, the current study, following a similar approach, employs the selected Good Governance factors as moderating variables. In this regard, the current study outlines hypotheses as follows.

Hypothesis 4a: Government effectiveness moderates the intensifying impact of the high-impactful growth variable on greenhouse gas emissions, such that the higher the quality of public services in 12 high-risk countries, the weaker the main impact of such a variable on greenhouse gas emissions.

Hypothesis 4b: Regulatory quality moderates the intensifying impact of high-impactful growth variable on greenhouse gas emissions, such that the higher the capacity of governments to develop and execute effective policies in 12 high-risk countries, the weaker the primary impact of such variable on greenhouse gas emissions.

Hypothesis 4c: Control of corruption moderates the intensifying impact of high-impactful growth variable on greenhouse gas emissions, such that the higher the control of corruption in 12 high-risk countries, the weaker the primary impact of such variable on greenhouse gas emissions.

Hypothesis 4d: The rule of law moderates the intensifying impact of high-impactful growth variable on greenhouse gas emissions, such that stronger law and order situations in 12 high-risk countries, the weaker the primary impact of such variable on greenhouse gas emissions.

Material and Method

This study gathered data from twelve environmentally vulnerable developing countries for the period from 1996 to 2020. The countries are selected on the basis of their consistent climatic vulnerabilities. These countries have been ranked in the top ten list of the Global Climate Risk Index (GCRI) in 1998-2017, 1999-2018, 2000-2019, 2018, and 2019. The GCRI ranks countries by their reported losses from harsh environmental conditions. The current study refers to these nations as High-Risk countries. Table 1 presents the list of environmentally vulnerable countries and the selected twelve High-Risk countries.

The collected data had a few missing values, which were treated using the interpolation technique (Bhuiyan et al., 2018). For reliable results, the data are standardized by taking the natural logarithm of the dependent and independent variables, and the moderating variables are standardized using the Z-score method (Kirikkaleli et al., 2023). Table 2 lists the variables used in this study. For long-run estimations, this study uses the Panel ARDL (Autoregressive Distributed Lag) PMG technique because the primary objective of this study is to estimate a common long-run relationship across the panel countries. This technique is preferred over the Mean Group (MG) and Dynamic Fixed Effects (DFE) methods because MG produces separate country-specific long-run coefficients and their average. But the current study focuses on a panel-wide long-run relationship. On the other hand, compared to the DFE, PMG imposes fewer restrictions on parameter homogeneity. The study also conducts a set of data diagnostic techniques including cross-sectional dependency, slope homogeneity, unit roots, and panel cointegration tests, before employing the Panel ARDL.

Table 1. High-Risk Countries

Rank	1998-2017	1999-2018	2000- 2019	2018	2019	*12-High-risk countries
1	Puerto Rico	Puerto Rico	Puerto Rico	Japan	Mozambique	Pakistan, Bangladesh,
2	Honduras	Myanmar	Myanmar	Philippines	Zimbabwe	Nepal, India,
3	Myanmar	Haiti	Haiti	Germany	The Bahamas	Philippines, Vietnam,
4	Haiti	Philippines	Philippines	Madagascar	Japan	Bolivia, Bahamas, Haiti,
5	Philippines	Pakistan	Mozambique	India	Malawi	Mozambique, Niger, and
6	Nicaragua	Vietnam	Bahamas	Srilanka	Afghanistan	Zimbabwe.
7	Bangladesh	Bangladesh	Bangladesh	Kenya	India	
8	Pakistan	Thailand	Pakistan	Rwanda	South Sudan	
9	Vietnam	Nepal	Thailand	Canada	Niger	
10	Dominica	Dominica	Nepal	Fiji	Bolivia	

Source: Global Climate Risk Index 2019, 2020, and 2021

*The High-risk countries are shortlisted based on the availability of their datasets.

Econometric Models

The panel ARDL long-run estimation equations are used to analyze the direct (Equation 1) and moderating (Equation 2) effects.

$$lnTGHG_{1_{it}} = a_i \sum_{j=1}^{k} b_{2it} lnRGDP_{it-j} + \sum_{j=0}^{k} b_{3it} lnDCPS_{it-j} + \sum_{j=0}^{k} b_{4it} lnGDS_{it-j} + \sum_{j=0}^{k} b_{5it} lnENU_{it-j} + er_{1it} \quad (1)$$

Hypotheses: ***H1***: $b_2 > 0$, ***H2***: $b_3 > 0$, ***H3***: $b_4 > 0$

$$lnTGHG_{1_{it}} = a_i \sum_{j=1}^{k} \beta_{2it} lnRGDP_{it-j} + \sum_{j=0}^{k} \beta_{3it} lnRGEF_{it-j} + \sum_{j=0}^{k} \beta_{4it} lnRGQT_{it-j} + \sum_{j=0}^{k} \beta_{5it} lnRGCR_{it-j} + \sum_{j=0}^{k} \beta_{6it} lnRGRL_{it-j} + \mathfrak{d}_{1it} \quad (2)$$

Hypotheses: ***H4a***: $\beta_3 < \beta_2$, ***H4b***: $\beta_4 < \beta_2$, ***H4c***: $\beta_5 < \beta_2$, ***H4d***: $\beta_6 < \beta_2$

Where *ln* is the natural logarithm, a_i represents the intercept, er_{1it} is the error term, and $b_{2it}..b_{5it}$ show the estimated parameters of regressors.

Table 2 Variables of this Study

Variables	Acronym	Measurement unit	Data Sources
Dependent Variable			
Total greenhouse gas emissions	TGHG	Kilotons of CO_2 equivalent	WDI
Independent Variables			
Real GDP	RGDP	A constant of 2015 in USD	WDI
Gross domestic savings	GDS	Ratio of GDP	WDI
Domestic credit to the private sector by banks	DCPS	Ratio of GDP	WDI
Total Population	TOP	Total count	WDI
Control Variable			
Primary energy use	ENU	Measured as TWh	Our World in Data
Moderating Variables			
Government Effectiveness	GEF	Excellence in civil services	WGI
Regulatory Quality	RQT	Execution of rules	WGI
Control of Corruption	CCR	Check and balance	WGI
Rule of Law	ROL	Uphold the laws generally	WGI
Interaction Terms			
RGDP×GEF	RGEF		Created by Author
RGDP×RQT	RGQT		
RGDP×CCR	RGCR		
RGDP×ROL	RGRL		

Results and Analysis

Table 3. Results of Statistical Approaches

Variables	lnTGHG	lnRGDP	lnDCPS	lnGDS	lnENU
CD test statistics					
Breusch-Pagan LM	1209*	1202*	570*	277*	1005*
Pesaran LM	99.5*	98.9*	43.9*	18.4*	81.5*
Pesaran CD	29.79*	31.8*	4.62*	(1.0)*	20.75*
CIPS (2007) test statistics					
Stationarity at Level	(1.41)	(1.56)	(0.76)	(2.22)	(2.07)
Stationarity at 1st Dif.	(4.20)*	(3.37)*	(3.92)*	(4.74)*	(4.04)*
Order Decision	I(1)	I(1)	I(1)	I(1)	I(1)
P & Y (2008) test statistics					
$\tilde{\Delta}$			$\tilde{\Delta}_{ADJ}$		
15.822*			18.149*		

Note: * indicates that results are significant at 1%.

The degree of dependence between the parameters can be assessed using cross-sectional dependence tests. Table 3 illustrates the outcomes of the Breusch-Pagan LM, Pesaran LM, and CD, CIPS unit root, and S-H tests. Cross-sectional dependency tests' statistics direct us to reject the null hypothesis "data is not cross-sectionally dependent for countries" at 1%. The CIPS shows that the data is stationary at the first difference. Therefore, the null hypothesis that the panel is not stationary is rejected at the I(1) integration order. The outcomes of slope homogeneity delta ($\tilde{\Delta}$) and adjusted delta ($\tilde{\Delta}_{ADJ}$) tests display the nonexistence of panel heterogeneity in datasets. Furthermore, the long-term relationships amongst the measures in the direct effect equation are confirmed by Pedroni (1999, 2004), Kao (1999), and Westerlund (2007) tests in Table 4.

Table 4. Cointegration Results

Pedroni (1999, 2004)			
H_a: Common AR coefficients within the dimension		H_a: Individual AR coefficients within the dimension	
P_w	(0.92)	G_a	1.57
P_x	(0.84)	G_b	(2.97)*
P_y	(4.65)*	G_c	(2.32)*
P_z	(5.05)*		
Kao (1999)		H_o: No co-integration	
t-Statistics	(2.41)*		
Westerlund (2007) Cointegration test results [H_0: No cointegration]			
Statistics	Value		z-value
G_t	(2.48)**		(1.69)
G_a	(8.77)		0.53
P_t	(5.10)*		0.39
P_a	(5.17)		0.44

Note: * and **show significant results at 1% and 5%, respectively. P_w, P_x, P_y & P_z are panel v-statistic, panel rho-statistic, panel PP-statistic & panel ADF-statistic, respectively; G_a, G_b & G_c are group rho-statistic, group PP-statistic & group ADF-statistic, respectively.

Long-run Findings

The reported results of the long-run ARDL model in Table 5 affirm the long-run nexus among the variables, which shows a significant impact of real GDP, gross domestic savings, and domestic credit to the private sector by banks on greenhouse gas emissions. The numerical value of the beta coefficient b_2 is 0.657; hence, it proves that **H1** is true which is **H1:**$b_2 > 0$. However, the statistical value of the beta coefficient b_3 is -0.402, which shows $b_3 < 0$, and the beta coefficient b_4 is 0.259, which portrays $b_4 > 0$ imply that hypotheses **H2** is not supported and **H3** is supported.

The numerical results imply that a 1% increase in the gross domestic product causes a 0.657% rise in greenhouse gas emissions in 12 High-risk countries. The findings show a significantly positive nexus between real GDP and hazardous emissions, which is consistent with the outcomes of (Phrakhruopatnontakitti, 2020) and (Zakaria & Bibi, 2019). Both studies have used carbon dioxide as a measure of environmental quality. The empirical findings of the current research strengthen the arguments that economic growth is crucial for developing countries; however, it comes at the cost of higher emissions. In this context, the World Bank's report on climate and development[1] argued that countries can transition to low emissions growth paths with proper management.

From the theoretical perspectives, the findings align with the Limits to Growth (LTG) and Environmental Kuznets Curve (EKC) theories. These theories suggest that economic output can exacerbate pollution, leading to environmental degradation. The LTG theory proposes halting growth to mitigate environmental harm, and the EKC theory suggests an ambiguous turning point of economic development where environmental conditions begin to improve. However, the current study argues that in today's world, halting growth is not feasible as it is integral to overall development. Examined countries that have already suffered significant environmental losses, such as weather-related fatalities and infrastructure losses, cannot afford to postpone environmental action in anticipation of an uncertain turning point suggested by the Environmental Kuznets Curve (EKC) hypothesis. Therefore, in the later part, the current study innovatively employs the chosen World Governance Indicators (WGI) as a moderator variable to examine the impact of GDP on the environment. By analyzing how good governance measures influence the RGDP-TGHG relationship, the study offers a deeper understanding of the factors that can be used as climate action strategies across the 12 High-risk countries. This approach helps High-risk countries take proactive measures that recognize the importance of the environment while prioritizing economic growth.

Furthermore, the results suggest that gross domestic savings positively influence environmental degradation; numerical outcomes imply that a 1% increase in gross domestic savings could lead to a 0.259% rise in greenhouse gas emissions. Higher savings can lead to increased investment in industries, particularly in developing countries where industrial outputs heavily depend on fossil fuels, contributing significantly to hazardous emissions, as argued by (Karakurt & Aydin, 2023) and (D. Ansari & Holz, 2020). Domestic credit to the private sector by the banks negatively influences greenhouse gas emissions, and similar findings were also reported in a panel of 24 countries study conducted by (Petrović & Lobanov, 2022). The numerical outcomes of the domestic credit to the private sector by the banks reveal that a 1% rise in domestic credit to the private sector causes a decline of 0.402% in GHG emissions. This could be influenced by banks that may require borrowers to adopt environmentally sustainable practices for receiving credit, as (Zhang, 2021) and (Ozili, n.d.) argued.

Moreover, this could also be attributed to the inclusion of investments by the private sector in renewable energy, energy efficiency, or waste reduction

[1] https://www.worldbank.org/en/topic/climatechange/publication/climate-and-development-an-agenda-for-action

projects (Gokmenoglu et al., 2021). Furthermore, the control variable, primary energy use, positively influences greenhouse gas emissions, but that impact is significantly lower than the main variable's effect, *i.e.,* RGDP, on greenhouse gas emissions. The results affirm that economic factors, including real GDP and gross domestic savings, intensify greenhouse gas emissions in observed high-risk countries. In contrast, domestic credit to the private sector positively impacts the environmental quality. This study's findings showed that economic growth patterns in the observed developing countries significantly contribute to the ecological vulnerabilities of these countries. This phenomenon underscores the urgent need for innovative solutions to address environmental degradation in these nations. In this regard, the current study examines the moderating role of good governance in the GDP-emission nexus.

Table 5. Panel ARDL Results on Direct Effects

Models	Model 1. (2, 3, 3, 3, 3)	
Variables	Total greenhouse gas emissions are the dependent variable	
	Coefficient	t-Stat
lnRGDP	0.657*	4.614
lnDCPS	(0.402)*	(5.100)
lnGDS	0.259*	3.695
lnENU	0.254*	3.189
N		264
S.E of Reg.		0.026
Sum Sq. Residual		0.079
Root MSE		0.016

Note: * shows results are significant at 1%. Lag length method: Akaike Information Criterion (AIC).

Preliminary Test Results

The findings of applied statistical methods are illustrated in Tables 6 and 7. The outcomes of the cross-sectional dependency tests direct us to reject the null hypothesis. The outcomes of the unit-root test illustrate that the data are stationary at first difference. Delta ($\tilde{\Delta}$) and adjusted delta ($\tilde{\Delta}_{ADJ}$) tests display the existence of panel heterogeneity. Furthermore, Pedroni 1999, 2004, Kao 1999, and Westerlund (2007) confirm the long-run cointegration among the variables.

Table 6. Results of Statistical Tests

Statistics	Variables			
	RGEF	RGQT	RGCR	RGRL
CD test statistics				
Breusch-Pagan LM	631*	265*	212*	470*
Pesaran LM	49.2*	17.4*	12.7*	35.2*
Pesaran CD	0.738	0.601	1.854***	1.872***
CIPS (2007) test statistics				
Stationarity at Level	(1.686)	(1.555)	(1.688)	(1.422)
Stationarity at 1st difference	(4.187)*	(3.919)*	(4.153)*	(4.557)*
Order Decision	I(1)	I(1)	I(1)	I(1)
P & Y (2008) Statistics	$\tilde{\Delta}$		$\tilde{\Delta}_{ADJ}$	
	15.196*		17.909*	

Note: * and *** indicate the significance of results at 1% and 10%, respectively.

Table 7. Cointegration Results

Pedroni (1999, 2004)			
H_a: Common AR coefficients		H_a: Individual AR coefficients	
P_w	(0.617)	G_a	1.833
P_x	0.554	G_b	(5.828)*
P_y	(3.335)*	G_c	(4.946)*
P_z	(3.722)*		

Kao (1999)	**t-Statistics**	(2.402)*

Westerlund (2007) Cointegration test results [H_0: No cointegration]		
Statistics		
	Value	z-value
G_t	(3.675)*	(2.485)
G_a	(4.357)	5.604
P_t	(11.577)**	(1.935)
P_a	(9.404)	2.410

Note: * and ** show significant results at 1% and 5%, respectively. P_w, P_x, P_y & P_z are panel v-statistic, panel rho-statistic, panel PP-statistic & panel ADF-statistic, respectively; G_a, G_b & G_c are group rho-statistic, group PP-statistic & group ADF-statistic, respectively.

Long-run Moderating Impact Results

As predicted in the hypotheses of moderating impacts of **H4a**, **H4b**, **H4c**, and **H4d**, good governance indicators can moderate the RGDP-TGHG relationship. The reported results of the panel ARDL model in Table 8 affirm the moderating influence of regulatory quality, control of corruption, and the rule of law on the RGDP-TGHG relationship in High-risk countries. However, it doesn't support the moderating influence of government effectiveness in the RGDP-TGHG nexus. This implies that government effectiveness does not moderate the relationship between real GDP and GHG emissions. Regardless of how effective the governments of High-risk countries are, economic growth still intensifies GHG emissions. However, the coefficient value of $\beta_3 < \beta_2$, but p>0.10; hence, based on the current sample, we do not have enough evidence to accept **H4a** as true. Findings further determine that, $\beta_4 < \beta_2$, hence **H4b** is true. Similarly, $\beta_5 < \beta_2$ and $\beta_6 < \beta_2$; hence, this study accepts that hypotheses **H4c** and **H4d** are also true.

Numerical outcomes reveal a positive and statistically significant impact of increasing real GDP on total greenhouse gas emissions. A one percent increase in economic output corresponds to a 0.328% rise in hazardous emissions. This finding is consistent with the notion that economic growth harms the environment. The negative coefficient values -0.002 of **RGQT** (real GDP × regulatory quality), -0.003 of **RGCR** (real GDP × control of corruption), and -1.064 of **RGRL** (real GDP × rule of law) suggest a potential weakening effect of moderating variables in the RGDP-TGHG nexus. However, **RGEF** (real GDP × government effectiveness) lacks statistical significance (p > 0.10). The numerical outcomes suggest that in the presence of regulatory quality in High-risk countries, the influence of economic growth on greenhouse gas emissions decreases. Results illustrate that an improvement in regulatory quality weakens the positive impact of RGDP on TGHG emissions, as indicated by the negative and significant coefficient of the interaction term (RGQT**)**. Similarly, control of corruption in High-risk countries can overcome the influence of economic growth on the environment. The empirical findings of the interaction term RGCR are negative and significant. This outcome suggests that control of corruption weakens the primary positive impact of RGDP on greenhouse gas emissions. Similarly, the negative and significant coefficient of the interaction term RGRL illustrates that improved rules and regulations can decrease the intensity of greenhouse gas emissions caused by real GDP. Based on these findings, our study suggests that High-risk countries uphold the rule of law on a priority basis. However, the other indicators can't be disregarded, but the rule of law expedites the overall effort of achieving sustainable economic growth in High-risk countries. The statistically significant coefficients for good governance (RQT, CCR, ROL) align with the theoretical background of the current study presented in Chapter 2, which suggests that good governance can act as a protective device against environmental harm. Irrefutably, if the civil services in high-risk countries are kept out of political influence and the rule of law is upheld by applying thorough regulations impartially and transparently. In that case, monetary growth maintains peace with nature. The findings suggest that in the RGDP-TGHG association, good governance can play an important role in moderating environmental degradation. Results are aligned with a few related studies by (Yasmeen et al., 2018), (Ibrahim & Law, 2016), and (Bouchoucha, 2021). The prior studies emphasized the importance of governance indicators as moderating variables. However, these studies did not examine the specific role of good governance indicators in the way explored by the current study.

Based on the empirical outcomes, this study proposes good governance through the rule of law, control of corruption, and Regulatory quality reforms as an effective climate action strategy and immediate remedial solution for environmental degradation in the twelve high-risk countries: Pakistan, Bangladesh, Nepal, India, Philippines, Vietnam, Mozambique, Haiti, Bahamas, Bolivia, Niger, and Zimbabwe.

Table 8. Panel ARDL Results of Moderating Effects

Total greenhouse gas emissions are the dependent variable [Model 3. (1, 2, 2, 2, 2, 2)]		
Variables	Coefficient	t-Stat
lnRGDP	0.328*	10.606
RGEF	(0.000)	(0.159)
RGQT	(0.002)*	(3.505)
RGCR	(0.003)*	4.062
RGRL	(1.064)*	(3.808)
N		276
S.E of Reg.		0.029
Sum Sq. Residual		0.132
Root MSE		0.021

Note: *, ** & *** show significance level at p<1%, p<5% & p<10% respectively. The maximum lag length is selected through the Akaike-Information-Criterion (AIC).

Dumitrescu-Hurlin Causality Results

Pairwise Dumitrescu-Hurlin's (2012) panel causality is applied to obtain the directional relationships among the variables. The direct impact results of D-H panel causality in Table 9 illustrate a bidirectional causality among all the relationships. However, a unidirectional causality runs from lnTGHG to lnENU only. Results of the moderating impacts show a bidirectional causality among lnTGHG and lnRGDP, RGRL and lnTGHG, RGEF and lnRGDP, RGEF and RGCR, RGQT and RGCR. However, a unidirectional causality runs from lnTGHG to RGEF, RQT to RGEF, RGRL to RGCR, RGEF to RGCR, and lnRGDP to RGRL. The causality test results reveal complex relationships between economic, environmental, and governance factors. This statistically supports the idea that explaining the relationship between the environment and economic growth in today's world has become more complicated to discuss. Hence, the current study has taken an innovative approach and explored these relationships. First, it determined if economic growth acts as a driver of environmental degradation in High-risk countries. Second, it sought to ascertain the effectiveness of existing World Governance Indicators (WGI) as a measure of good governance in mitigating the negative environmental impacts of economic growth. Through this approach, the study assessed the potential of good

governance to reduce environmental vulnerabilities faced by these nations.

Table 9. Causality Test Results

Direct effects equation		lnTGHG	lnRGDP	lnGDS	lnDCPS	lnENU	
lnTGHG	W-Stat	.	5.292*	5.917*	5.330*	3.618**	
lnRGDP	W-Stat	5.042*	.	6.000*	6.731*	4.126**	
lnGDS	W-Stat	4.438*	2.978*	.	3.691**	2.658	
lnDCPS	W-Stat	4.924*	3.026*	3.365*	.	5.185*	
lnENU	W-Stat	1.992	3.679**	6.795*	5.395*	.	
Moderating effects equation		lnTGHG	lnRGDP	RGEF	RGQT	RGCR	RGRL
LnTGHG	W-Stat	.	5.292*	3.833**	2.280	2.907	3.516**
LnRGDP	W-Stat	5.042*	.	3.640**	3.161	1.936	5.205*
RGEF	W-Stat	2.761	4.356*	.	3.027	6.505*	4.441*
RGQT	W-Stat	3.367	2.889	3.958**	.	4.553*	3.031
RGCR	W-Stat	2.817	2.878	1.798	5.128*	.	3.271
RGRL	W-Stat	5.092*	2.535	1.266	3.409	3.945*	.

Note: * and ** indicate that results are significant at 1% and 5%, respectively. H_0: No causality among the series.

Conclusions and Implications

This study has examined a complex interplay of economic growth, environmental degradation, and good governance. The study scrutinized statistical associations among real GDP, domestic credit to the private sector by banks, gross domestic savings, good governance indicators, and greenhouse gas emissions in nations: Pakistan, Bangladesh, India, Nepal, the Philippines, Vietnam, Haiti, Mozambique, the Bahamas, Niger, Bolivia, and Zimbabwe from 1996 to 2020. The countries are named high-risk countries due to their higher climatic vulnerabilities. For testing the set hypotheses of this study, various statistical checkpoints have been established to ensure that datasets move step by step toward robust outcomes. At first, the data were rescaled by taking the natural logarithm of the dependent, independent, and control variables. Meanwhile, the Z-Score standardization technique was applied to the good governance variables. After obtaining rescaled panel datasets, we created interaction terms including RGDP × government effectiveness, RGDP × regulatory quality, RGDP × control of corruption, and RGDP × rule of law.

The study employed Breusch-Pagan LM, Pesaran LM, and CD tests to assess potential cross-sectional dependence among the variables. Rejection of the null hypothesis in all tests indicated the presence of cross-sectional dependence. Consequently, it utilized second-generation unit root tests, which confirmed that all variables were stationary at first differences. In the next stage, the delta and adjusted delta tests were conducted, and based on statistical findings, the null hypothesis suggesting slope homogeneity was rejected at a 1% significance level. Later, the variables of concern were analyzed for long-run cointegration using Pedroni, Kao, and Westerlund cointegration statistics. The test results suggested that all the variables are co-integrated in the long run. To further investigate these long-run relationships and potential moderating effects, we employed a Panel ARDL model. The study's theoretical background suggested that environmental degradation is a byproduct of economic growth. Likewise, this relationship was also established by the long-run estimated results of the study.

The findings provided valuable insights into the relationship between growth factors and greenhouse gas emissions in twelve environmentally vulnerable developing nations. The outcomes confirmed a significant influence of real GDP, gross domestic savings, and domestic credit to the private sector on greenhouse gas emissions. The study underscored a positive link between RGDP and greenhouse gas emissions. The results align with the studies conducted by (Koc & Bulus, 2020), (Rajpurohit & Sharma, 2021), and (Ehigiamusoe & Lean, 2019). In those studies, the authors used carbon emissions as a proxy for environmental degradation. Further data assessments of the current study showed that GDS also positively influences environmental degradation, attributed to increased investments in industries reliant on fossil fuels, particularly in developing nations. In contrast, the negative impact of domestic credit to the private sector by banks on TGHG suggested a potential role of the banking sector in promoting environmentally sustainable practices in the examined countries. The eco-friendly role of DCPS was also supported by a study conducted by (Ehigiamusoe & Lean, 2019), when researchers divided the sample into different income groups, they discovered that DCPS doesn't intensify hazardous emissions in the group of high-income countries. The current study finds the same results in environmentally vulnerable developing countries.

Moreover, the findings exhibited an absence of effective decision-making in managing environmental sustainability in High-risk countries; this conclusion was drawn upon the outcomes that showed that an increased RGDP could intensify greenhouse gas emissions in the region. Therefore, given the significance of the Paris Agreement's 1/CP.17 and Sustainable Development Goal 13, this study empirically sought to ascertain the moderating role of good governance indicators in achieving environmental sustainability. In this context, the study investigated government effectiveness, regulatory quality, control of corruption, and the rule of law as moderator variables in the relationship between real GDP (RGDP) and total greenhouse gas emissions (TGHG). As anticipated in the hypotheses (H4b, H4c, and H4d), the findings of the study confirmed the moderating impact of regulatory quality, control of corruption, and the rule of law on the RGDP-TGHG relationship but disproved the moderating influence of government effectiveness (H4a). The findings showed that while economic growth (RGDP) positively influenced TGHG,

the introduced moderating variables (RGQT, RGCR, and RGRL) exhibited negative coefficients, suggesting a potential weakening effect. Findings on moderating effects underscored the significance of regulatory quality, control of corruption, and the rule of law in mitigating the environmental impact of RGDP in High-risk countries. Moreover, the rule of law emerged as a stronger climate action strategy than the other indicators.

The current study provides valuable insights into the monetary variable intensifying greenhouse gas emissions in High-risk countries. It also proposes good governance indicators, regulatory quality, control of corruption, and the rule of law as practical solutions that can minimize the harmful influence of real GDP on the environment in nations under observation. Specifically in environmentally vulnerable countries, the study's findings are helpful for practitioners. The outcomes of this study help policymakers manage economic growth in a way that does not harm the environment.

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