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INDUSTRIAL GROWTH, GHG EMISSIONS, AND THE MODERATING ROLE OF RENEWABLE ENERGY: A COMPARATIVE STUDY OF SOUTH ASIAN ECONOMIES

Sonia Nisar[1], Tahir Mahmood[2], Syeda Samina Tahira[3], Syed Muhammad Amir [4], Alya Syed[5], Umer Qazi[6]

[*1,5,6]*Faculty of Social Sciences, Abasyn University, Peshawar*
[2,3,4]*Faculty of Social Sciences, University of Agriculture, Faisalabad, Pakistan*

tahir.mahmood74@uaf.edu.pk

Corresponding Author: *

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ABSTRACT
This paper assesses the interlinkages between industrialization, GHG emissions, and RE consumption in four major developing economies. Industrial growth entails significant GHG emissions since there has been substantial high fossil fuel use. The EGLS model analysis reveals that industrial growth will lead to a substantial rise in emission levels, while the integration of renewable energy sources does not appear to mitigate these emissions effectively. The bottom line of the study is a clear message to policymakers: it is crucial to consider the gradual shift to renewable energy sources in the policy framework in order to ensure sustained economic growth while successfully countering environmental challenges.
Keywords: *Renewable energy, GHG emissions, industrial growth, developing economies, EGLS model.*

INTRODUCTION

Economic growth being an integral component of development is dependent on the level of industrialization in a country (Yang et al., 2021). However, the Industrialization significantly amplifies greenhouse gas emissions (Dong et al., 2021), primarily due to the widespread reliance on fossil fuels for energy, manufacturing processes, and transportation (Kheshgi et al., 2000). While with the high growth of population rate, the use of energy raises day by day, to meet such high demand, the fossil fuels use are increasing which causes high Greenhouse emissions (Deshmukh et al., 2023).

Among many developing countries, especially in South Asia rapid industrial growth and accompanying increase in population have taken a toll on the environment (Ilyas et al., 2024). The previous one is on global prosperity in regard to the amount of environmental damage so it will be possible as a basic problem for these countries (Hong, et al., 2019; Wang & Azam, 2024).

The relationship between industrialization and greenhouse gas emissions has been extensively studied, but little is known about the moderating effect of renewable energy in lowering these emissions, particularly in the context of developing South Asian countries (Tang et al., 2023; Dunyo et al., 2024). Furthermore, deindustrialization results in economic stagnation even though it might provide some emission alleviation (Xie et al., 2024).

In four significant South Asian economies Pakistan, China, Bangladesh, and India this study intends to investigate the dynamic relationship between industrial expansion, GHG emissions, and the possible moderating influence of renewable energy.

This study will investigate how renewable energy may be able to mitigate the environmental effects of industrialization without impeding economic growth, using an Extended Generalized Least Squares (EGLS) model.

Literature review

1. Industrialization and GHG Emissions

The consequences of industrialization have long been debated, as industrialization proves to be a double-edged sword. Industrialization essentially furthers economic development at the same time as contributing to environmental degradation at an alarming rate. A significant literature shows that a rapid rate of industrialization in recent decades-especially in developing nations-is causally associated with GHG emissions. Dong et al. (2021) study that most global GHG emissions are attributed to industrial activities based on fossil fuel combustion. This is particularly evident in developing countries where industrial growth at all costs is sometimes more important than concerns for the environment. Kheshgi et al. (2000) support that "industrial processes, manufacture and transportation, for example, require huge supplies of non-renewable energy, which has resulted in increased global warming".

Economic growth and population increase in South Asia have resulted in an uptrend in energy consumption, as evidenced by increased global CO2 emissions from 20,625,273 kilotons in 1990 to 34,344,006 kilotons in 2019 according to the World Bank in 2020. This is where the leading contributors among countries in South Asia, including India and Pakistan, (Gunarathne et al. 2020) and (Adnan et al. 2024) cite increased emissions. Despite efforts to curb emissions, industrial activities continue to drive environmental degradation, making sustainable development a critical issue (Liu et al., 2020). (Cerutti et al., 2021)(Ruba et al., 2021)(Latief et al., 2021)

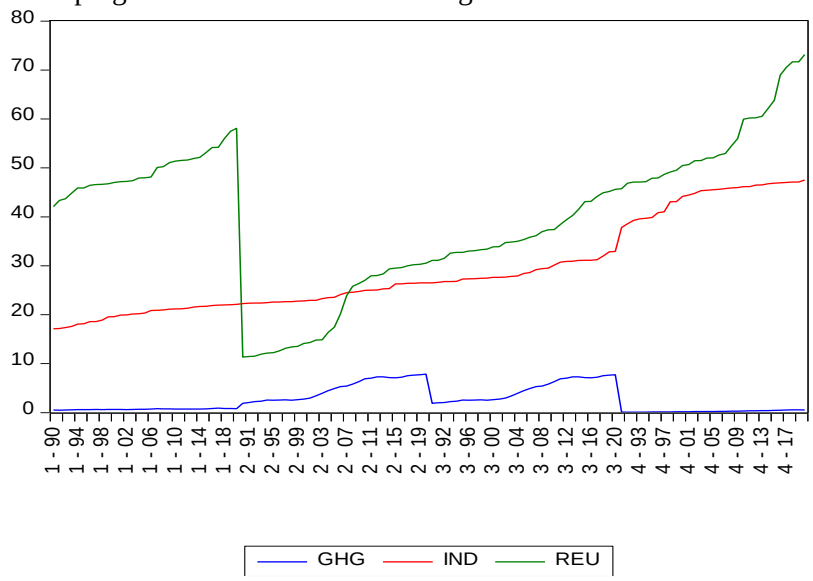

Figure 1 illustrates the trends in GHG emissions, industrial growth, and renewable energy use (REU) over time, demonstrating the strong correlation between industrial development and GHG emissions

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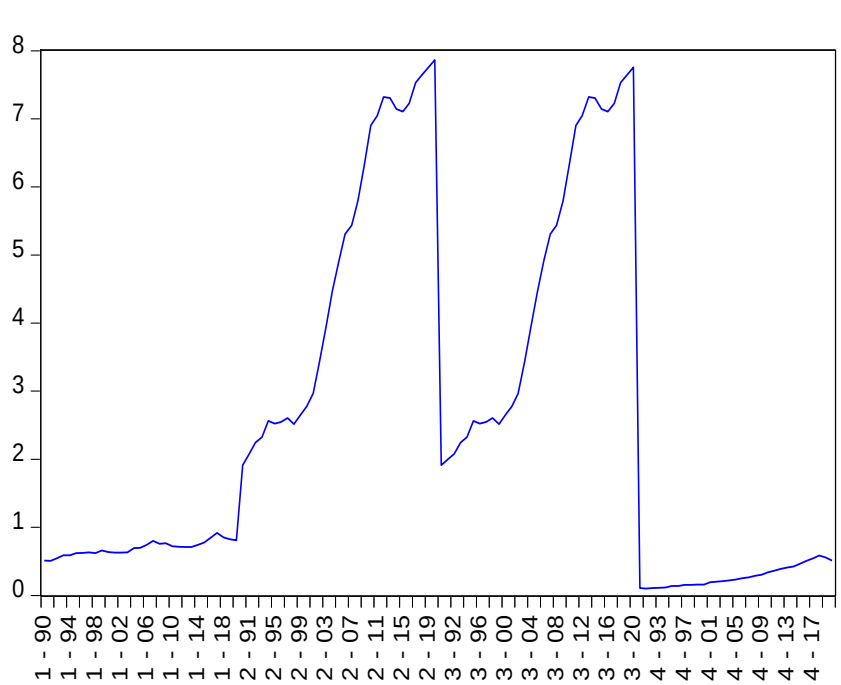
2. The Role of Renewable Energy in Mitigating GHG Emissions

Generally, renewable energy has been taken for one of the major instruments towards mitigating negative industrialization. A few works were directed to probe the role that could be played by renewable energy in lessening GHG emissions. Yesbolova et al. (2024) find in this line that while increasing consumption of renewable energy in the Turkic Republics reduced significantly in CO2-related emissions, dependence on the same by industrial production continued to be complex. Biomass, solar wind, and hydroelectricity could be the ultimate renewable sources of energy in order to reduce the ecological footprint of most industrial activities in the South Asian context.

According to Sahoo et al. (2020), the shift from non-renewable to renewable sources of energy will have a less pronounced effect on reducing emissions with uncompromised economic growth. Adam & Nsiah (2019) again bear in mind that the integration of

renewable energy into industrial processes is key to ensuring sustainable industrialization. However, according to Mental (2022), the exact impact of renewable energy on the relationship between GHG and industrialization has not yet been accounted for, if anything too little, especially within developing countries like Pakistan, India, Bangladesh, and China.



The graph shows the fluctuation of GHG emissions over time. The data starts with low emissions in the early years and shows a significant increase in emissions peaking around the year 2017, followed by a sharp decline to near-zero levels in the subsequent years.

3. Country-Specific Industrial and Environmental Challenges

Pakistan:

Pakistan's industrial sector contributes significantly to its national GHG emissions, accounting for 32% of total emissions, followed by transportation (28%) and electricity production (27%) (Climate Transparency Report, 2022). However, premature deindustrialization has been observed in recent decades, potentially mitigating GHG emissions at the cost of economic growth (Rodrik, 2015). Muhammad (2013) projects that Pakistan will release 400 million metric tons of CO2 by 2025 if current trends continue.

India:

After slowing down in the early 2000s, industrial growth has recovered with investment in infrastructure and policy reforms acting as driving agents. The industry is dominated by cement and steel industries and currently represents a lion's share of the country's total CO2 emissions (Climate Transparency Report, 2022). The share of the industrial sector is 30.6% in direct energy-related CO2 emissions and 18.7% in indirect ones.

China:

The industrial growth of China over the last two decades has been phenomenal and has heavily contributed to global CO2 emission. In 2020, the estimated amount of CO2 emission from industries was around 10.06 billion metric tons, accounting for approximately 30% of China's total emissions (Global Carbon Project, 2021). The country's reliance on coal-based energy production continues to exacerbate environmental concerns.

Bangladesh:

The Bangladesh economy began falling behind its neighbors in the initial stages of industrialization. However, the country has in recent times emerged as one of the fastest growth rates among the developing world in sectors like textiles and garments. In Bangladesh, about 33% of the total CO2 is contributed from industrial emissions, while from energy use in the industry contributes about 18% (Bangladesh Climate Transparency Report, 2020).

Each of these countries has a unique set of challenges in terms of balancing industrial growth with environmental sustainability. The rate at which industrialization has spread across the South Asia region has raised concerns over the potential long-term environmental impacts (Gasimli et al., 2022); GHG emissions have continued to rise, despite efforts toward transition to cleaner energy.

4. Transitioning to Sustainable Industrial Growth

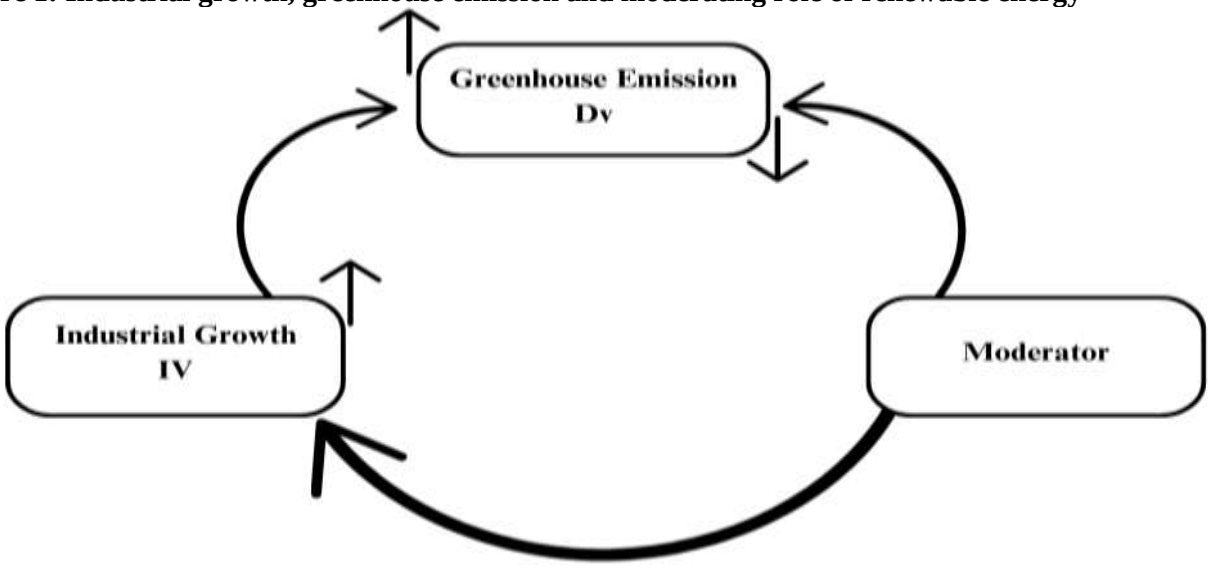
Whereas the detrimental impacts of industrialization on the environment are undeniable, the remedies still exist. It is suggested by Sahoo et al. (2020) that the shift of industries from fossil fuel to renewable energy would drastically cut GHG emissions and at the same time give a major impetus to the economy as well. In Pakistan, China, Bangladesh, and India, the sectors integrating renewable energy into their industries might act as a forerunner to new industrial development in an eco-friendly way.

On the other hand, even with industrial growth, renewable energy can play a mitigating role in emissions reduction-as has been shown by Raihan and Tuspekova (2022) in their study related to Russia. The study at hand attempts to add to such insights by examining how renewable energy is likely to lighten the environmental burden of industrialization in South Asia, using an application of the EGLS model to make an assessment of this relationship.

5. Theoretical underpinning

The model of proposed study based on environmental theories that are the pollutants haven hypothesis (PHH), which examines the effects of alternate and overseas direct inflows on environmental dilapidation and the Stochastic Impacts through Regression on Population Affluence and Technology (STIRPAT) theory used to analyze how growing population, monetary boom and technology (Industry and strength etc.) have an effect on environmental deterioration and quality. The study is consists of 3 variables, in which the experimental variable is industry growth (Ind) and Greenhouse gas emissions (GHG) is measured variable, the (Reu) is a renewable energy (Indreu) is taking as interaction term of renewable energy and industry.

Figure 1: Industrial growth, greenhouse emission and moderating role of renewable energy



6. Hypotheses of the Study

H_1: There is a significant and positive impact of industry growth on Greenhouse gas emissions. H_2: There is a significant moderating role of renewable in the linkage between industry growth and greenhouse gas emissions.

3 Research Methodology

The present research employs several inferential econometric techniques and up-to-date data to assess the relationship between the variables under

investigation. The steps and general overview of econometric analysis are shown in Fig. 3

3.1 Data.

To study the impact of renewable energy consumption on the relationship between industry and greenhouse gas emissions, this research is quantitative in nature. The study tested the proposed hypothesis by utilizing the explanatory and correlational approaches. The research conducted under the time series study design. This study assesses the relationship between the studied variables using several inferential econometric methodologies and current data. This comparative study of Asian region countries examines impact of industrial growth on GHG emission by utilizing current data and multiple inferential econometrics approaches. This study assumes World Development Indicators (WDI) data from 1990 to 2020. The dependent variable is GHG emission and independent variable industrial growth, the moderating variable of renewable energy.

Figure 2: The flowchart outlines econometric research

Table 1

Definition of variable

Variables	*Unite of measurement*	*Symbol of the variable*	*Data sources*
Green gas emission(pc)	Tons	GHG	World Bank
Industry Growth	%	Ind	World Bank
Renewable	%	Reu	World Bank
Interaction (ind*reu)	-	Indreu	Ind *ren data

The variables are listed in Table 1 together with the corresponding logarithmic conditions, measurement units, and data sources. The average levels of GHG, IND, REU, and INTERACTION during the course of the 31-year period are shown in Table 2 by the mean values. The high standard deviation indicates

that GHG is highly variable. The data distributions' asymmetry and peakedness are indicated by the skewness and kurtosis values. The significant p-values of the Jarque-Bera test reveal that the data for GHG, IND, and INTERACTION are not normally distributed.

3.2 Equation of Regression Model

$$GHG_{it} = f\,(IND_{it}\,,\ REU_{it}\,,\ INDREU_{it}) + \varepsilon_{ita}$$

Table

Descriptive Statistics

	GHG	*IND*	*REU*	*INTERACTION*
Mean	2.618757	29.35527	40.53831	1264.012
Median	1.416509	26.50965	44.50500	990.5189
Maximum	7.866840	47.55740	73.16000	3479.299
Minimum	0.099144	17.15889	11.34000	252.6482
Std. Dev.	2.636926	9.410687	14.94817	799.7039
Skewness	0.837316	0.792735	-0.266373	1.091231
Kurtosis	2.171948	2.236612	2.576820	3.391349
Jarque-Bera	18.03198	15.99848	2.391642	25.40084
Probability	0.000121	0.000336	0.302456	0.000003
Sum	324.7259	3640.054	5026.750	156737.5
Sum Sq. Dev.	855.2654	10893.01	27484.07	78661734
Observations	124	124	124	124

Table 3

Correlation

Probability	*GHG*	*IND*	*REU*	*INTERACTION*
GHG	1.000000			

IND	-0.220410	1.000000		
	0.0139	-----		
REU	-0.497154	0.530315	1.000000	
	0.0000	0.0000	-----	
INTERACTION	-0.411145	0.900298	0.831020	1.000000
	0.0000	0.0000	0.0000	-----

The tests that evaluate cross-section dependence in the residuals are included in Table 4. Using the Breusch-Pagan LM test, cross-sectional dependence was investigated, and it was found in all three variables. To check for stationarity, we employed the second-generation unit root test technique, the CADF test. At the first difference, it was found that all three variables were stationary. All three variables were found to be stationary at the first difference, indicating that there are interdependencies between the cross-sections in the data. All tests show significant cross-section dependence in the residuals.

Table 4

Cross-sectional dependence and unit root test findings of research data

Variable	*cross-section dependence*		*level*		*1st difference*	
	statistic	Prob	Statistic	Prob	Statistic	Prob
GHG	167.8414	0.0000	0.9969	0.9995	0.0851	0.0613
IND	46.71959	0.0000	1.0000	0.9992	0.0080	0.0001

REU	12.95116	0.0000	1.0000	1.0000	0.0242	0.0058

According to table 5's panel regression analysis, which used GHG as the dependent variable, IND significantly and favorably affects GHG emissions (p-value = 0.0000). REU affects GHG emissions negatively but not significantly (p-value= 0.5226). GHG emissions are significantly and negatively impacted by. INTERACTION (p-value = 0.0000). R-squared = 0.380416 indicates that the model accounts for about 38.04% of the variation in GHG emissions. The results indicate that whereas interaction effects greatly reduce greenhouse gas emissions, industrial activity significantly increases them. However, this model does not demonstrate a statistically significant direct effect of renewable energy use on greenhouse gas emissions

Table 5:
EGLS

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
IND	0.433195	0.013408	32.30886	0.0000
REU	0.465255	0.012482	37.27323	0.0000
INTERACTION	-0.009408	0.000262	-35.93238	0.0000
C	-17.06682	0.535950	-31.84408	0.0000
	Effects Specification			
Cross-section fixed (dummy variables)				
	Weighted Statistics			
R-squared	0.984048	Mean dependent var		4.184843
Adjusted R-squared	0.983230	S.D. dependent var		5.428285
S.E. of regression	0.711434	Sum squared resid		59.21820
F-statistic	1202.905	Durbin-Watson stat		0.241072
Prob(F-statistic)	0.000000			
	Unweighted Statistics			
R-squared	0.907683	Mean dependent var		2.618757
Sum squared resid	78.95553	Durbin-Watson stat		0.062020

Discussion and Conclusion

Discussion

This study examines the dynamic relationship between industrial growth, greenhouse gas (GHG) emissions, and the moderating role of renewable energy in four major East Asian economies: Pakistan, China, Bangladesh, and India. East Asian nations' capacity to deal with environmental concerns tends to lag behind their fast economic growth (Campos-Romero & Óscar Rodil-Marzábal, 2024). Due to their rapid growth, these economies have not been able to establish effective environmental policies. The study based two hypothesis that are H1 There is a significant and positive impact of industry growth on Greenhouse gas emissions and second is interaction of renewable and industry growth significant impact on GHG. After analysis the finding of the results shed light on several critical aspects of this relationship, providing valuable insights for policymakers and stakeholders in these regions. The findings confirm the hypothesis that industrial growth significantly and positively impacts GHG emissions. This supports previous observations made by such studies as Dong et al. 2021, Kheshgi et al. 2000, and Yesbolova et al. 2024 cited in Fan et al. 2023, pointing out that rapid industrialization results in environmental costs. This also points to the fact that rapidly increasing industrial activities are requiring increasing use of fossil fuels, energy, and transport for the increased CO2 emission rate. This is considered a very serious challenge with which to achieve sustainable economic growth and at the same time prevent negative environmental consequences.

Regional analysis explains the variation in the rate of industrial growth and GHG emission among the selected countries. The rapid growth of the industrial sector in China is matched by a steep increase in its GHG emissions, which indicates the environmental cost of rapid economic growth. Early deindustrialization in Pakistan has kept its GHG emissions low, but its economic stagnation is equally undesirable. Rapid increases in the use of fossil fuel and extensive manufacturing activities have also made India's and Bangladesh's industrial sectors major contributors to overall GHG emissions.

Conclusion

Industrial growth's contribution to GHG emissions and the role of renewable energy in mitigation are issues related to four important emerging economies that are explored through this paper: China, India, Bangladesh, and Pakistan. The findings verify that industrial growth accounts for a significant proportion in the increase of GHG emissions within the nations under consideration, hence underlining the environmental cost of rapid industrialization. The high dependence on fossil fuels for energy, manufacturing, and transportation becomes a major driver in this matter, hence a major challenge to attaining sustainable economic growth.

Interestingly, even though renewable energy on its own does not directly indicate the statistical significance for reduction in GHG emissions, its interaction with industrial growth does have a significant moderating effect. What this, in effect, means is that the introduction of renewable energy into the industrial process may tone down the environmental impact of industrialization more than mere industrial growth without consideration of renewable energy sources.

The model brings out regional peculiarities in the interaction between the processes of industrialization and GHG emissions. The rapid expansion of industry in China has been matched by a rapid rise in emissions, but the premature deindustrialization of Pakistan is associated with comparatively low emissions at the cost of stagnant economic growth. For India and Bangladesh, the challenge of bringing a balance between industrial growth and environmental sustainability remains formidable in view of the high dependence on fossil fuels. In sum, the study finds that integrating renewable energies into industrial strategies creates the pathway to sustainable development for emerging economies. This will not only restrain the environmental impact of industrial growth but also align economic development with global environmental sustainability goals. Indeed, policymakers in those regions must give due priority to adopting renewable energy technologies and to implementing policies encouraging their integration in industrial processes to strike a balance between economic growth and environmental preservation.

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