Policy Journal of Social Science Review

Online ISSN 3006-4635 Print ISSN 3006-4627

Vol. 4 No. 2 (2026)

Who Owns the Air? Governance Failures, Corruption, and the Tragedy of the Environmental Commons in Pakistan

*[1]**Afia Ilyas**

[2]**Azam Hussain**

*[1]Assistant Professor, Government Postgraduate College for Women, Haripur Khyber Pakhtunkhwa 22620, Pakistan.

[2]Graduate Coordinator, Department of Economics, The University of Haripur, Haripur Khyber Pakhtunkhwa 22620, Pakistan

[1]afiafaysal@gmail.com, [2]azamswati515@gmail.com

Abstract

Drawing on the framework of the tragedy of the commons, this study examines the effects of urbanization, energy structure, and governance quality on carbon dioxide (CO_2) emissions in Pakistan. Using annual time-series data from 1996 to 2024, the analysis explores the dynamic interplay between energy consumption, renewable energy penetration, urban population growth, and institutional dimensions, including government effectiveness, rule of law, and control of corruption. The empirical estimation employs Robust Least Squares to address potential heteroskedasticity and mitigate the influence of outliers, ensuring parameter stability and robust inference. The results indicate that urban population expansion and greater renewable energy adoption significantly reduce per capita CO_2 emissions, highlighting the environmental benefits of sustainable urban development and clean energy transition. Governance indicators exhibit heterogeneous effects: the rule of law and corruption control are positively associated with emissions, suggesting that institutional strengthening may initially stimulate economic and energy-intensive activities in the absence of stringent environmental enforcement. After controlling for structural and institutional factors, per capita energy consumption does not exert a statistically significant independent effect on emissions. The findings underscore that governance reforms must be aligned with explicit environmental objectives to ensure that institutional improvements contribute to emission mitigation rather than unintentionally reinforcing carbon-intensive growth. By integrating urban dynamics, energy structure, and institutional quality into a unified analytical framework, the study advances the growth–environment discourse in developing country contexts and provides policy-relevant insights for Pakistan's long-term environmental sustainability.

Keywords: Carbon emissions; Urban growth; Energy transition; Fiscal governance; Institutional effectiveness; Pakistan.

Article Details:

Received on 30 Jan, 2026

Accepted on 27 Feb, 2026

Published on 28 Feb, 2026

Corresponding Authors*

Afia Ilyas

1. Introduction

The rise in global carbon emissions has made institutional accountability, environmental governance, and the management of shared natural resources important themes in academic and policy discourse(Bringezu *et al.,* 2016).Pakistan's severe ecological degradation, energy instability, and rapid urbanisation have made the subject of "who owns the air" more than just a philosophical one(Afridi., 2025). The persistent tragedy of the commons, widespread corruption, and inadequate regulatory frameworks emphasise this pressing governance dilemma. Carbon dioxide (CO_2) emissions have increased significantly over the past 20 years despite numerous international commitments and regulatory frameworks, primarily as a result of the usage of fossil fuels, industrial expansion, and unsustainable energy practices. The persistent tragedy of the commons, widespread corruption, and inadequate regulatory frameworks emphasise this pressing governance dilemma. Over the past 20 years, carbon dioxide (CO_2) emissions have increased internationally despite numerous international commitments and regulatory frameworks, primarily as a result of the use of fossil fuels, industrial expansion, and unsustainable energy practices(Anwar *et al.,* 2020). The World Bank (2024) reports that structural changes in Pakistan's CO_2 emissions per capita are associated with political instability, uneven energy reforms, and insufficient implementation of environmental legislation. The quality of governance has been demonstrated to have a substantial impact on environmental sustainability, especially in developing countries (Azimi *et al.,* 2023). The Worldwide Governance Indicators (WGI) framework highlights corruption prevention, government effectiveness, and the rule of law as essential components of institutional success(Handoyo., 2023).Empirical research demonstrates that strong institutions are significantly linked to better environmental outcomes because strong governance affects policy implementation, enhances regulatory enforcement, and reduces opportunities for rent-seeking behaviour(Tang *et al.,* 2024; Rio& Lores., 2017). However, ineffective government regulations make it difficult to control industrial emissions, manage environmental externalities, or move towards clean energy systems (Van den Bergh., 2013).Pakistan's governance issues include inadequate monitoring technology, fragmented environmental organisations, delayed changes, and a lack of judicial ability to address environmental violations(Hiader *et al.,* 2024).

Corruption exacerbates these issues and accelerates ecological deterioration by enabling pollution-intensive businesses to avoid environmental restrictions, get illegal licenses, or avoid fines(Si *et al.*, 2025Therefore, the combination of corruption, a weak rule of law, and ineffective governmental systems results in both direct and indirect increases in carbon emissions(Muhammad & Long.,2021), highlighting the necessity of a thorough institutional analysis in order to comprehend Pakistan's environmental trajectory. The structural and demographic features of Pakistan's economy increase environmental stress(Khan *et al.,* 2021)where urban expansion raises carbon emissions in the absence of adequate governance measures like pollution monitoring, environmental zoning, and public transportation(Lyu *et al.*, 2025). Furthermore, non-renewable energy sources including coal, oil, and natural gas make up the majority of Pakistan's national energy mix(Ahmad *et al.*, 2022Regulatory barriers, budgetary limitations, inadequate grid integration, and a delayed adoption of renewable energy technology have all hindered Pakistan's transition to greener energy sources(Salim *et al.*, 2025). Due mostly to institutional flaws and budgetary limitations, renewable energy consumption still makes up a small portion of overall energy use, despite a slight growth in recent years. CO_2 emissions are not only a problem for the environment, but they also indicate more severe structural dysfunctions caused by bad governance. The coordination across numerous authorities, precise policy directives, and uniform enforcement required for efficient environmental administration have historically been absent from Pakistan. Policies like the Pakistan Environmental Protection Act (1997) and the National Environmental Quality Standards (NEQS) have often failed to produce the intended results due to insufficient implementation mechanisms, political meddling, a lack of resources, and corruption within regulatory agencies. Hardin's assertion that environmental commons are still vulnerable to overuse in the absence of coordinated action and strict regulation is supported by the fact that inadequate monitoring systems allow firms to emit toxins without repercussions (Adeboye., 2025). The intersections of economic interests, energy security concerns, governance challenges, and the influence of industrial lobbying make environmental decision-making a difficult process(Komendantova et al., 2018). This complex governance environment emphasises the need for a comprehensive empirical investigation that links institutional issues to carbon emissions in order to better understand how governance failures result in environmental degradation(Hassan *et al.,* 2020).

Given these dynamics, this study empirically examines how CO2 emissions relate to key governance metrics in Pakistan between 1996 and 2024, such as urban population growth, energy use, and consumption of renewable energy, as well as government efficacy, rule of law, and corruption prevention. Using time-series data from the World Development Indicators (WDI) and the Worldwide Governance Indicators (WGI), the study aims to assess how institutional quality and demographic-energy factors jointly influence Pakistan's environmental outcomes. This period allows for a comprehensive analysis of the connection between changes in carbon emissions and variations in governance quality.

2. Literature Review

2.1. CO2 Emissions, Government Effectiveness, and Control of Corruption

The interdependence of CO2 emissions and institutional quality emphasises how crucial government efficacy and corruption prevention are in determining environmental results (Yang *et al.*, 2022). Higher government efficacy typically results in more effective environmental policy implementation, which lowers per-capita CO2emissions.Countries with higher government effectiveness tend to implement environmental policies more efficiently, resulting in lower per-capita CO2 emissions(Hassan *et al.*, 2018). Bhattacharya *et al.*, (2023) demonstrate that bureaucratic capacity and policy coordination directly influence the enforcement of pollution control measures, thereby reducing emissions intensity.Empirical evidence further suggests that government effectiveness interacts with economic growth, allowing countries to achieve higher output with comparatively lower carbon emissions (Arango-Miranda et al., 2018). Anti- corruption reforms significantly lower per-capita CO2 emissions by enhancing transparency and accountability in industrial compliance(Oge.,2016). The rule of law provides a legal framework to hold polluters accountable, ensuring that policy enforcement is credible and predictable. Setzer& Benjamin., (2020) highlighted that weak legal institutions exacerbate emissions, as delayed judicial interventions allow environmental violations to persist. Structural-break time-series analyses indicate that periods of political instability or institutional weakening correspond with measurable spikes in CO_2 per capita (Olasunkanmi.,2021). Countries with more effective governments and less corruption consistently have lower CO2 emissions per capita, according to mixed-methods approaches paired with satellite-based emissions data and governance metrics (Ndubuisi & Nisafety., 2025).When taken as a whole, these studies show that monitoring corruption and government efficacy are key institutional levers in creating a healthy environment.

2.2. **CO_2 Emissions, Rule of Law, and Urban Population**
The interplay between CO_2 emissions, rule of law, and urban population has received increasing attention in environmental economics and governance studies. It is commonly acknowledged that the rule of law is a crucial institutional component affecting environmental results (Atta& Sharifi., 2024).Robust legislative frameworks guarantee uniform enforcement of environmental standards, establishing reliable deterrents against polluting activities(Atta&Sharifi., 2025).According to empirical research, a lax rule of laraises per-capita CO_2 emissions because industrial operations are carried out with little inspection and regulatory infractions are rarely punished (Atta *et al.*, 2024).Increased demand for energy, transportation, housing, and industrial goods all major sources of carbon emissions—causes urban population development to put enormous strain on environmental quality, especially in emerging nations (Sarkodie *et al.,* 2020). Urban emissions are also extremely sensitive to the governance context, according to research combining demographic and legal data; cities in areas with more robust legal enforcement systems have slower growth in per-capita CO_2 emissions despite fast urban expansion(Yang et al., 2025).When taken as a whole, these studies show that although urbanisation increases energy consumption and emissions, its detrimental effects on the environment can be lessened by the existence of strong legal structures.

2.3. CO_2 Emissions, Energy Use, and Renewable Energy Consumption
It is commonly acknowledged that one of the most important factors influencing CO_2 emissions is energy consumption, with higher energy use typically translating into higher carbon production, especially when energy comes from fossil fuels (Nejat *et al.*, 2015). According to empirical research, CO_2 emissions are positively correlated with per-capita energy consumption, expressed in kilogrammes of oil equivalent, which reflects the direct emissions intensity of fossil fuel-based production and consumption(Haung *et al.*, 2023; Sadik-Zada *et al.*, 2020). An increasingly important tactic for reducing carbon emissions is the growth of renewable energy consumption, expressed as a proportion of total final energy use(Huisingh *et al.*, 2015).Research shows that increased use of hydroelectric, solar, and wind energy lowers the carbon intensity of economic activity, especially when renewables replace fossil fuel-based power(Kabeyi& Olanrewaju., 2022; Farghali et al., 2023).Time-series and panel analyses show that governance systems, technology efficiency, and policy backing all significantly influence the environmental advantages of renewable energy (Pan *et al.*, 2019; Basher *et al.*, 2015).Furthermore, studies show that increasing energy efficiency in the household and commercial sectors and incorporating renewable energy into the national grid can further decouple energy usage from emissions, supporting long-term sustainability(Reddy *et al.*, 2024). All of these studies point to the need for deliberate investment in renewable energy sources to lessen the environmental impact of economic expansion, even though overall energy consumption is what causes CO_2 emissions.

2.4. Research Gap
Wide array of reports exist on CO_2 emission data and interlinking of institutional policies across different countries in managing the renewable energy strategies and CO_2 emission, however, the determinants that manage the environmental outcomes remains unanswered. Moreover, the studies lack the detailed institutional challenges prevailing in Pakistan that influence the institutional policies and leads to governance failures. Furthermore, challenges like political instability, inconsistent institutional policies, and weak institutional regulation and monitoring also are additive factors that need to be investigated. In addition to these challenges, few studies exist that interlink the determinants like energy consumption, economic growth, rule of law, corruption control, with CO_2 emissionas single study. Moreover,

the studies reported to date, do not differentiate the fossil and renewable energy consumption and consider them as one measurable variable. A long-term time series analysis which covers the changing structural dynamics of Pakistan with reference to CO_2 emission and governance indicators as one study, is also very limited. These factors necessitate the time series analysis keeping in view the institutional challenges, prevailing institutional policies and energy consumption in Pakistan.

2.5. Contribution of the Study

Using data for Pakistan from 1996 to 2024, this study offers a thorough empirical model that links CO2 emissions with six important determinants: urban population, fossil fuel energy use, renewable energy consumption, government effectiveness, corruption control, and rule of law. A clearer view of Pakistan's energy emissions patterns can be obtained by distinguishing between conventional and renewable energy sources. Additionally, this study employs sophisticated time-series methods to support the empirical data. Most significantly, the study improves knowledge of Pakistani institutional quality and policymaking and provides a thorough grasp of environmental governance innovation, which can aid Pakistan in making a seamless transition to cleaner and more sustainable energy systems.

3. Theoretical Framework

The current theoretical framework utilizes the expanded standard Solow-Swan growth model to add institutional factors like the rule of law, government efficacy, and corruption control and environmental outcomes (CO_2 emissions per capita). To build up an experimentally estimable model that incorporates data for Pakistan from in years 1990–2024, a set of equations relating capital accumulation, labor growth, technology, energy use, urbanization, renewable energy use, and governance to CO_2 emissions are derived.

3.1. Introduction to the Solow Growth Model

A neoclassical approach that explains long-term economic growth based on capital accumulation, labour force expansion, and technical advancement is the Solow–Swan Growth Model (Solow, 1956; Swan, 1956). Solow's fundamental idea is that while institutional quality affects how well resources are converted into output, long-term growth depends on technical advancement. A typical Cobb-Douglas production function is assumed by the model:

$$Y_t = K_t^{\propto}(L_t A)_t{}^{1-\propto}$$

where:
Y(t) = aggregate output,
K(t) = capital stock,
L(t) = labor force,
A(t) = technology level,
α = output elasticity of capital.
Dividing by labor (L) gives the per- worker production function:
$y_t = \ k_t^{\propto}.A_t$
Assuming A(t) grows exogenously at rate g and L(t) at rate n.
Capital accumulation is described by:

$$K_t = sY_t \ - \delta k_t$$

Capital accumulation follows:

$$K_t = sy_t - (n + g + \delta)k_t$$

where:
s = savings rate,
δ = depreciation rate.

The economy converges to steady- state capital per worker k* when $\acute{k}$ = 0:
$sk^{\propto}$= (n+g+δ)k
Thus:
k^{*} = s/$(n+g+\delta)^{1/1-\propto}$

3.2. Extending the Solow Model Toward Environmental Outcomes

Environmental deterioration, emissions, and governance are not taken into account by the conventional Solow model. However, environmental factors including limitations on sustainable growth are included in contemporary extensions (Brock & Taylor, 2010; Smulders, 1999). As a result, economic production, energy consumption, and technology can all be used to express CO2 emissions (E):

E_t=$\varphi.Y_t(EC_t/A_t)$
where:
EC= energy consumption.
Institutional quality modifies ϕ and A(t):

By lowering the carbon intensity of energy usage (ϕ) and increasing institutional and technological efficiency A(t) through the use of cleaner energy, strong governance reduces emissions. On the other hand, poor governance raises ϕ because of corruption, lax regulations, and a persistent reliance on dirty energy sources.

CO2 emissions are influenced by institutional and technological efficiency in addition to economic output and energy use. This formulation's denominator, A(t), shows that advancements in technology, institutional efficacy, and governance quality lower emissions per unit of energy use. This looks at how Pakistan's environmental results are affected by government efficacy, corruption prevention, and the rule of law.

Thus, environmental quality becomes endogenous through institutions:

$$E_t\text{=f}(G_{t,}CC_t, RL_t,UP_t,EU_t,RE_t)$$

3.3. Linking Solow Model Variables with Pakistan's Context (1996–2024)

In light of Pakistan's high energy consumption in relation to rapid growth and institutional flaws, capital accumulation, energy structure, urbanisation, and institutional governance all affect CO2 emissions.

Transforming the Solow equation for empirical use:

$$CO_{2t}=\beta_0+\beta_1GE_t+\beta_2CC_t+\beta_3RL_t+\beta_4UP_t+\beta_5EU_t+\beta_6RE_t+\epsilon_t$$

By treating institutions as productivity-enhancing factors, adding urban population as a demographic growth component (n), using energy consumption as a stand-in for capital-energy intensity, and adding renewable energy as the technological progress component (A), this is consistent with the Solow framework.

3.4. Final Theoretical Structure

Solow Base:

$$Y_t = K_t^{\propto}(L_tA)_t^{\ 1-\propto}$$

Environmental and institutional extension:
CO_{2t}= f (institutions, demography, energy structure)
Empirical transformation:

$$CO_{2t}=\beta_0+\beta_1GE_t+\beta_2CC_t+\beta_3RL_t+\beta_4UP_t+\beta_5EU_t-\beta_6RE_t+\epsilon_t$$

Policy Journal of Social Science Review
Online ISSN Print ISSN
3006-4635 3006-4627
Vol. 4 No. 2 (2026)

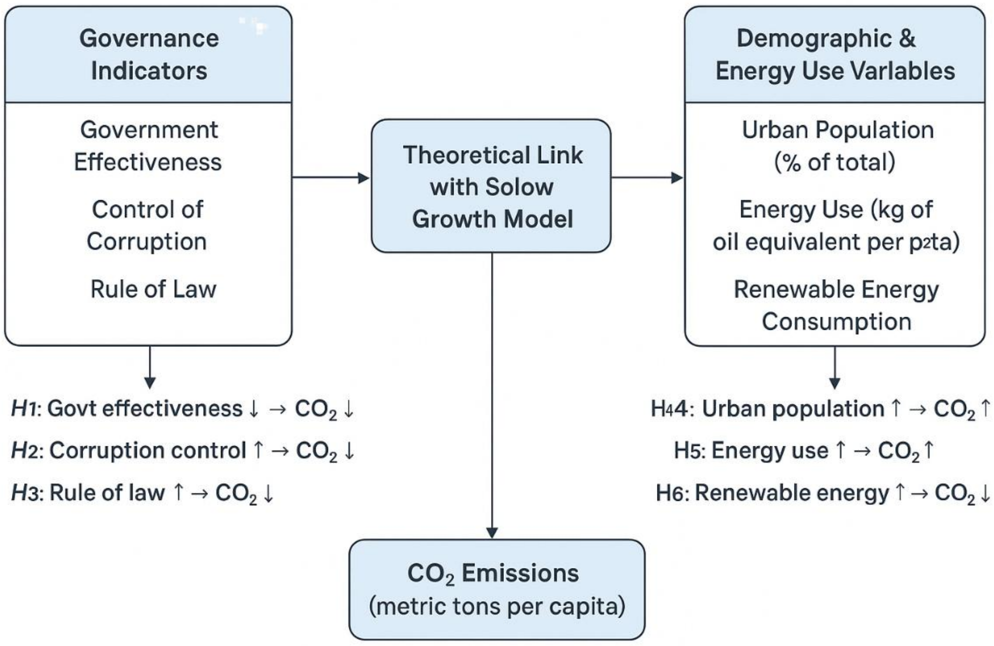

Figure 1: Theoretical Framework of the Study

4. Methodology

The methodology encompasses data on Pakistan's CO_2 emission, energy consumption, institutional efficiency, demographic structures, corruption control, and governance quality taken from the World Development Indicators (WDI) for years 1990 through 2024. THE WDI provides time series data for all the selected indicators. For better understanding of empirical analysis,detailed explanations of every variable, their operational definitions, theoretical expectations, and data sources are included in the methodology.

4.1 Variable Description and Operational Definitions

The study uses six independent variables government performance, corruption control, rule of law, urban population, energy use, and renewable energy consumption as well as one dependent variable, CO2 emissions. CO2 emissions, which are measured in metric tonnes per capita and serve as a stand-in for environmental quality, indicate the quantity of carbon dioxide generated by the combustion of fossil fuels and industrial operations. CO2 emissions are expected to decrease with increased government efficacy. The quality of public services, the competence of public servants, and the government's ability to implement policies are all indicators of government effectiveness.

It is anticipated that increased anti-corruption initiatives will lessen environmental harm. The degree to which public authority is exercised without misuse or corruption is evaluated by control of corruption. The rule of law serves as a gauge for the effectiveness of legal frameworks, enforcement tactics, and regulatory compliance; a robust rule of law is generally linked to less pollution. The proportion of people who live in urban regions indicates the level of urbanisation, which is expected to increase CO2 emissions due to increasing energy use, transportation, and industrial activity. Increased CO2 emissions are associated with increased energy demand, particularly from fossil fuels. The total amount of energy used per person is measured in kilogrammes of oil equivalent per person. CO2 emissions are expected to decrease with a greater reliance on renewable energy. The contribution of sustainable energy sources is captured when renewable energy consumption is stated as a proportion of total final energy use.

Table 1 provides a detailed summary of all variables, including their symbols, units, expected link with CO2 emissions, and data sources. The dependent variable CO2 emissions is measured in metric tonnes per capita. It is expected that higher values will reduce CO2 emissions. The indices for rule of law (RL), government effectiveness (GE), and control of corruption (CC) range from −2.5 to +2.5. Urban population (URB) and energy use (EU) are expected to have positive correlations with CO2 emissions, whereas renewable energy consumption (REN) is expected to reduce emissions. All of the variables' data comes from the WDI (2024).

The following empirical model is estimated in order to examine the impact of energy trends, demographic shifts, and governance on carbon dioxide emissions:

$$CO_{2t} = \beta_0 + \beta_1 GE_t + \beta_2 CC_t + \beta_3 RL_t + \beta_4 URB_t + \beta_5 EU_t + \beta_6 RE_t + \epsilon_t$$

The study employs correlation analysis to examine the direction and strength of relationships between CO2 emissions, governance indicators, urbanisation, and energy-related variables after using descriptive statistics to summarise the central tendencies and dispersion of the variables, depending on the characteristics of the data.Robust Least Squares (RLS) provides reliable estimates even when the dataset contains anomalies or heteroskedasticity, in contrast to Ordinary Least Squares (OLS), which is extremely sensitive to outliers and extreme observations. This is particularly important for data pertaining to the environment and governance, which may include aberrant spikes caused by unanticipated trends in urbanisation, energy shocks, or policy changes. RLS ensures that the computed coefficients accurately reflect the central tendency of the data and reduces the impact of outliers by giving extreme observations less weight. This methodological approach makes the empirical results more trustworthy and credible.

Table 1: ***List of Variables***

Variables	Symbol	Units / Scale	Expected Relationship with CO2 Emissions	Data Source
CO2 Emissions (metric tons per capita)	CO2	Metric tons per capita	Dependent Variable	WDI (2024)
Government Effectiveness	GE	Index (−2.5 to +2.5)	Negative (↑ GE → ↓ CO_2)	WDI (2024)
Control of Corruption	CC	Index (−2.5 to +2.5)	Negative (↑ CC → ↓ CO_2)	WDI (2024)
Rule of Law	RL	Index (−2.5 to +2.5)	Negative (↑ RL → ↓ CO_2)	WDI (2024)
Urban Population (% of total)	URB	Percentage (%)	Positive (↑ URB → ↑ CO_2)	WDI (2024)
Energy Use (kg of oil equivalent per capita)	EU	kg of oil equivalent per capita	Positive (↑ EU → ↑ CO_2)	WDI (2024)
Renewable Energy Consumption (% of total final energy use)	REN	Percentage (%)	Negative (↑ REN → ↓ CO_2)	WDI (2024)

General ADF form (reference)
The general ADF regression (trend-augmented form) is:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \varepsilon_t$$

where $y_{t=}y_{t-}\, y_{t-1}$
(p) is the lag length and e is a white-noise error.
Null hypothesis: H_0: γ=0 (unit root, nonstationary).
Alternative hypothesis: H_1: γ<01 (stationary).

1 Carbon dioxide per capita —CO_{2t}

Upper (trend-augmented) form

$$\Delta CO_2 = \alpha_{CO_2} + \beta_{CO_2} t + \gamma_{co_2} CO_{2,t-1} + \sum_{i=1}^{p} \delta\, CO_{2,I} \Delta CO_{2,t-i} + \varepsilon_{CO_{2,}} t$$

Lower (no constant, no trend) for

$$\boldsymbol{\Delta CO_{2t} = \gamma_{co_2} CO_{2,t-1} + \sum_{i=1}^{p} \delta_{co_{2,i}} \Delta CO_{2,t-i} + \varepsilon_{CO_{2,t}}}$$

2 Government effectivenessGE_t

Upper (trend-augmented) form

$$\Delta GE_t = \alpha_{GE} + \beta_{GE} t + \gamma_{GE} GE_{t-1} + \sum_{I=1}^{P} \delta_{GE,i} \Delta GE_{t-i} + \varepsilon_{GE,t}$$

Lower (no constant, no trend) form

$$\boldsymbol{\Delta GE_t = \gamma_{GE,i} \Delta GE_{t-i} + \sum_{i=1}^{p} \delta_{GE,i} \Delta GE_{t-i} + \varepsilon_{GE,t}}$$

3. Control of corruption CC_t

Upper (trend-augmented) form

$$\Delta CC_t = \alpha_{cc} + \beta_{cc^t} + \gamma_{cc} cc_{t-1} + \sum_{i=1}^{p} \delta_{cc,i}\, \Delta CC_{t-i} + \varepsilon_{cc,t}$$

Lower (no constant, no trend) form

$$\boldsymbol{\Delta CC_t = \gamma_{cc} CC_{t-1} + \sum_{i=1}^{p} \delta_{cc,i}\, \Delta CC_{t-i} + \varepsilon_{cc,t}}$$

4. Rule of lawRL_t

Upper (trend-augmented) form

$$\boldsymbol{\Delta RL_t = \alpha_{RL} + \beta_{RL^t} + \gamma_{RL} RL_{t-1} + \sum_{I=1}^{P} \delta_{RL,i} \Delta RL_{t-i} + \varepsilon_{RL,t}}$$

Lower (no constant, no trend) form

$$\boldsymbol{\Delta RL_t = \gamma_{RL} RL_{t-1} + \sum_{i=1}^{p} \delta_{RL,I}\, \Delta RL_{t-i} + \varepsilon_{RL,t}}$$

5. Urban population (% of total) URB_t

Upper (trend-augmented) form

$$\Delta URB_t = \alpha_{URB} + \beta_{URB^t} + \gamma_{URB} URB_{t-1} + \sum_{i=1}^{p} \delta_{URB,i} \Delta URB_{t-i} + \varepsilon_{URB,t}$$

Lower (no constant, no trend) form

$$\Delta URB_t = \gamma_{URB} URB_{t-1} + \sum_{i=1}^{p} \delta_{URB,i} \Delta URB_{t-i} + \varepsilon_{URB,t}$$

6. Energy use (kg of oil equivalent per capita) — EU_t

Upper (trend-augmented) form

$$\Delta EU_t = \alpha_{EU} + \beta_{EU^t} + \gamma_{EU} EU_{t-1} + \sum_{i=1}^{p} \delta_{EU,i} \Delta EU_{t-i} + \varepsilon_{EU,t}$$

Lower (no constant, no trend) form

$$\Delta EU_t = \gamma_{EU} EU_{t-1} + \sum_{i=1}^{p} \delta_{EU,i} \Delta EU_{t-i} + \varepsilon_{EU,t}$$

7. Renewable energy share (%) —RE_t

Upper (trend-augmented) form

$$\Delta RE_t = \alpha_{RE} + \beta_{RE^t} + \gamma_{RE} RE_{t-1} + \sum_{i=1}^{p} \delta_{RE,i} \Delta RE_{t-i} + \varepsilon_{RE,t}$$

Lower (no constant, no trend) form

$$\Delta RE_t = \gamma_{RE} RE_{t-1} + \sum_{i=1}^{P} \delta_{RE,i} \Delta RE_{t-1} \Delta RE_{t-i} + \varepsilon_{RE,t}$$

5. Results

The study's empirical results are presented in this section, which uses the Robust Least Squares (RLS) approach to estimate Pakistan's carbon dioxide (CO2) emissions per capita from 1996 to 2024. In order to ensure that the estimated coefficients are trustworthy and not disproportionately impacted by extreme observations, the RLS technique is used to solve potential problems of outliers and heteroscedasticity in the time-series data. Along with demographic and energy-related factors including urban population share, energy use per capita, and share of renewable energy consumption, the analysis examines the influence of institutional quality, as measured by government efficacy, corruption control, and rule of law.
The findings are interpreted in the context of the extended Solow-Swan growth model, emphasising the ways in which energy characteristics and governance systems interact to influence CO2 emissions in Pakistan. In the context of Pakistan's institutional and economic environment, this method enables reliable inference regarding the short-term and long-term consequences of these variables, offering insights into the mechanisms behind environmental degradation and the tragedy of the commons.

An introductory summary of the behaviour and distributional features of the variables for Pakistan is given by the descriptive statistics (see, Table 2).

Table 2: ***Descriptive Statistics of the Variables***

Methods	PAK_CO2	PAK_EU	PAK_GE	PAK_RE	PAK_RL	PAK_UP	PAK_CC
Mean	0.841203	444.2701	-0.652768	45.25500	-0.802080	35.99955	-0.920440
Median	0.821866	440.8292	-0.683352	45.90000	-0.827249	35.92250	-0.889571

Maximum	0.988583	470.7235	-0.383815	48.10000	-0.658621	38.36500	-0.801857
Minimum	0.756406	419.5120	-0.833723	41.60000	-0.972614	33.98200	-1.089611
Std. Dev.	0.069683	16.44033	0.134342	2.216084	0.091935	1.323705	0.110077
Skewness	0.607058	0.175336	0.506044	-0.449369	0.071668	0.184004	-0.415299
Kurtosis	2.308474	1.807864	2.130134	1.726277	1.822061	1.922152	1.555148

With a mean value of 0.84 metric tonnes and a rather small range between 0.76 and 0.99, carbon dioxide emissions per capita (PAK_CO2) show a modest variation in emissions across the study period. The low standard deviation indicates that CO2 emissions have fluctuated moderately over time. The kurtosis value of 2.3 suggests a distribution that is somewhat flatter than the normal distribution, although the positive skewness suggests a slightly right-tailed distribution. Since the null hypothesis of normality cannot be rejected, the Jarque-Bera statistic and its corresponding probability verify that CO2 emissions are normally distributed. Pakistan's increasing reliance on energy consumption is shown in the mean value of 444.27 kilogrammes of oil equivalent for energy use per capita (PAK_EU). The low standard deviation and narrow dispersion around the mean point to a comparatively steady pattern of energy consumption during the study period. The Jarque-Bera test verifies normality, and the skewness and kurtosis values show a roughly symmetric and somewhat platykurtic distribution. The negative mean values for government effectiveness (PAK_GE), corruption control (PAK_CC), and rule of law (PAK_RL) demonstrate Pakistan's ongoing institutional flaws.Kurtosis values below three indicate flatter-than-normal distributions, and these governance indicators show moderate variability with small positive or negative skewness. These variables' distributions do not substantially vary from normality, according to the Jarque–Bera probability.The mean value of renewable energy consumption as a percentage of total energy use (PAK_RE) is 45.26 percent, with modest fluctuation over the study period. A longer left tail, which denotes times of comparatively lower renewable energy consumption, is suggested by the negative skewness. With modest dispersion and a nearly symmetrical distribution, Pakistan's urban population (PAK_UP) averages about 36% of the country's total population, indicating a steady rate of urbanisation.The Jarque-Bera statistics and associated probability values for every variable are higher than standard significance thresholds, suggesting that the null hypothesis of a normal distribution cannot be rejected. Overall, these descriptive findings imply that the data are well-behaved and appropriate for additional econometric analysis, such as robust least squares estimation and correlation analysis. Table 3 shows the correlation matrix.

Table 3: ***Correlation Matrix***

Correlation Probability	PAK_CO2	PAK_CC	PAK_EU	PAK_GE	PAK_RE	PAK_RL	PAK_UP
PAK_CO2	1.000000						

PAK_CC	0.702996	1.000000					
	0.0005	-----					
PAK_EU	0.663947	0.507608	1.000000				
	0.0014	0.0223	-----				
PAK_GE	0.405181	0.421629	0.641528	1.000000			
	0.0764	0.0641	0.0023	-----			
PAK_RE	-0.744089	-0.388356	-	-0.398185	1.000000		

Policy Journal of Social Science Review

Online ISSN 3006-4635 Print ISSN 3006-4627

Vol. 4 No. 2 (2026)

			0.799666				
	0.0002	0.0906	0.0000	0.0821	-----		
PAK_RL	0.645210	0.516756	0.347027	0.097032	-0.376425	1.000000	
	0.0021	0.0196	0.1339	0.6840	0.1019	-----	
PAK_UP	0.471384	0.268254	0.650615	0.088187	-0.731575	0.549817	1.000000
	0.0359	0.2528	0.0019	0.7116	0.0002	0.0120	-----

Energy use per capita (PAK_EU) and control of corruption (PAK_CC) have a strong and statistically significant positive correlation with carbon dioxide emissions per capita (PAK_CO2), suggesting that changes in governance quality and increased energy consumption are closely linked to rising emissions. Additionally, there is a positive correlation between CO2 emissions and both urban population (PAK_UP) and rule of law (PAK_RL), indicating that greater emission levels are accompanied with rising urbanisation and institutional dynamics.A limited linear link in the bivariate context is implied by the positive but comparatively weaker and only marginally significant correlation between CO2 emissions and government effectiveness (PAK_GE). On the other hand, there is a large and statistically significant negative correlation between CO2 emissions and renewable energy consumption (PAK_RE), which emphasises the role of renewable energy in reducing environmental deterioration.

Notable correlations between the explanatory variables are also revealed by the matrix. The relationship between economic activity, institutional capability, and urban growth is reflected in the positive and strong correlation between energy use per capita and both urban population and government effectiveness. The percentage of renewable energy in the energy mix is lower during times of greater reliance on fossil fuels and urban expansion, according to a negative correlation between renewable energy consumption and energy use, urban population, and governance factors.Indicators of governance, such as the rule of law and corruption control, have a positive correlation with one another, indicating their interdependence within institutional quality. Overall, the correlation results point to significant linkages between Pakistan's CO2 emissions, energy structure, urbanisation, and governance. However, they also highlight the necessity of multivariate research to separate individual effects beyond simple pairwise interactions. Table 4 shows the unit root estimates.

Table 4: ***Unit Root Estimates***

Variables	Level trend and intercept	1st difference	Decision
Co2	-2.82454	-4.436970	I(1)
	(0.2071)	(0.0034)	
CC	-2.318501	-4.307831	I(1)
	(0.1765)	(0.0040)	
EU	-1.048594	-4.177389	I(1)
	0.7133	0.0052	
GE	-1.984381	-3.373965	I(1)
	0.2904	0.0272	
RE	-1.910670 (0.3207)	-5.415045	I(1)
		(0.0005)	
RL	-2.188881 (0.2161)	-5.124014	I(1)
		(0.0009)	
UP[a]	-4.125265	-5.12542	I(0)
	(0.001)	(0.000)	

Note: [a] shows significant with PP unit root test.

The Augmented DickeyFuller (ADF) procedure-based unit root test results show that the study's variables have mixed stationarity qualities. When tested using intercept and trend, carbon dioxide emissions (CO_2), control of corruption (CC), energy use per capita (EU), government effectiveness (GE), renewable energy consumption (RE), and rule of law (RL) are all non-stationary at levels because their corresponding p-values are higher than standard significance levels and their test statistics are statistically insignificant. Each of these variables, however, becomes stationary after taking the first difference, with test statistics that are significant at the 5 percent level or higher. This indicates that shocks to these series have long-lasting effects at levels but fade once differenced, confirming that these variables are integrated of order one, I(1). The urban population variable (UP) is significant and shows I(0) variable by using PP unit root test. Table 5 shows the robust least squares estimates for ready reference.

Table 5: ***Robust Least Square Regression Results***

Dependent Variable: PAK_CO2				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
PAK_CC	0.181174	0.094661	1.913924	0.0556
PAK_EU	0.000710	0.001114	0.637591	0.5237
PAK_GE	-0.062776	0.090042	-0.697179	0.4857
PAK_RE	-0.023073	0.006451	-3.576841	0.0003
PAK_RL	0.337156	0.116532	2.893247	0.0038
PAK_UP	-0.025452	0.011449	-2.223204	0.0262
C	2.882858	0.749471	3.846524	0.0001
	Robust Statistics			
R-squared	0.788855	Adjusted R-squared		0.691403
Rw-squared	0.873275	Adjust Rw-squared		0.873275
Akaike info criterion	18.47291	Schwarz criterion		31.79027
Deviance	0.011749	Scale		0.032952
Rn-squared statistic	73.38281	Prob(Rn-squared stat.)		0.000000
	Non-robust Statistics			
Mean dependent var	0.841203	S.D. dependent var		0.069683
S.E. of regression	0.030827	Sum squared resid		0.012354

The results of the robust least squares regression show how urbanisation, energy considerations, and institutional quality affect Pakistan's CO_2 emissions per capita during the research period. An R-squared value of roughly 0.79 indicates that the model has excellent explanatory power, suggesting that the variables included account for nearly 79% of the variation in CO_2 emissions. The model's overall statistical reliability is confirmed by the robust Wald statistic, which is highly significant. Robust estimate increases the reliability of the results by ensuring that they are not influenced by heteroskedasticity or outliers. Control of corruption is one of the governance variables that has a positive and marginally significant impact on CO_2 emissions. This suggests that changes in corruption control are linked to higher emissions, perhaps as a result of increased industrial and economic activity that follows institutional reforms. In the Pakistani setting during the sample period, government efficacy has a minimal direct impact on environmental outcomes, as evidenced by a negative but statistically insignificant connection with CO_2 emissions. However, the rule of law has a positive and statistically significant impact on CO_2 emissions, suggesting that advances in legal and regulatory frameworks may be accompanied by increased productivity and energy usage, which would increase emissions rather than decrease them.Mixed effects are seen in

Policy Journal of Social Science Review
Online ISSN Print ISSN
3006-4635 3006-4627
Vol. 4 No. 2 (2026)

energy-related factors. Energy use per capita has a positive but negligible coefficient, indicating that, once other variables are taken into account, changes in total energy consumption do not directly cause changes in CO_2 emissions. On the other hand, CO_2 emissions are strongly and significantly impacted negatively by the use of renewable energy, suggesting that a higher proportion of renewable energy in the overall energy mix efficiently lowers environmental pollution. This emphasises how important it is for Pakistan to adopt clean energy in order to reduce its carbon emissions.

There is a strong negative correlation between CO_2 emissions and urban population, indicating that more urbanisation may result in better infrastructure, more environmentally conscious people, or more efficient energy use, all of which could lower emissions per person. When all explanatory variables are maintained constant, the baseline level of emissions is captured by the positive and statistically significant constant term. Overall, the findings show that urbanisation and the use of renewable energy are important factors in lowering CO_2 emissions, while the effects of governance indicators are complicated and context-dependent, supporting the idea that both institutional and structural factors influence Pakistan's environmental commons. Figure 1 shows the influence statistic.

Figure 1: Influence Statistics

The influence statistics offer a diagnostic evaluation of whether the robustness of the estimated regression results is significantly impacted by any specific observations. The majority of observations fall inside the traditional critical boundaries, according to the RStudent (studentized residuals) plot, suggesting that the residuals are generally well-behaved. A few data in the latter years, however, marginally surpass the cutoff, indicating the existence of moderate outliers. These variations seem to be isolated and are not common, suggesting that they do not significantly skew the estimation as a whole. According to the Hat Matrix (leverage) figure, the majority of observations have moderate leverage, which means that the extreme values of the explanatory variables do not cause them to exert undue impact. Particularly in recent years, one or two observations exhibit comparatively larger leverage than the rest of the sample, although they are still within acceptable bounds. This implies that the regression estimates are not dominated by a single observation using leverage alone. The majority of data points fall well inside the critical boundaries, according to the DFFITS statistic, which assesses the effect of removing an observation on the fitted values. Even if one observation has a significantly higher negative DFFITS value, it does not hold true across several diagnostics, suggesting that the robust estimation method effectively manages its influence. Lastly, the COVRATIO plot indicates that most observations fall within the range, suggesting that removing any one observation would not significantly affect the computed coefficients' precision. There are slight variations near the threshold, but these do not indicate significant instability. Overall, the influence diagnostics verify that none of the data have overwhelming or destabilising effects on the model, even though a handful exhibit minor influence. This demonstrates that the Robust Least Squares estimates are reliable and that the outcomes are not influenced by significant observations or outliers. Figure 2 shows the leverage plots.

Policy Journal of Social Science Review
Online ISSN Print ISSN
3006-4635 3006-4627
Vol. 4 No. 2 (2026)

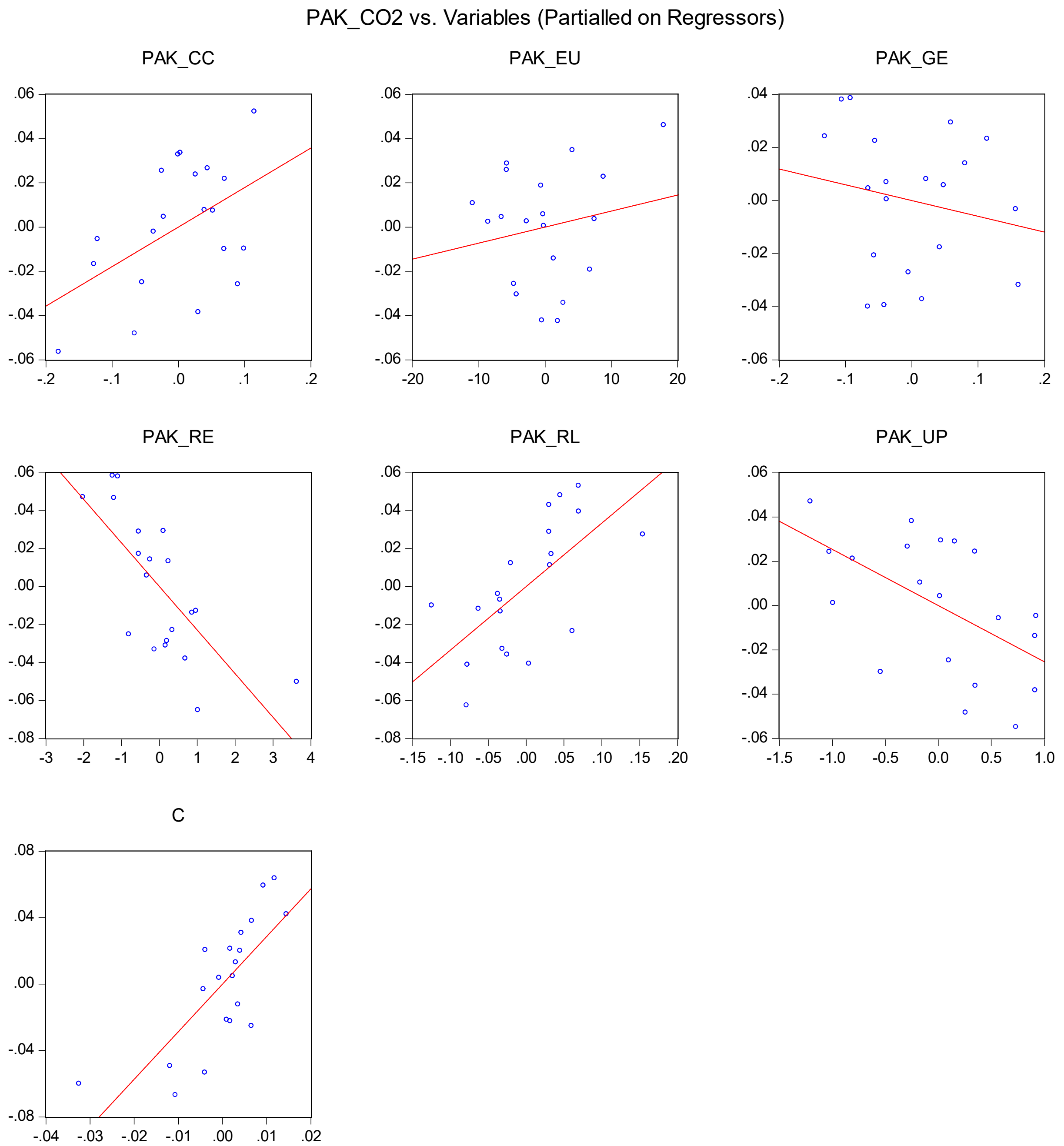

Figure 2: Leverage Plot

After adjusting for the effects of every other regressor in the model, the partial regression plots show the isolated relationship between CO2 emissions and each explanatory variable. The direction and intensity of the estimated coefficients derived from the robust least squares regression are validated by these figures. When all other variables are held constant, the partial plot for corruption control displays an upward-sloping fitted line, suggesting a positive association with CO2 emissions. This implies that enhanced efforts to combat corruption are linked to increasing emissions, which probably reflects the increased economic activity and energy consumption that come with institutional reforms. non line with its statistical insignificance non the regression results, energy use per capita likewise shows a slightly positive slope, although the scattered pattern of the observations around the fitted line suggests a weak link. A possible emissions-reducing effect is suggested by the slightly negative slope of government effectiveness; however, the dispersion of points suggests that this relationship is weak and not statistically robust. On the other hand, the use of renewable energy shows a distinct fitted line that slopes downward, indicating a substantial negative correlation with CO_2 emissions. This shows that when other factors are taken into consideration, an increase in the proportion of renewable energy considerably lowers emissions, highlighting the importance of clean energy in reducing environmental deterioration. The rule of law partial plot exhibits a strong positive slope, indicating that changes in institutional and legal frameworks are linked to larger emissions, maybe as a result of increased industrial activity and enforcement that promotes economic growth. Additionally, the urban population has a negative slope, suggesting that lower CO_2 emissions per capita are linked to increasing levels of urbanisation, possibly as a result of increased energy efficiency, better infrastructure, or economies of scale in metropolitan environments. When all explanatory variables are taken into account, the constant term plot captures the baseline level of emissions with a strong positive fitted relationship. Overall, these partial regression plots visually confirm that urban population and renewable energy consumption lower CO_2 emissions, while rule of law and corruption control are positively correlated with emissions in Pakistan during the study period. They are also consistent with the robust least squares results.

6. Conclusions

The purpose of this study was to investigate how Pakistan's carbon dioxide emissions are shaped by urbanisation, energy structure, and governance quality within the larger framework of the environmental commons tragedy. The analysis offers detailed evidence on how institutional and structural factors interact to affect environmental outcomes using annual time-series data from 1996 to 2024 using robust least squares estimate. The unit root tests made sure that the time-series characteristics of the data were properly addressed before estimate, and the descriptive and correlation analyses showed significant relationships between CO_2 emissions, governance indicators, energy use, and urban population. The empirical findings highlight the significance of shifting Pakistan's energy mix towards cleaner energy sources by showing that the use of renewable energy is crucial in lowering CO_2 emissions. Additionally, it was discovered that urbanisation had a moderating effect on emissions per capita, indicating that urban expansion can lead to better environmental results when combined with enhanced infrastructure and energy efficiency. However, once other variables were taken into account, energy use per capita did not show a statistically significant independent effect on emissions, underscoring the significance of energy mix rather than energy amount alone. The governance variables showed complex and context-dependent effects: while government effectiveness had a statistically weak tendency to reduce emissions, control of corruption and rule of law were positively associated with CO_2 emissions. This suggests that, in the absence of strong environmental regulation, institutional improvements may initially stimulate economic and industrial activity that increases environmental pressure.

Overall, the results corroborate the study's main claim that governance and institutional quality must be taken into consideration when analysing environmental degradation in Pakistan rather than relying only on economic or energy-based causes. The findings draw attention to the contradiction that, absent clear alignment with environmental goals, changes in governance could not inevitably result in environmental sustainability. In order to overcome the tragedy of the environmental commons, the report highlights the necessity of combining strict environmental rules with institutional reforms and boosting investment in renewable energy. This study adds to the literature by showing how governance shortcomings and energy structure interact together to influence long-term environmental effects in a poor nation setting by placing the analysis inside an expanded Solow-based framework.

7. Policy Recommendation

According to the empirical results, Pakistan should make the quick development of renewable energy a top policy priority in order to lower carbon dioxide emissions and relieve pressure on the environment. The significant influence of renewable energy consumption on decreasing emissions highlights the necessity of ongoing investment in solar, wind, and hydropower, backed by transparent regulatory frameworks and financial incentives that promote both public and private involvement. At the same time, rather than just increasing the availability of energy, energy policy should concentrate on increasing efficiency and lowering carbon intensity. Economic activity and environmental degradation can be separated by encouraging energy-efficient technologies, modernising infrastructure, and fostering green innovation.

The findings also show that unless governance changes are clearly in line with environmental goals, they are not enough to guarantee environmental sustainability. To prevent greater economic activity from translating into larger emissions, tougher environmental rules, efficient enforcement mechanisms, and transparent monitoring systems should be added to improvements in the control of corruption and the rule of law. Additionally, well-planned urban growth may help reduce emissions per capita, according to the moderating effect of urbanisation. The environmental advantages of urban growth can be maximised by policies focused on energy-efficient housing, public transportation expansion, and sustainable urban planning. To address Pakistan's carbon emissions and safeguard the environment, an integrated policy approach that incorporates sustainable urban development, renewable energy expansion, and ecologically focused governance reforms is crucial.

References

1. Bringezu, S., Potočnik, J., Schandl, H., Lu, Y., Ramaswami, A., Swilling, M., & Suh, S. (2016). Multi-Scale Governance of Sustainable Natural Resource Use—Challenges and Opportunities for Monitoring and Institutional Development at the National and Global Level. Sustainability, 8(8), 778. https://doi.org/10.3390/su8080778
2. Afridi, M. K. (2025). Environmental challenges in Pakistan: assessing impacts and exploring solutions. Contemporary Journal of Social Science Review, 3(1), 2079-2092.
3. Anwar, M. N., Iftikhar, M., Khush Bakhat, B., Sohail, N. F., Baqar, M., Yasir, A., & Nizami, A. S. (2020). Sources of carbon dioxide and environmental Issues. In Sustainable Agriculture Reviews 37: Carbon Sequestration Vol. 1 Introduction and Biochemical Methods (pp. 13-36). Cham: Springer International Publishing.
4. Azimi, M.N., Rahman, M.M. & Nghiem, S. Linking governance with environmental quality: a global perspective. Sci Rep 13, 15086 (2023). https://doi.org/10.1038/s41598-023-42221-y
5. Handoyo, S. (2023). Worldwide governance indicators: Cross country data set 2012–2022. Data in Brief, 51, 109814.
6. Tang, K., Ma, C., Zhou, W., & Wang, M. (2024). Environmental regulation and enterprise behavior in China: rent-seeking or innovation?. *Journal of Environmental Planning and Management*, 1-31.
7. Rio, F. D., & Lores, F. X. (2017). Regulation and rent-seeking: The role of the distribution of political and economic power. *Journal of Public Economic Theory*, *19*(5), 986-1008.
8. Van den Bergh, J. C. (2013). Policies to enhance economic feasibility of a sustainable energy transition. *Proceedings of the National Academy of Sciences*, *110*(7), 2436-2437.
9. Haider, A., Mathlouthi, N., & Ahmad, I. (2024). Beyond the books: real world challenges in implementing environmental laws in Pakistan. *Available at SSRN*.

10. Si, C., Hassan, F. A., Antohi, V. M., Ahmad, W., Fortea, C., Cristache, N., ... & Zlati, M. L. (2025). Informal economy and environmental degradation in developing countries: the conditioning role of institutional quality. *Frontiers in Environmental Science*, *13*, 1645194.
11. Muhammad, S., & Long, X. (2021). Rule of law and CO2 emissions: a comparative analysis across 65 belt and road initiative (BRI) countries. *Journal of Cleaner Production*, *279*, 123539.
12. Khan, A., Sicen, L., Khan, B., & Salman, N. (2021). On the influence of demographic structure and industrial growth on environmental quality. *Journal of Environmental Management*, *288*, 112453.
13. Lyu, S., Huang, Y., & Sun, T. (2025). Urban sprawl, public transportation efficiency and carbon emissions. *Journal of Cleaner Production*, *489*, 144652.
14. Ahmad, U. S., Usman, M., Hussain, S., Jahanger, A., & Abrar, M. (2022). Determinants of renewable energy sources in Pakistan: An overview. *Environmental Science and Pollution Research*, *29*(19), 29183-29201.
15. SALIM, A., REHMAN, S. U., ABDULKAWI, W. M., & AHMED, H. Y. (2025). Overcoming Barriers to Solar Energy Adoption in Pakistan: Current Status, Policy Gaps, and Institutional Reforms. *Results in Engineering*, 108537.
16. Adeboye, O. (2025). Addressing Transboundary Environmental Harm through Technology: Mitigating the Tragedy of the Commons in Global Resource Management. *Fountain University Law Journal*, *2*(4), 1-11.
17. Komendantova, N., Ekenberg, L., Marashdeh, L., Al Salaymeh, A., Danielson, M., & Linnerooth-Bayer, J. (2018). Are energy security concerns dominating environmental concerns? Evidence from stakeholder participation processes on energy transition in Jordan. *Climate*, *6*(4), 88.
18. Hassan, S. T., Khan, S. U. D., Xia, E., & Fatima, H. (2020). Role of institutions in correcting environmental pollution: An empirical investigation. *Sustainable Cities and Society*, *53*, 101901.
19. Yang, B., Ali, M., Hashmi, S. H., & Jahanger, A. (2022). Do income inequality and institutional quality affect CO2 emissions in developing economies?. *Environmental Science and Pollution Research*, *29*(28), 42720-42741.
20. Hassan, S. T., Khan, S. U. D., Xia, E., & Fatima, H. (2020). Role of institutions in correcting environmental pollution: An empirical investigation. *Sustainable Cities and Society*, *53*, 101901.
21. Bhattacharya, G. (2023). Industry size and trade protection in the presence of environmental regulations: an empirical investigation of the indian manufacturing sector. World Trade Review, 22(5), 509-540.
22. Arango-Miranda, R., Hausler, R., Romero-Lopez, R., Glaus, M., & Ibarra-Zavaleta, S. P. (2018). Carbon dioxide emissions, energy consumption and economic growth: A comparative empirical study of selected developed and developing countries."The role of exergy". Energies, 11(10), 2668.
23. Öge, K. (2016). Which transparency matters? Compliance with anti-corruption efforts in extractive industries. Resources Policy, 49, 41-50.
24. Setzer, J., & Benjamin, L. (2020). Climate litigation in the Global South: constraints and innovations. Transnational Environmental Law, 9(1), 77-101.
25. Olasunkanmi, A. O. (2021). STRUCTURAL BREAKS AND ASYMMETRIC ANALYSES OF CO2 EMISSIONS, ENERGY CONSUMPTION AND ECONOMIC GROWTH NEXUS IN NIGERIA (Doctoral dissertation).

26. Ndubuisi, O. G., & F Nisafety E, F. I. S. P. O. N. (2025). Improving Advanced Research Methods for Climate Change and Environmental Sustainability.
27. Atta, N., & Sharifi, A. (2024). A systematic literature review of the relationship between the rule of law and environmental sustainability. Sustainable Development, 32(6), 7051-7068.
28. Atta, N., & Sharifi, A. (2025). A review of the knowledge structure and trends in research on the interlinkages between the rule of law and environmental sustainability. Sustainable Development, 33(2), 2216-2249.
29. Atta, N., Sharifi, A., & Ying Lee, C. (2024). The relationship between the rule of law and environmental sustainability: empirical evidence from the analysis of global indices. *International Journal of Sustainable Development & World Ecology*, *31*(8), 1023-1039.
30. Sarkodie, S. A., Owusu, P. A., & Leirvik, T. (2020). Global effect of urban sprawl, industrialization, trade and economic development on carbon dioxide emissions. *Environmental Research Letters*, *15*(3), 034049.
31. Yang, Z., Wu, J., Shang, X., Fu, R., Xie, L., & Ge, Q. (2025). Scaling laws of CO2 emissions during global urban expansion. *npj Urban Sustainability*, *5*(1), 3.
32. Nejat, P., Jomehzadeh, F., Taheri, M. M., Gohari, M., & Majid, M. Z. A. (2015). A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries). *Renewable and sustainable energy reviews*, *43*, 843-862.
33. Huang, Y., Kuldasheva, Z., Bobojanov, S., Djalilov, B., Salahodjaev, R., & Abbas, S. (2023). Exploring the links between fossil fuel energy consumption, industrial value-added, and carbon emissions in G20 countries. *Environmental Science and Pollution Research*, *30*(4), 10854-10866.
34. Sadik-Zada, E. R., & Loewenstein, W. (2020). Drivers of CO2-Emissions in Fossil Fuel abundant settings:(Pooled) mean group and nonparametric panel analyses. *Energies*, *13*(15), 3956.
35. Huisingh, D., Zhang, Z., Moore, J. C., Qiao, Q., & Li, Q. (2015). Recent advances in carbon emissions reduction: policies, technologies, monitoring, assessment and modeling. *Journal of cleaner production*, *103*, 1-12.
36. Kabeyi, M. J. B., & Olanrewaju, O. A. (2022). Sustainable energy transition for renewable and low carbon grid electricity generation and supply. *Frontiers in Energy research*, *9*, 743114.
37. Farghali, M., Osman, A. I., Chen, Z., Abdelhaleem, A., Ihara, I., Mohamed, I. M., ... & Rooney, D. W. (2023). Social, environmental, and economic consequences of integrating renewable energies in the electricity sector: a review. *Environmental Chemistry Letters*, *21*(3), 1381-1418.
38. Pan, X., Ai, B., Li, C., Pan, X., & Yan, Y. (2019). Dynamic relationship among environmental regulation, technological innovation and energy efficiency based on large scale provincial panel data in China. *Technological Forecasting and Social Change*, *144*, 428-435.
39. Basher, S. A., Masini, A., & Aflaki, S. (2015). Time series properties of the renewable energy diffusion process: implications for energy policy design and assessment. *Renewable and Sustainable Energy Reviews*, *52*, 1680-1692.
40. Reddy, V. J., Hariram, N. P., Ghazali, M. F., & Kumarasamy, S. (2024). Pathway to sustainability: An overview of renewable energy integration in building systems. *Sustainability*, *16*(2), 638.