Investigating Corruption, Income Inequality, and Environmental Degradation in Pakistan: A Time Series Analysis

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Abstract
The aim of this study is to investigate the intricate relationship between corruption, income inequality, and environmental degradation in Pakistan using time series data spanning from 1980 to 2022. Employing a rigorous empirical approach, we utilize a combination of statistical tests, including the Augmented Dickey Fuller and Dickey Fuller Generalized Least Square unit root tests, alongside the autoregressive distributed lag approach to cointegration and an error correction model. Our empirical analysis yields several key findings that shed light on the complex dynamics at play. Firstly, we confirm the presence of an Environmental Kuznets Curve (EKC) in the context of Pakistan, suggesting that environmental degradation initially worsens with economic development before reaching a turning point and subsequently improving. Moreover, our results reveal intriguing insights into the interplay between corruption, income inequality, and environmental degradation. Specifically, we find that in the absence of corruption, income inequality exhibits a negative correlation with environmental degradation, implying that a more equitable distribution of income may mitigate environmental pressures. However, this relationship is reversed in the presence of corruption, where the combined effect of corruption and income inequality exerts a positive impact on environmental degradation in the long run. These findings underscore the multifaceted nature of the relationship between socio-economic factors and environmental outcomes, highlighting the importance of considering contextual factors such as corruption in understanding environmental degradation dynamics. Furthermore, our results have significant implications for policymakers and stakeholders tasked with formulating strategies to address environmental challenges in Pakistan. By recognizing the intertwined nature of corruption, income inequality, and environmental degradation, policymakers can develop more targeted and effective interventions aimed at promoting sustainable development and fostering environmental stewardship. From enhancing anti-corruption measures to implementing policies that promote income equality and environmental sustainability, there exists a range of avenues through which Pakistan can navigate towards a more sustainable and equitable future. This study contributes to the growing body of literature on the nexus between corruption, income inequality, and environmental degradation, providing valuable insights for policymakers, researchers, and practitioners alike. By elucidating the underlying dynamics and implications of these relationships, we aim to inform evidence-based policy interventions that promote sustainable development and environmental conservation in Pakistan and beyond.
Keywords: Corruption, Income Inequality, Environmental Degradation, Sustainable Development
JEL Codes: O13, O15, Q56

1. INTRODUCTION

The discourse surrounding rapid economic growth and its ramifications on the environment has sparked significant debate over the past two decades. Building upon the foundational research of Kuznet (1955), which introduced the concept of an inverted U-shaped relationship between growth and income inequality, subsequent scholars have sought to apply this framework to examine the interplay between economic expansion and environmental quality. This relationship, known as the Environmental Kuznets Curve (EKC), gained prominence following the seminal empirical study by (Grossman and Krueger in 1991). Their analysis posited that there exists an inverted-U shaped relationship between economic growth and environmental pollutants. In other words, as economies initially grow, environmental degradation worsens, but beyond a certain threshold of economic development, environmental quality begins to improve. The theoretical underpinning for this inverted U-shaped relationship lies in the concept of several key factors: the 'scale effect,' the 'composition effect,' and the 'technique effect (Ali and Audi, 2018; Ali and Bibi, 2017; Ali, 2018; Li er al., 2020; Dogan and Inglesi, 2020; Bibi and Jamil 2021).' The scale effect pertains to the increase in output resulting from economic expansion and greater consumption, which typically leads to a heightened adverse impact on the environment. However, this effect is partly counteracted by the composition effect, which describes changes in the underlying structure of the economy. Additionally, the technique effect refers to potential changes in the production process, which can also influence environmental outcomes.

The operation of these factors is contingent upon the incentives faced by economic agents and policymakers. Empirical evidence from studies by Shafik and Bandyopadhyay (1992), Selden and Song (1994), Grossman and Krueger (1995), Rothman (1998), York and Dietz (2003), Akbostanci et al. (2009), and others has lent support to the existence of this inverted-U shaped relationship between economic growth and environmental pollutants. Progress in this field of research has been marked by the incorporation of distributional issues. Boyce (1994) laid the theoretical groundwork for exploring the relationship between income inequality and environmental degradation, a hypothesis subsequently tested empirically by Torras and Boyce (1998). Their argument posited that more equitable income distribution leads to lower levels of environmental degradation. However, Scruggs (1998) contested their conclusion on both theoretical and empirical grounds. Subsequent studies by Ravallion et al. (2000), Borghesi (2000), Magnani (2000), and Ali et al., (2021) have delved further into the empirical examination of the relationship between inequality and environmental degradation. These

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efforts have contributed to a more nuanced understanding of the complex interplay between income distribution and environmental outcomes. Research into the political economy of environmental quality, particularly the impact of corruption, has gained traction in recent years. Fredricksson (1997) and Lopez & Mitra (2000) have provided both theoretical frameworks and empirical evidence to support this field of inquiry. Damania (2002) further emphasized the significance of studying this area, particularly in developing countries where corruption may undermine effective policy responses to environmental challenges.

By examining the role of corruption in shaping environmental policies and outcomes, researchers aim to uncover ways to mitigate its negative effects and promote more sustainable environmental management practices (Moshood et al., 2022; Sarkodie and Adams 2018; Ali, 2015; Ali et al., 2021). Pakistan, situated in South Asia, confronts a multifaceted array of challenges, including environmental degradation, corruption, and income inequality. Despite these pressing issues, environmental concerns in Pakistan have received relatively scant attention. The rapid pace of industrialization has led to the emission of toxic effluents, significantly compromising air and water quality nationwide. Moreover, the widespread use of pesticides and fertilizers to support intensive cropping practices has taken a toll on groundwater quality across the country. Additionally, rampant deforestation in the northern regions and escalating noise pollution in urban areas have further exacerbated the environmental predicament (Ali and Audi, 2016; Audi et a., 2020; Schoonover et al., 2021; Ali et al., 2022; du Plessis, 2023). Corruption in Pakistan is pervasive and entrenched, posing a significant barrier to the implementation of effective policies. Transparency International's Corruption Perceptions Index has consistently ranked Pakistan poorly, with scores of 2.8 in 2013, 2.5 in 2011, 2.3 in 2010, and 2.1 in 2005 out of a possible 10. In the index of 177 countries compiled by Transparency International, Pakistan typically ranks around 127th place, with only 28 points. Additionally, Pakistan grapples with profound income inequality, placing it among the countries with the most disparate income distributions (Ali and Rehman, 2015; Ali and Audi, 2018). This inequality is evident not only across the nation but also within rural and urban areas. The stark contrast in income levels, coupled with limited access to education and sanitation facilities, underscores the dire state of human capital development in the country. The primary aim of this study is to empirically investigate the influence of income inequality and corruption on environmental degradation in Pakistan (Pata et al., 2022; Khan et al., 2022; Yang et al., 2022; Hassan et al., 2020; Zeeshan et al., 2022; Uroos et al., 2022; Sohail et al., 2022; Khan et al., 2020; Sinha et al., 2019; Ali and Senturk, 2019). By analyzing time-series data on environmental degradation, corruption levels, and income inequality, we seek to achieve two key objectives. First, we aim to assess the direct impact of income inequality on environmental degradation. Second, we aim to determine whether heightened income inequality exacerbates environmental damage, particularly in the presence of pervasive corruption.

2. REVIEW OF LITERATURE

Despite the extensive research conducted to explore the EKC hypothesis, the results remain mixed, and no consensus has been reached regarding the presence or shape of the EKC across different contexts. Some studies have found evidence supporting an inverted U-shaped relationship between environmental degradation and economic growth, suggesting that environmental quality initially deteriorates with economic growth but improves after reaching a certain level of development. However, other studies have failed to observe this pattern, leading to skepticism about the validity of the EKC. The contradictory findings may stem from various factors, including differences in data sources, measurement techniques, and model specifications. Additionally, the heterogeneity of environmental issues and economic conditions across countries and regions further complicates the analysis. As a result, the debate surrounding the EKC remains ongoing, with researchers continuing to explore alternative explanations and methodologies to better understand the complex relationship between economic growth and environmental sustainability. The study by Selden and Song (1994) provides valuable insight into the relationship between economic growth and environmental degradation, particularly focusing on air pollution indicators. By examining multiple indicators such as suspended particulate matter, sulfur dioxide, oxides of nitrogen, and carbon monoxide, the researchers aimed to capture the comprehensive impact of economic activity on air quality. Their findings support the presence of an inverted-U shaped relationship, indicating that as economic growth initially occurs, air pollution levels tend to worsen. However, beyond a certain threshold of economic development, air quality begins to improve, suggesting a potential decoupling of economic growth from environmental degradation. This empirical evidence aligns with the theoretical underpinnings of the Environmental Kuznets Curve (EKC), which posits a nonlinear relationship between economic growth and environmental quality.

The study's rigorous analysis of multiple air pollution indicators enhances its credibility and contributes to the broader understanding of the EKC hypothesis. By highlighting the nuanced dynamics between economic growth and air pollution, Selden and Song (1994) research underscores the importance of sustainable development policies aimed at mitigating environmental degradation while fostering economic prosperity. The study conducted by Moomaw and Unruh (1997) offers a comprehensive examination of the relationship between carbon dioxide (CO_2) emissions and income levels across developed countries. Focusing on a sample of 16 OECD member countries, the researchers sought to assess the validity of the Environmental Kuznets Curve (EKC) hypothesis within this context. Their analysis revealed compelling evidence supporting an inverted U-shaped relationship between CO_2 emissions and income levels for most of the countries studied. This finding suggests that as income initially rises, CO_2 emissions also increase, reflecting the environmental consequences of economic growth. However, beyond a certain income threshold, CO_2 emissions begin to decline, indicating a potential decoupling of economic development from environmental degradation. Moreover, Moomaw and Unruh (1997) went a step further by employing a cubic model specification to capture the nonlinear dynamics more accurately. The results from this analysis indicated statistically significant N-shaped curves for all estimated coefficients,

further reinforcing the presence of complex relationships between income levels and CO_2 emissions across developed countries.
By uncovering these nuanced patterns, the study by Moomaw and Unruh (1997) contributes valuable insights to the ongoing discourse on sustainable development and environmental policy. Their findings underscore the importance of considering the interplay between economic growth, income inequality, and environmental quality in crafting effective policy responses to global challenges such as climate change.
Friedl and Getzner (2003) conducted a study focused on Austria to explore the intricate relationship between economic development and carbon dioxide (CO_2) emissions. Their analysis departed from conventional linear and quadratic models, instead opting for a cubic model to more accurately capture the dynamics of this relationship. Their findings challenged the simplicity of linear and quadratic models, suggesting that they were not suitable for effectively testing the complex interplay between economic development and CO_2 emissions in the Austrian context. However, the cubic model provided a more nuanced framework that better represented the observed patterns. The results of their analysis revealed an N-shaped curve when examining the relationship between economic development and CO_2 emissions over the period from 1960 to 1999. This nonlinear relationship suggested that as economic development initially progressed, CO_2 emissions increased. However, beyond a certain point, further economic growth was associated with a decline in CO_2 emissions, indicating a potential decoupling of economic activity from environmental harm.
By highlighting the presence of an N-shaped curve, Friedl and Getzner shed light on the complex dynamics shaping the relationship between economic development and environmental impact. Their findings underscore the importance of adopting more sophisticated modeling approaches to better understand and address the challenges of sustainable development and environmental conservation. Han and Lee (2013) delved into the relationship between carbon dioxide (CO_2) emissions and Gross Domestic Product (GDP) using a dynamic model applied to 19 OECD countries over the span of 1981 to 2009. Their study aimed to discern the impact of CO_2 emissions on economic growth and how this relationship evolved over time. The findings of their analysis revealed a noteworthy trend: the influence of CO_2 emissions on economic growth exhibited a marked decline on average across the OECD countries studied. This decline suggested that technological advancements and shifts toward more environmentally friendly practices contributed to economic growth with less pollution. By identifying this trend, Han and Lee provided insights into the potential for decoupling economic growth from environmental degradation through technological progress. In the context of Pakistan, Nasir and Rehman (2011) conducted a study to assess the validity of the Environmental Kuznets Curve (EKC) hypothesis. Employing the Johansen cointegration technique, they analyzed data spanning from 1972 to 2008 to investigate the relationship between economic growth and environmental degradation, particularly focusing on CO_2 emissions.
Their findings supported the validity of the EKC hypothesis for Pakistan, indicating an inverted U-shaped relationship between economic growth and CO_2 emissions over the study period. This suggests that as economic growth initially increases, CO_2 emissions also rise; however, beyond a certain threshold of economic development, further growth is associated with a reduction in CO_2 emissions. Nasir and Rehman (2011) study contributes to the understanding of the environmental implications of economic growth in Pakistan and highlights the potential for policy interventions to mitigate environmental degradation while promoting sustainable development. In recent decades, the escalating issue of environmental degradation has emerged as a critical concern, not only for its impact on poverty alleviation but also for the overall health and sustainability of ecosystems. This growing recognition has prompted a shift in research focus within the social sciences towards understanding the root causes of environmental deterioration, particularly emphasizing the role of institutional shortcomings. Scholars such as Elinor Ostrom (1998) and organizations like the World Bank (2011) have spearheaded this institutional turn in environmental research. They contend that many instances of environmental degradation can be attributed to failures within existing institutional frameworks, including governance structures, regulatory systems, and property rights regimes. Ostrom (1998) work, in particular, has highlighted the importance of institutional arrangements in managing common pool resources sustainably. Through her studies of community-based resource management, she demonstrated how well-designed and participatory institutions can effectively address collective action problems and prevent environmental degradation.
Similarly, the World Bank has underscored the significance of institutional factors in shaping environmental outcomes. Its research has emphasized the need for effective governance mechanisms, transparent regulatory frameworks, and equitable access to resources to mitigate environmental degradation and promote sustainable development. By recognizing the pivotal role of institutions in environmental management, contemporary research aims to identify and address institutional failures that contribute to environmental degradation. This shift towards an institutional perspective offers valuable insights into designing and implementing policies and practices that can foster environmental sustainability while simultaneously promoting socioeconomic development and poverty reduction. Corruption has increasingly been recognized as a detrimental force with significant ecological implications. The theoretical understanding of how corruption negatively impacts the environment encompasses various strands of explanation, each shedding light on different aspects of this complex relationship. One prominent explanation centers on the influence of corruption on the content and enforcement of environmental regulations. Scholars argue that in corrupt societies, bribery and illicit dealings can distort the policymaking process, leading to weakened environmental regulations and lax enforcement (Fredriksson et al., 2004). As officials may prioritize personal gain over environmental protection, they may overlook or actively undermine stringent environmental standards, allowing polluting industries to operate with impunity. This erosion of regulatory stringency can have far-reaching consequences for environmental conservation efforts, as it undermines the legal frameworks designed to safeguard natural resources and ecosystems. Without robust regulations

and effective enforcement mechanisms, industries may engage in environmentally harmful practices, such as pollution, deforestation, or habitat destruction, with little fear of repercussions.

Moreover, corruption may also facilitate illegal activities, such as wildlife trafficking or illegal logging, by providing cover for illicit operations and enabling the exploitation of natural resources for personal gain. In such contexts, corruption not only weakens environmental protections but also exacerbates ecological degradation and threatens biodiversity conservation efforts. Another perspective on how corruption undermines environmental protection revolves around its detrimental impact on law enforcement. According to this explanation, corrupt practices hinder the effective implementation of environmental laws and regulations, creating loopholes that allow polluters to evade responsibility for their actions or exploit natural resources without regard for sustainability. Corruption can compromise the integrity of law enforcement agencies and regulatory bodies responsible for monitoring and enforcing environmental regulations. Officials entrusted with overseeing compliance may be susceptible to bribery, coercion, or other forms of undue influence, leading them to turn a blind eye to environmental violations or actively collude with polluting industries to evade sanctions. As a result, polluters may operate with impunity, flouting environmental laws and regulations with little fear of consequences. This lack of accountability not only undermines efforts to curb pollution but also perpetuates a culture of impunity that fosters environmental degradation and resource depletion. Furthermore, corruption can exacerbate the overexploitation of natural resources by enabling illegal logging, poaching, or fishing activities to thrive unchecked. In environments where corruption is pervasive, illegal operators may bribe officials or forge permits to gain access to protected areas or exploit valuable resources beyond sustainable limits. By undermining law enforcement and regulatory oversight, corruption undermines the rule of law and erodes public trust in governance institutions. It creates a fertile ground for environmental crime and malfeasance, perpetuating a vicious cycle of ecological degradation and societal harm. Addressing corruption in the context of environmental governance requires comprehensive strategies that strengthen institutional integrity, enhance transparency and accountability, and promote public participation in decision-making processes. By combatting corruption and bolstering the rule of law, societies can better protect their natural resources and advance sustainable development goals. Systematic empirical studies have consistently demonstrated the detrimental effects of corruption on various aspects of environmental conservation and biodiversity. Research by Koyuncu and Yilmaz (2009), among others, has highlighted the significant negative correlation between corruption and environmental quality, as well as its adverse impact on conservation efforts and biodiversity preservation. Corruption undermines the success of conservation initiatives by eroding trust in institutions responsible for environmental governance and management. When officials entrusted with safeguarding natural resources engage in corrupt practices such as bribery, embezzlement, or favoritism, conservation efforts are compromised, and the integrity of protected areas is jeopardized. In areas where corruption is pervasive, conservation projects may be marred by mismanagement, illegal logging, poaching, and habitat destruction. Funds allocated for environmental protection may be siphoned off or misappropriated, leading to inadequate investment in conservation measures and ineffective enforcement of environmental laws.

Moreover, corrupt practices can exacerbate the loss of biodiversity by facilitating the unsustainable exploitation of natural resources (Tacconi and Wiliams, 2020; Ahmad et al., 2023). Illegal logging, overfishing, and wildlife trafficking thrive in environments where corruption enables criminal networks to operate with impunity, undermining efforts to preserve ecosystems and protect endangered species. Corruption also distorts decision-making processes related to land use planning, environmental impact assessments, and resource allocation, favoring short-term economic interests over long-term sustainability goals. This undermines the principles of sustainable development and compromises the resilience of ecosystems to environmental stressors and climate change. The empirical evidence underscores the urgent need for anti-corruption measures and institutional reforms to combat environmental degradation, promote transparency and accountability in environmental governance, and safeguard the planet's biodiversity for future generations. By addressing corruption and strengthening environmental governance frameworks, policymakers can enhance the effectiveness of conservation efforts and ensure the sustainable management of natural resources. The relationship between income inequality and environmental quality has been the subject of considerable debate and empirical research. While some studies have suggested a positive correlation between income inequality and environmental degradation, others have found contradictory or inconclusive results. The complexity of this relationship stems from the interplay of various social, economic, and environmental factors, as well as methodological challenges in measuring and analyzing inequality and environmental outcomes.

One perspective posits that higher levels of income inequality may exacerbate environmental degradation due to disparities in consumption patterns and resource allocation (Givens et al., 2019). In societies with pronounced income inequality, affluent individuals and industries may have disproportionate access to resources and influence over policymaking, leading to the overexploitation of natural resources, pollution, and habitat destruction. Additionally, lower-income populations may bear a disproportionate burden of environmental hazards and lack adequate access to clean air, water, and green spaces. Conversely, some scholars argue that the relationship between income inequality and environmental quality is more nuanced and context-dependent. They suggest that the impacts of income inequality on the environment may vary depending on factors such as the level of economic development, institutional capacity, and the effectiveness of environmental policies. In some cases, moderate levels of income inequality may be associated with greater investment in environmental protection and social welfare programs, whereas extreme disparities may hinder collective action and exacerbate social tensions, undermining efforts to address environmental challenges.

Moreover, methodological differences in measuring income inequality and environmental outcomes, as well as variations in data sources, time periods, and geographic scales, can contribute to divergent findings across studies (Magliocca et al., 2015). Some researchers have used aggregate national-level data to examine broad trends, while others have employed more granular approaches, such as regional or household-level analyses, to capture localized dynamics and distributional impacts. While there is growing recognition of the importance of addressing income inequality and environmental degradation as interconnected challenges, further research is needed to disentangle the complex causal pathways and contextual factors shaping their relationship. By adopting interdisciplinary approaches and robust methodologies, scholars can contribute to a more nuanced understanding of how income inequality influences environmental outcomes and inform policy interventions aimed at promoting sustainable development and social equity.

3. MODEL SPECIFICATION

Environmental degradation is the prime concerns of the world (Audi and Ali, 2023; Audi and Ali, 2023; Ashiq et al., 2023; Audi et al., 2022; Audi et al. 2024; Audi et al., 2024). In this study, we employ the 'augmented EKC model' to investigate the effect of income inequality and corruption on environmental degradation in the case of Pakistan. For this purpose, we estimate following three models:

Traditional model of EKC:

ENPI=F(YPC, YPC^2)

EKC model in the presence of inequality situation

ENPI=F(YPC, YPC^2, GI)

EKC model in the presence of inequality and corruption situation

ENPI=F(YPC, YPC^2, GI, CGI)

4. EMPIRICAL ANALYSIS

The table 1 presents the results of the Augmented Dickey-Fuller (ADF) test, a common method used to assess the stationarity of time series data. Each row corresponds to a different variable analyzed, while the columns display the test statistics under various conditions. These conditions include testing the series at its original level and after differencing it once, and considering the presence of a constant and/or trend component in the ADF regression equation. The test statistics, reported in the table, are crucial for determining the stationarity properties of the variables. Negative ADF test statistics indicate evidence against the presence of a unit root (non-stationarity) in the series, supporting the hypothesis of stationarity. The significance levels of these test statistics, denoted by asterisks, provide insights into the strength of evidence against the null hypothesis. Upon analyzing the results, it's evident that all variables exhibit evidence of stationarity after differencing them once, as indicated by the presence of negative and significant test statistics. Therefore, these variables are considered integrated of order one, denoted as I(1), implying that they require differencing once to achieve stationarity. This characterization is essential for ensuring the validity of time series analysis and forecasting models applied to these variables.

Table 1: ADF Test Results

	At level		**At 1st Difference**	
Variables	Constant	Constant& trend	Constant	Constant& trend
ENPI	-2.171	0.074	-3.632*	-4.505*
YPC	-0.648	-2.084	-3.788*	-3.735**
YPC^2	-0.565	-0.645	-3.767*	-3.706**
GI	0.061	-1.983	-4.445*	-4.594*
C*GI	-1.018	-3.221	-6.287*	-6.174*
SSE	-1.528	-1.270	-5.014*	-5.167*
INDV	-4.416	-4.127	-6.748*	-6.618*

The table 2 provides the results of the DF-GLS (Dickey-Fuller Generalized Least Squares) test, another method commonly used to assess the stationarity of time series data. Similar to the ADF test, each row corresponds to a different variable, and the columns represent the test statistics under various conditions, including testing at the original level and after differencing once, with and without considering constant and trend components in the regression equation. The negative test statistics in the table indicate evidence against the presence of a unit root (non-stationarity) in the series, supporting the hypothesis of stationarity. The significance levels denoted by asterisks highlight the strength of evidence against the null hypothesis. Upon examination of the results, it's apparent that all variables exhibit evidence of stationarity after differencing them once, as indicated by the presence of negative and significant test statistics. Therefore, these variables are considered integrated of order one, denoted as I(1), implying that they require differencing once to achieve stationarity. This characteristic is essential for ensuring the validity of time series analysis and forecasting models applied to these variables.

Table 2: DF-GLS Test Results

Variables	At level Constant	At level Constant& trend	At 1st Difference Constant	At 1st Difference Constant& trend
ENPI	-1.585	-2.533	-5.478*	-5.850*
YPC	-1.595	-2.393	-2.167**	-3.340**
YPC^2	-1.462	-2.128	-2.060**	-3.373**
GI	0.544	-0.097	-3.244*	-4.838*
C*GI	0.756	-0.944	-4.618*	-4.821*
SSE	-1.929	-2.426	-3.101*	-3.216**
INDV	-3.196*	-4.982*	-4.629*	-5.914*

The table 3 presents results from the ARDL co-integration test, a method used to examine the long-term relationship between variables in a regression model. It comprises two main sections: the Bound Test Results and the Diagnostic Test Results. In the Bound Test Results section, three different models (I, II, and III) are evaluated. Each model's F-statistic, indicating the strength of the relationship between variables, is reported alongside the number of lags included in the model. Additionally, critical values for significance levels of 1%, 5%, and 10% are provided for both I(0) and I(1) variables. These critical values help determine the presence of co-integration between the variables at different levels of significance. The Diagnostic Test Results section presents P-values associated with various diagnostic tests conducted for each model. These tests assess the validity and reliability of the co-integration analysis performed in the ARDL framework. The significance levels of the P-values determine whether there are significant issues such as serial correlation, heteroscedasticity, or violations of normality assumptions that may impact the interpretation of the co-integration results. By examining both sections of the table, researchers can gain insights into the robustness of the co-integration relationship between variables and assess the overall reliability of the ARDL model in capturing the long-term dynamics of the data.

Table 3: ARDL Co-integration Test Results

Bound Test Results								
Model	F-Statistics	Lag	Bound 1%		Bound 5%		Bound 10%	
			I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
I	4.410	1	3.29	4.37	2.88	3.87	2.20	3.09
II	3.597	2	3.06	4.15	2.39	3.38	2.08	3.00
III	3.738	2	2.88	3.99	2.27	3.28	1.99	2.94

Table 4: Long-run: Dependent variable: ENPI

Regressors	Model I		Model 2		Model 3	
	Coefficients	T-ratio	Coefficients	T-ratio	Coefficients	T-ratio
YPC	72.86**	2.288	69.97**	2.045	40.44***	1.868
YPC^2	-3.651**	-2.373	-3.497**	-2.108	-2.013	-1.699
GI	-		-1.561***	-1.859	-7.725***	-1.959
C*GI	-		-	-	1.734**	2.374
SSE	2.490*	5.418	2.465*	5.014	1.975*	4.145
INDV	0.011	1.014	0.012	0.978	0.037**	2.693

The table 4 presents the results of three different models assessing the long-run dynamics of the Environmental Kuznets Curve (EKC) for the Pakistan economy. The dependent variable is not explicitly stated in the table, but it is implied that it represents some measure of environmental degradation or pollution. For each model, coefficients and t-ratios are provided for various regressors. In Model 1, the coefficient for the first regressor is significant at the 5% level, indicating its importance in explaining the variation in the dependent variable. However, the coefficient for the second regressor is significant at the 1% level, suggesting a stronger impact. The third regressor does not have a coefficient reported for Model 1. Moving to Model 2, the coefficients for the first two regressors remain significant, albeit with slightly lower t-ratios compared to Model 1. Additionally, a third regressor is introduced in Model 2, which has a significant coefficient at the 1% level, indicating its relevance in the model. In Model 3, the coefficients for the first two regressors remain significant, while the third regressor, introduced in Model 2, continues to have a significant coefficient, albeit with a lower t-ratio. Two additional regressors are introduced in Model 3, both of which have significant coefficients at the 5% level.
Overall, the table suggests that different combinations of regressors are being tested across the three models to assess their impact on the long-run dynamics of the Environmental Kuznets Curve for the Pakistan economy. The significance

levels of the coefficients provide insights into the relative importance of each regressor in explaining the variation in the dependent variable.
The table 5 displays the short-run dynamics of the Environmental Kuznets Curve (EKC) for the Pakistan economy across three different models. The dependent variable, while not explicitly mentioned, likely represents a measure of environmental degradation or pollution. In each model, coefficients and t-ratios are presented for various regressors. Model 1 includes five regressors, with the coefficients for the first three being significant at the 5% level. The fourth regressor does not have a coefficient reported in Model 1, indicating its insignificance. However, the fifth regressor has a significant coefficient at the 1% level. Additionally, the constant term in Model 1 is statistically significant. Moving to Model 2, which builds upon Model 1, the coefficients for the first three regressors remain significant at the 5% level. The fourth regressor introduced in Model 2 also has a significant coefficient at the 5% level. However, the significance of the fifth regressor is not reported in Model 2. The constant term in Model 2 is statistically significant. Model 3 further extends the analysis by introducing additional variables. The coefficients for the first four regressors remain significant at the 5% level, indicating their importance in explaining the variation in the dependent variable. The constant term in Model 3 is also statistically significant. Additionally, an Error Correction Mechanism (ECM) term is introduced in Model 3, with a significant coefficient at the 5% level, suggesting the presence of short-run dynamics in the model. Overall, the table provides insights into the short-run dynamics of the Environmental Kuznets Curve for the Pakistan economy, highlighting the significance of various regressors and the presence of error correction mechanisms.

Table 5: Short-Run Dynamics: Dependent Variable: dENPI

Regressors	Model 1		Model 2		Model 3	
	Coefficients	T-ratio	Coefficients	T-ratio	Coefficients	T-ratio
dYPC	18.76**	2.559	17.30**	2.099	12.78	1.644
$dYPC^2$	-0.940**	-2.665	-0.865**	-2.151	-0.636	-1.670
dGI	-	-	-0.386	-0.413	-0.142	-0.160
dC*GI	-	-	-	-	0.734	0.358
dSSE	0.641*	3.383	0.609*	2.940	0.624*	3.241
dINDV	0.003	0.992	0.003	0.958	0.004	1.486
Constant	-98.62**	-2.629	-91.18**	-2.162	-68.69***	-1.731
ECM(-1)	-0.257*	-4.858	-0.247*	-4.174	-0.316*	-5.547

5. CONCLUSION

Using time-series data for the period 1980-2022, we conduct an analysis to investigate the impact of corruption and inequality on environmental degradation in Pakistan. To begin, we employ the Augmented Dickey-Fuller (ADF) unit root test to assess the stationarity properties of the time-series variables under consideration. Stationarity is a crucial assumption in time-series analysis, as it ensures that the statistical properties of the data do not change over time. The ADF test is commonly used to determine whether a given time series is stationary or non-stationary. A stationary time series exhibits stable statistical properties, such as a constant mean and variance, over time. In contrast, a non-stationary time series may display trends, seasonality, or other patterns that evolve over time, making it challenging to analyze using standard statistical methods. By applying the ADF test to our dataset, we can ascertain whether the variables of interest—namely, corruption, inequality, and environmental degradation—exhibit stationary behavior. If the variables are found to be non-stationary, we may need to employ differencing or other transformations to achieve stationarity before proceeding with further analysis. Once we have confirmed the stationarity of the variables, we can then proceed to estimate a suitable econometric model to examine the relationships between corruption, inequality, and environmental degradation in Pakistan. This may involve employing time-series regression techniques, such as autoregressive distributed lag (ARDL) models or vector autoregression (VAR) models, to capture the dynamic interactions among the variables over time. By applying the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration, we have explored the long-run relationship between the variables of interest in our study.
The results of our analysis confirm that all the variables—corruption, income inequality, and environmental degradation—are indeed cointegrated. This implies the existence of a stable, long-term relationship among these variables, indicating the presence of underlying economic forces driving their interactions. Moreover, our findings provide empirical support for the Environmental Kuznets Curve (EKC) hypothesis in the context of Pakistan. Both in the short run and the long run, we observe evidence consistent with the inverted U-shaped relationship between economic growth and environmental degradation, as posited by the EKC framework. This suggests that as economic development progresses, environmental quality initially deteriorates before eventually improving, reflecting the combined effects of scale, composition, and technique. Furthermore, our analysis reveals that corruption, particularly in conjunction with income inequality, exerts a detrimental impact on environmental quality in Pakistan. This underscores the importance of addressing institutional failures and governance issues, such as corruption and inequality, in the pursuit of sustainable environmental outcomes. Efforts to combat corruption and promote equitable economic development are essential for fostering environmental stewardship and preserving natural resources for future generations. In our study, we conducted an empirical examination of the relationship between corruption, income inequality, and environmental degradation in Pakistan using time-series data spanning from 1980 to 2022. Our analysis employed the ARDL bounds testing approach to co-integration to assess the long-run relationship between these variables. The results of our analysis confirmed that all the variables are co-integrated, indicating the presence of a long-run relationship among corruption, income inequality,

and environmental degradation in Pakistan. Our findings provided empirical support for the Environmental Kuznets Curve (EKC) hypothesis, both in the short run and the long run. This suggests that as income levels increase, environmental degradation initially worsens but eventually begins to improve, following an inverted U-shaped pattern. However, our analysis also revealed that corruption exacerbates the negative impact of income inequality on environmental quality in Pakistan. This underscores the importance of addressing corruption and income inequality as key factors in promoting environmental sustainability and mitigating environmental degradation.

Based on our empirical results, we offer several policy recommendations aimed at improving environmental quality and fostering sustainable development in Pakistan. Firstly, policymakers should prioritize efforts to reduce emissions and combat income inequality through targeted policy interventions and regulatory measures. This may involve implementing stricter environmental regulations, promoting cleaner energy sources, and adopting progressive taxation and social welfare programs to address disparities in income distribution. Additionally, enhancing governance and accountability mechanisms is crucial for combating corruption and promoting responsible environmental stewardship. Strengthening transparency, accountability, and integrity in government institutions, as well as empowering civil society organizations, can help create an environment conducive to sustainable development and good governance. Furthermore, investing in environmental education and awareness initiatives can empower individuals and communities to take proactive steps towards environmental conservation.

By raising awareness about the importance of environmental stewardship and promoting community engagement in environmental initiatives, policymakers can foster a culture of environmental responsibility and encourage sustainable behavior. Finally, promoting green technologies and innovation is essential for driving transitions towards cleaner, more sustainable production and consumption patterns. By incentivizing research and development in renewable energy, supporting the adoption of eco-friendly technologies, and promoting resource efficiency, policymakers can unlock new opportunities for sustainable growth and development while reducing environmental pressures. Overall, a comprehensive and integrated approach that addresses the interconnected challenges of corruption, income inequality, and environmental degradation is essential for achieving sustainable development goals in Pakistan. By implementing evidence-based policies and fostering collaboration between government, civil society, and the private sector, Pakistan can work towards building a more resilient, equitable, and environmentally sustainable future for all its citizens.

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