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# Political Institutions and Environmental Sustainability: Asymmetric Effect of Institutional Quality Indicators on Ecological Degradation

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**Abstract**

This study investigates the asymmetric effects of political stability and corruption on ecological footprint using time series data from 1984 to 2021 for Pakistan. The paper uses the nonlinear autoregressive distributed lag (NARDL) method to get accurate results regarding the positive and negative shocks of political stability. Besides, the NARDL method is utilized to identify the cointegrating link between the parameters, with a particular focus on uncovering asymmetric consequences in the long term. In addition, this research also includes natural resources, urbanization and economic progress in the model. The study results show that (i) political instability in Pakistan reduces environmental quality in both shocks; (ii) control of corruption increases the air quality in the negative shock; (iii) natural resources and urban population positively affect environmental quality; and (iv) economic progress has a favourable effect on environmental worsening. Additionally, the findings of the NARDL estimates and the outcomes of the robustness check are consistent. Particularly noteworthy is the fact that the general policy recommendation highlights the need for policymakers to vigorously synchronize their efforts to contend with the severe environmental degradation and political risk in Pakistan.

**Keywords:** Political stability, institutional quality, ecological footprint, NARDL, Pakistan
**JEL Classification:** C22, N55, O13, Q56

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## 1. Introduction

The most pressing challenge faced by the world today is climate change and the accompanying global warming, primarily instigated by the uncontrolled release of greenhouse gas (GHG) emissions (Wang *et al.*, 2024). A major turning point in addressing this crisis came in 2015, when 196 countries unequivocally committed themselves to the Paris Climate Agreement, a pact designed to limit the typical temperature increase to a level well under 2 °C, thereby mitigating the deleterious effects of global warming. The efficacy of global agreements, such as the Paris Agreement and subsequent accords, including the Glasgow Agreement and other eco-friendly initiatives, depends critically on the institutional excellence inherent in countries. These institutions are accountable for formulating and implementing regulations to reduce carbon dioxide ($CO_2$) emissions. Institutions, which take various forms, including governmental, social and political entities, are subject to numerous contextual influences that affect their ability to implement and enforce environmentally conscious policies (Capano and Lepori, 2024).

In recent years, growing attention has been paid to institutional factors of environmental pollution. Institutions significantly influence environmental quality through direct and indirect channels, such as formulating and implementing regulations and policies. Scholars have proposed various proxies for assessing the quality of institutions, with political stability, corruption and adherence to the rule of law being prominent. These indicators demonstrate efficacy and operational capabilities of governance structures (Ogbonna *et al.*, 2021; Hashmi *et al.*, 2022). A robust and independent institutional structure is necessary to establish and implement environmental initiatives. An administration characterized by an anti-corruption ethos is crucial for the development and execution of a comprehensive climate strategy that encompasses the entire country, supported by a stringent rule of law. Conversely, inadequate institutional frameworks may lead to corporations exploiting regulatory loopholes and disregarding emission control measures to maximize profits (Wang *et al.*, 2022). Thus, institutional involvement in environmental sustainability is crucial and validates the idea that enhancing air quality may cut growth costs and boost revenue (Hassan *et al*., 2020). Strong institutional principles and strict legal requirements can force organizations to reduce pollution. For reducing environmental deterioration and promoting sustainable development, institutional quality is essential.

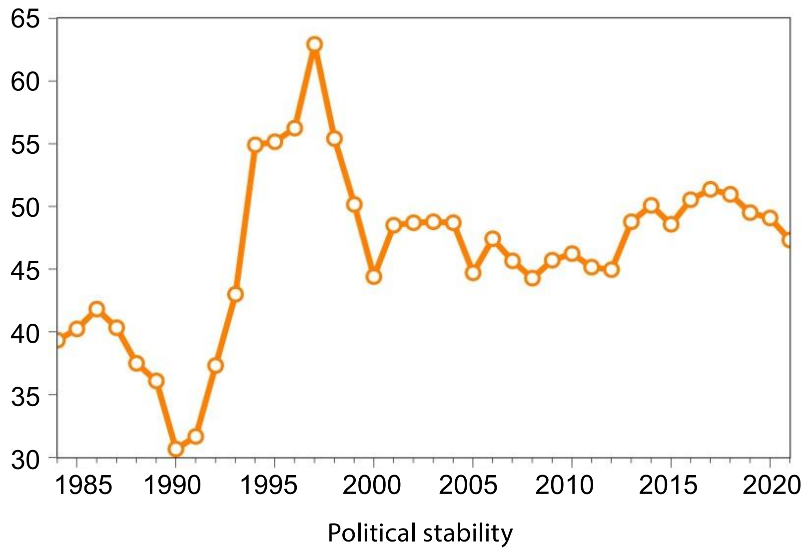
The spatial institutional ripple impact underscores the profound implications of robust institutions extending beyond national borders to contribute to emission reduction in neighbouring countries. Economic progress requires impartial and capable institutions that play a pivotal role in ameliorating environmental degradation (Slesman *et al.*, 2021). The significance of institutions becomes particularly pronounced in addressing the challenges of weak institutions, which perpetuate the low-income trap and pose significant barriers to formulating and executing effective environmental policies, unconventional energy schemes and clean technologies. Consequently, the imperative role of robust institutions in curbing environmental degradation is underscored. In recent academic studies, researchers have mostly utilized proxies, such as the rule of law or corruption, to gauge the influence of institutional quality on environmental sustainability (Arminen and Menegaki, 2019). Researchers have undertaken individual assessments of various institutional facets contextualized within specific national or regional contexts, recognizing the intricate nature of diverse institutional quality and the application of varied empirical methodologies. There are serious problems when pollution is solely linked to economic metrics while ignoring social, political and institutional variables. In this regard, neglecting the influence of governance indicators such as political stability (*PS*) and control of corruption (*CC*) will result in inadequate knowledge of the sources of pollution. Nonetheless, the literature reveals nuanced and divergent findings on the intricate association between institutions and pollution.

According to Johnston (1986), corruption is "the misuse of public positions and resources for personal perks", and it lowers living standards (Sahli and Rejeb, 2015). According to Akhbari and Nejati (2019), corruption is not only in the formal government sector but also in the profit-making operations of non-governmental entities. Consequently, low degrees of corruption encourage the establishment of institutions that promote sustainable development, protect the next generation's rights and distribute natural resources and environmental resources – which together make up public goods – during the production process, without ever compromising the circulation of benefits among generations (Akhbari and Nejati, 2019). As a result, techniques to lower pollutants and protect the atmosphere will be used.

Likewise, *PS* refers to a government's ability to accomplish its goals while maintaining its authority. Early literature neglected the link between *PS* and the environment. *PS* has always been essential to social well-being. Political breakdowns have proved their harmful effects on economies throughout time. Political shocks have many unpredictable causes, causing economic losses (Purcel, 2019). Government consistency and a corruption-free culture can help create an effective environmental plan. In simpler terms, the inept government responsible for the low-income trap limits environmental legislation, green technology and complex energy systems. Political instability affects social and economic targets by shifting legislators' focus away from sustainability issues (Mrabet *et al.*, 2021). A stable, competent government free from undue influences can establish and enforce fair environmental policies. For instance, research conducted by Kirikkaleli and Adebayo (2024) supports the notion that *PS* mitigates emissions in Brazil. Likewise, Mahmood and Alanzi (2020) found that enhancing *PS* reduces $CO_2$ emissions in Saudi Arabia. On the other hand, lobbyists may influence a fragile administration, compromising its decision-making processes. Governments experiencing instability are susceptible to lobbying organizations or international pressure groups, hindering the enactment of robust environmental regulations or adoption of cleaner technologies. Vu and Huang (2020) documented the exacerbating effects of political risk on emissions. Zhang and Chiu (2020) disclosed the intensification of emissions during political unrest. These claims highlight the need for further research to understand the impact of *PS* on $CO_2$ emissions.

A thorough investigation of the consequences of *PS* on ecological footprint (*EF*) in the most prominent politically and economically volatile country, Pakistan, as depicted in Figure 1, is paramount for a comprehensive understanding of the interconnected inquiry at hand. In Pakistan, we have been facing prolonged political instability. The problem of corruption escalates with each passing day and every political power transition. Consistently, the ruling party strives to preserve its power, while the rival party strategizes to gain command of the government. This is the reason why the political circumstances are not consistently strong and create a basis for disruption in the country (Zeeshan *et al.*, 2022). These occurrences profoundly affect both human existence and the economic structure. This endeavour aims to explore the multifaceted dynamics that govern the intricate relationship between *PS*, *CC* and *EF*. Consequently, elucidating these refined connections has crucial implications for advancing scholarly discourse on the multifaceted interplay between *PS*, *CC* and *EF*. Scholarly investigations indicate that the consequences of political economy are complex and depend on various political elements, such as the developmental phases of economies, geographical foundations, manifestations of democratic governance and electoral systems. These political variables have different effects on energy dynamics and environmental conditions, highlighting the need for more nuanced and empirically supported evidence to disentangle the complexities inherent in the relationship between *PS*, *CC* and *EF*.

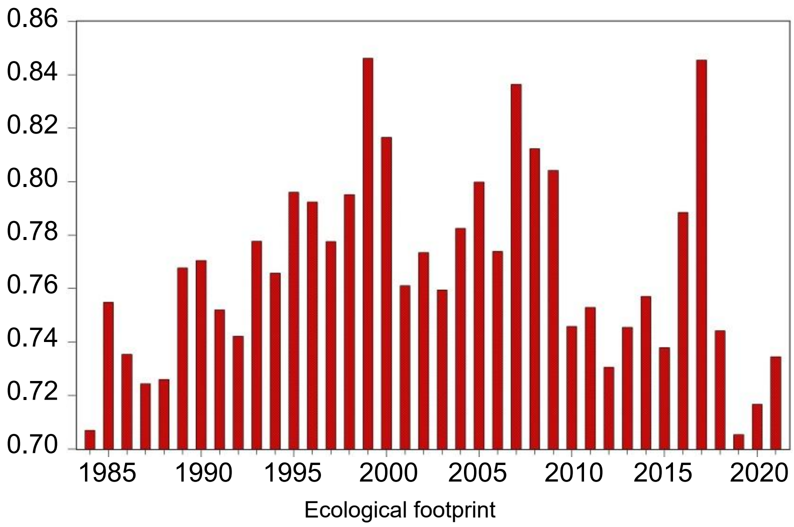
**Figure 1: Political stability in Pakistan**




Source: PRS Group (2023)

This research aims to contribute significantly to the ongoing academic conversation by exploring various avenues. This study is a pioneering effort in the academic field, addressing the previously unexplored connection between *PS*, *CC* and *EF*. Unlike previous studies, our investigation takes a comprehensive approach, examining *PS* and *CC*, and thus surpasses the limitations of single-feature assessments commonly used in earlier research. Notwithstanding Sohail *et al.* (2022), this study uses *EF* instead of environmental performance. Due to the frequent use of $CO_2$ emissions as a metric, academia has been criticized for failing to understand other aspects of sustainability. Since the individual's impact on the ecosystem is not explored, this metric has been criticized for being exclusive. Therefore, *EF* is now considered an advanced measure (Nathaniel, 2021). The *EF* is a novel methodology in the field of environmental economics that quantifies the environmental consequences of both economic and non-economic actions. Moreover, the *EF* serves as an indicator that accurately represents the progress of both national and international efforts towards achieving sustainable development. Specifically, it evaluates the effects of human activities on farmland, oceans, infrastructure, grazing land, carbon footprint and forests (Langnel *et al.*, 2021). Figure 2 displays the mixed *EF* trend from 1984 to 2021. According to the Global Footprint Network (GFN), Pakistan has a biocapacity deficit of −0.3 global hectares (gha) per person since its biocapacity per person is 0.4 gha and its *EF* is 0.7 gha. Additionally, this study probes into the intricate dynamics of the connection between *PS* and *EF* using the advanced nonlinear autoregressive distributive lags (NARDL) technique to uncover asymmetric patterns. The insights gained from this study are expected to provide nuanced perspectives, enabling the formulation of wise policy frameworks to address the environmental and energy challenges inherent in Pakistan's economic context.

**Figure 2: Ecological footprint in Pakistan**




Source: Global Footprint Network (2023)

## 2. Literature Review

The current reservoir of research into environmental performance and political economy is being challenged for two primary reasons. First and foremost, the assessment of *PS* is insufficient. Furthermore, the empirical conclusions are questionable due to the utilization of outdated estimating procedures in these investigations, which results in uncertain empirical estimations. The origins of the relationship between environmental sustainability and political stability may be traced back to the influential research conducted by Grossman and Krueger (1995). Their study revealed a U-shaped connection between environmental degradation and gross domestic product per capita. The relationship between environmental degradation and economic development, referred to as the environmental Kuznets curve (EKC) has been a topic of extensive dispute in the academic literature. However, despite several studies, no definitive proof exists to support this relationship. The fundamental reason is that some studies have regarded the correlation between pollution and expansion as an automatic mechanism. According to Grossman and Krueger (1995), it is not feasible since the EKC primarily relies on public policy responses based on government initiatives for air quality control. Furthermore, a recent conflict has arisen that highlights the significance of *PS* and the backdrop in assessing the environmental condition.

The quality of institutions is a critical factor in ensuring the viability of a country, as shown by a developing body of literature. Conversely, the empirical results concerning the nexus between environmental and institutional quality are inconsistent. While some researchers have found that institutional quality contributes to environmental destruction (Hassan *et al.*, 2020; Yamineva and Liu, 2019), others have contended that facets of institutional quality, such as democracy and *CC*, have a positive effect on the atmosphere (Adams and Klobodu, 2017; Wang *et al.*, 2018). For example, Tamazian and Bhaskara (2010) found that institutional quality lowers air pollution while analysing the influence of institutional quality on pollution in 24 transition countries. Similarly, Abid (2016) discovered that institutional quality has a negative relationship with ecosystem deterioration in Sub-Saharan African countries. Adams and Klobodu (2017) found that democracy and bureaucratic quality considerably reduces pollution in 38 African countries. Conversely, Dasgupta and De Cian (2018) emphasized that governments and institutions bear responsibility for ecosystem degradation. In a similar vein, poor institutional quality exacerbates environmental deterioration, according to Hassan *et al.* (2020).

According to Al-Mulali and Ozturk (2015), *PS* has a diminishing effect on the *EF* in 14 countries in the Middle East and North Africa (MENA) region over a period of time. Government stability lowers *EF* in India, Bangladesh, Sri Lanka and Pakistan, as demonstrated by Sabir *et al.* (2020). Their results show that to attain sustainable development, these countries must concentrate on upholding environmental rules and policies and strengthening the integrity of their institutions. In their study, Su *et al.* (2021) discovered a correlation between the reduction of political risk and decreasing $CO_2$ emissions in Brazil. Mrabet *et al.* (2021) highlighted that *PS* and human progress are crucial in diminishing the *EF*. Sui *et al.* (2021) also examined *PS* as a potential factor contributing to cross-national environmental spillovers. Their research demonstrates that enhanced *PS* in a particular country enhances the air quality in that country and positively affects surrounding countries through spillover mechanisms. Simionescu *et al.* (2023) reported that *PS* enhances pollution levels in studied economies. Recently, Xu *et al.* (2024) indicated that political stabilization helps South Asian economies shift towards sustainable energy by increasing the proportion of renewables in their energy usage patterns. On the contrary, political turmoil hinders the transformation effort. Furthermore, political stabilization in South Asia was observed to counterbalance the negative effect of increasing emissions on converting towards sustainable energy.

The research mentioned above illustrates various effects of political economy on environmental sustainability. These investigations suggest that political economy has various effects depending on the specific political measures, such as the stage of economic development, geographical location and kind of democratic system. These factors, in turn, have different implications for the atmosphere. Therefore, it is necessary to have more precise and convincing proof to unravel the complex relationship between *PS*, *CC*, and environmental quality.

# 3. Theoretical Model, Data and Methodology

## 3.1 Theoretical framework and model

Regarding the theoretical foundations, we found that implementing strict environmental regulations requires *PS* (Purcel, 2019). Policymakers are more capable of starting novel, improved environmental pollution reduction programmes when there is *PS* (Congleton, 1992). Furthermore, *PS* creates ideal circumstances for the start of new initiatives centred on the generation and use of greener energy. Nevertheless, no government can launch modern policies and programmes focused on emission-free and sustainable energy consumption if there is political turmoil and uncertainty (Uzar, 2020). *PS* enhances environmental sustainability if $\gamma_1 = EF_t/PS_t < 0$; if not, the atmosphere is uninhibited by a rise in *PS*. Through inconsistencies and inefficient resource utilization, corruption potentially has a detrimental effect on the ecosystem. Meanwhile, due to its detrimental effects on economic expansion, it may also favour environmental sustainability (Cole, 2007). We assume $\gamma_2 = EF_t/CC_t < 0$; if the association between *CC* and *EF* is negative; if not, $\gamma_2 = EF_t/CC_t > 0$. Natural resources can affect environmental longevity. Elliott (2012) found that a country's consumption patterns largely dictate how natural resources are extracted, affecting sustainability. An increase in resource usage brought on by human needs for infrastructure, electricity and water affects the ecosystem in terms of land loss and global warming. Moreover, improper natural resource breakdown may culminate in atmospheric problems due to overuse and exploitation, both of which can worsen the state of the atmosphere (Khan *et al.*, 2020). Hence, we assume $\gamma_3 = EF_t/NR_t < 0$; if the link between *NR* and *EF* is negative; if not $\gamma_3 = EF_t/NR_t > 0$. Urbanization increases the essential for energy consumption, which leads to harmful pollution and ecosystem devastation, as highlighted by Adams and Klobodu (2017). If there is a positive correlation between *UP* and *EF*, then we consider $\gamma_4 = EF_t/UP_t > 0$, if not $\gamma_4 = EF_t/UP_t < 0$. According to Balsalobre-Lorente *et al.* (2018), economic growth is the key root cause of high emission levels as it necessitates excessive energy intake, affecting the environmental quality. Thus, we presume $\gamma_5 = EF_t/EG_t < 0$; if *EG* harms *EF* else $\gamma_5 = EF_t/EG_t > 0$. Keeping these claims in mind, we created a specific environmental sustainability model which is shown below:

$$EF_t = \gamma_0 + \gamma_1 PS_t + \gamma_2 CC_t + \gamma_3 NR_t + \gamma_4 UP + \gamma_5 EG_t + \mu_t \tag{1}$$

where *EF* represents the ecological footprint, *PS* indicates political stability, *CC* stands for control of corruption, *NR* refers to natural resources, *UP* represents urbanization, *EG* denotes economic growth and $\mu$ is the error term.

## 3.2 Data

This article intends to study how *PS* and *CC* affect *EF* in Pakistan while keeping *NR*, *UP* and *EG* under consideration. For this purpose, we employ time series data from 1984 to 2021. The range of the time setting of this study is subject to the accessibility of data. *EF* (measured in global hectares per capita) is obtained from the Global Footprint Network database (GFN). In the investigation, our key factor is *PS*. *PS* is considered as the index of *PS*, which ranges from 0 to 100 and is downloaded from the International Country Risk Guide (ICRG; PRS Group, 2023). Likewise, the *CC* data are extracted from ICRG. *NR* is total natural resources rents (% of GDP), *UP* is measured as urban population (% of total population) and *EG* is estimated as constant in 2015 USD. The *NR*, *UP* and *EG* data are collected from the World Development Indicators (WDI) dataset.

## 3.3 Methods

### 3.3.1 Unit root test

To examine the association between variables, we employ a variety of techniques and processes. We initially perform the unit root test to discover whether the factors are steady because the model is a time series and the data are annual. To decide whether the variables are stationary, the Phillips and Perron (PP) unit root test designed by Phillips and Perron (1988) and augmented Dickey–Fuller (ADF) by Dickey and Fuller (2012) are useful.

### 3.3.2 NARDL

Granger causality, an error correction model (ECM) and an autoregressive distributed lag (ARDL) model are employed to check the long-term link between parameters. However, conventional linear approaches disregard the nonlinear nature of factors. To consider the nonlinear behaviour of parameters, Shin *et al.* (2014) established the NARDL strategy by building on the bound test method of Pesaran *et al.* (2001). NARDL is better than traditional ARDL models in several respects. Its initial goal is to discover asymmetries in a nonlinear style, challenging the linearity assumption. Secondly, the NARDL methodology checks the possible asymmetry of the positive and negative impacts of the explanatory factor on the dependent element in both the short and long timeframes. Thirdly, unlike the ARDL linear approach, the NARDL approach permits cointegration for the single equation technique. Due to this, *PS* and *CC* are separated into two indices: negative shock ($PS_t^-$, $CC_t^-$) and positive shock ($PS_t^+$, $CC_t^+$), respectively. The model form is as follows:

$$PS_t^+ = \sum_{j=1}^{t} \Delta PS_t^+ = \sum_{j=1}^{t} \max(\Delta PS_t^+, 0) \tag{2}$$

$$PS_t^- = \sum_{j=1}^{t} \Delta PS_t^- = \sum_{j=1}^{t} \max(\Delta PS_t^-, 0) \tag{3}$$

$$CC_t^+ = \sum_{j=1}^{t} \Delta CC_t^+ = \sum_{j=1}^{t} \max(\Delta CC_t^+, 0) \tag{4}$$

$$CC_t^- = \sum_{j=1}^{t} \Delta CC_t^- = \sum_{j=1}^{t} \max(\Delta CC_t^-, 0) \tag{5}$$

The above equations are influenced by positive and negative partial sum analysis to investigate the asymmetric influence of *PS* and *CC* on *EF*. The long-run equation is formed by the methodology of Shin *et al*. (2014):

$$EF = \gamma_o + \gamma_1 PS_t^+ + \gamma_2 PS_t^- + \gamma_3 CC_t^+ + \gamma_4 CC_t^- + \gamma_5 NR_t + \gamma_6 UP_t + \gamma_7 EG_t + u_t \tag{6}$$

The NARDL short-run ECM is as follows:

$$\Delta EF = \gamma_0 + \sum_{I=0}^{n} \gamma_1 \Delta PS_{t-j}^+ + \sum_{I=0}^{n} \gamma_2 \Delta PS_{t-j}^- + \sum_{I=0}^{n} \gamma_3 \Delta CC_{t-j}^+ + \sum_{I=0}^{n} \gamma_4 \Delta CC_{t-j}^- + \sum_{I=1}^{n} \gamma_5 \Delta NR_{t-j} \tag{7}$$

$$+ \sum_{I=1}^{n} \gamma_6 \Delta UP_{t-j} + \sum_{I=1}^{n} \gamma_7 \Delta EG_{t-j} + \varphi_1 ECM_{t-1} + u_t$$

where $\gamma_1, \ldots, \gamma_7$ are the short-run coefficients. Additionally, the coefficient of ECM is signified by $\varphi_1$.

## 4. Results and Discussion

The data descriptive statistics are shown in Table 1. *EF* has a mean value of 0.76, followed by 46.37 for *PS*, 1.98 for *CC*, 1.64 for *NR*, 33.37 for *UP* and 1.81E+11 for *EG*, respectively. The standard deviation volatility measurement reveals that *PS*, *UP* and *EG* are extremely volatile, whereas *EF*, *CC* and *NR* are less so. Moreover, *PS* and *UP* are negatively skewed. The whole series is platykurtic since the value < 3, except for *PS* and *CC*, which are leptokurtic. In addition, the Jarque–Bera test indicated normal distribution in all the parameters except *CC*.

**Table 1: Descriptive statistics**

| | *EF* | *PS* | *CC* | *NR* | *UP* | *EG* |
|---|---|---|---|---|---|---|
| **Mean** | 0.7672 | 46.3783 | 1.9684 | 1.6435 | 33.3701 | 1.81E+11 |
| **Median** | 0.7634 | 47.3750 | 2 | 1.3874 | 33.4800 | 1.60E+11 |
| **Maximum** | 0.8462 | 62.9167 | 3 | 2.8912 | 37.4400 | 3.41E+11 |
| **Minimum** | 0.7053 | 30.6667 | 1 | 0.7400 | 29.1010 | 6.98E+10 |
| **Std. dev.** | 0.0360 | 6.6703 | 0.3416 | 0.5897 | 2.4408 | 7.99E+10 |
| **Skewness** | 0.4341 | −0.2311 | 0.4731 | 0.5204 | −0.0989 | 0.4539 |
| **Kurtosis** | 2.6528 | 3.3943 | 6.4295 | 1.9683 | 1.8723 | 2.0360 |
| **Jarque–Bera** | 1.3842 | 0.5844 | 20.0394 | 3.4004 | 2.0754 | 2.7764 |
| **Probability** | 0.5005 | 0.7466 | 0.0000 | 0.1827 | 0.3543 | 0.2495 |

Source: Authors' own calculations

The Broock, Dechert and Scheinkman (BDS) test by Broock *et al.* (1996) is utilized to look into the potential of nonlinear characteristics throughout the dataset. Table 2 shows that the predefined linearity hypothesis is not true for any data series covering several integrating levels (2, 3, …, 6), at a significance level of 1%. This finding implies that all the variables have nonlinear behaviour. It implies that formula errors and uneven results might result from applying linear procedures to nonlinear data.

### Table 2: BDS test

| Variables | *EF* | *PS* | *CC* | *NR* | *UP* | *EG* |
|---|---|---|---|---|---|---|
| **Dimension** | BDS stat. | BDS stat. | BDS stat. | BDS stat. | BDS stat. | BDS stat. |
| **2** | 0.1833*** | 0.1229*** | 0.1528*** | 0.1079*** | 0.2045*** | 0.1985*** |
| **3** | 0.3048*** | 0.1935*** | 0.2147*** | 0.1710*** | 0.3446*** | 0.3342*** |
| **4** | 0.3770*** | 0.2345*** | 0.2541*** | 0.2130*** | 0.4435*** | 0.4259*** |
| **5** | 0.4219*** | 0.2497*** | 0.2568*** | 0.2299*** | 0.5155*** | 0.4902*** |
| **6** | 0.4472*** | 0.2629*** | 0.2385*** | 0.2234*** | 0.5695*** | 0.5390*** |

Note: *** represents statistically significant at the 1% level.
Source: Authors' own calculations

Prior to conducting the primary inquiry, we employ standard statistical methods to look into any possible relationships between the parameters and the value utilizing the NARDL approach. It is consequently essential to ascertain the degrees of stationarity of the factors. To confirm that the variables are stationary, we use the PP and ADF techniques. Based on the results displayed in Table 3, all the variables, except for *EF* and *CC*, have unit roots at level but are stationary at I(1).

### Table 3: Unit root test

| Variable | ADF | PP |
|---|---|---|
| ***EF*** | −3.5137** | −3.4358** |
| ***PS*** | −2.5383 | −2.0970 |
| ***CC*** | −2.7862* | −3.8571*** |
| ***NR*** | −2.6005 | −2.6005 |
| ***UP*** | −1.6108 | −1.4717 |
| ***EG*** | −2.0940 | −1.9175 |
| **d*EF*** | – | – |
| **d*PS*** | −4.3290*** | −4.3266*** |
| **d*CC*** | – | – |
| **d*NR*** | −6.2432*** | −6.3072*** |
| **d*UP*** | −2.9801** | −4.1492*** |
| **d*EG*** | −4.5406*** | −4.49832*** |

Note: ** and *** signify statistically significant at the 5% and 1% levels, respectively.
Source: Authors' own calculations

The next stage determines whether the elements have a stable, long-term relationship. We use the bound $F$-statistics for this. Setting up a suitable lag time before employing the bound testing process to confirm long-term connectivity is essential. We employ the Akaike information criterion to ascertain the proper lag duration since it yields consistently accurate results. Next, we evaluate the $F$-value of the NARDL model to verify that the factors are integrated, as shown in Table 4. The results indicate that the statistical tests are 1% above the important I(1) upper bound. The results demonstrate the cointegration of the time series variables, indicating a long-term link between the time series components in the estimated model.

**Table 4: Bound test results**

| Model | | *F*-value | Remarks |
|---|---|---|---|
| ***EF = f(PS, CC, NR, UP, EG)*** | | **9.9605*** ** | **Conclusive** |
| **Critical value bounds** | | | |
| **Significance** | I(0) bound | I(1) bound | |
| **10%** | 2.03 | 3.13 | |
| **5%** | 2.32 | 3.50 | |
| **2.5%** | 2.60 | 3.84 | |
| **1%** | 2.96 | 4.26 | |

Note: *** displays significance at 1% levels.
Source: Authors' own calculations

In order to measure the asymmetrical consequences of *PS* on *EF* in Pakistan, Table 5 shows the estimated empirical findings of the NARDL model. The long-run outcomes of *PS* positive and negative shocks affect *EF* significantly. We found that *PS* increases pollution levels in Pakistan in both shocks. A 1% increase in *PS* will worsen the atmosphere by 0.51% and 0.94%, respectively. This could be explained by several characteristics that are common to Pakistan's economy and that increase *EF*, including government unrest, deteriorating socioeconomic issues, a poor investment profile, increasing political aggression, external disputes, corrupt government authorities, military engagement in politics, religious disputes, poor law and order, ethnic tensions and low-quality bureaucracy. For example, increased corruption weakens environmental regulations, resulting in illegal resource extraction, production and consumption, rising emissions and declining environmental health (Chen *et al.*, 2018). In addition, by implementing strict laws prohibiting illegitimate pollution by imposing fines on such unlawful activities, institutional quality plays a crucial role in safeguarding the ecosystem (Wang *et al.*, 2018). The use of renewable energy sources, technological advancement and research and development are all stifled by political instability, which raises pollution levels. These results parallel the study by Awosusi *et al.* (2022), which found that political instability increases *EF*.

Additionally, Table 5 shows that in a positive shock, a boost of 1% in *CC* results in an environmental quality increase of 0.0016%, which is not significant and in a negative shock, a rise of 0.048% at a 5% significance level occurs when a fall of 1% in *CC* occurs. The environmental laws in the country will be reinforced by improved corruption control, as evidenced by the negative connection between the factors. Consequently, this will force companies to abide by these rules, which may lessen their impact on the ecosystem. Furthermore, better governance in Pakistan may further the goals of environmental interest organizations by promoting political freedom and independent information transmission, which can help lower pollution. As a result, both public knowledge and support for green policies will increase. As an outcome, the public's desire for better environmental quality will grow along with environmental consciousness. This outcome agrees with that of Ozturk and Al-Mulali (2015), who demonstrated that *CC* and improved governance reduce pollution.

Table 5 illustrates how *NR* significantly and negatively affects *EF*. Considering the statistically significant outcome, increasing the use of natural resources improves environmental performance over time by 0.08%. In regard to natural gas and other resources, Pakistan is a resource-rich country. Thus, this conclusion concerns Pakistan's usage of native energy sources, which produce fewer emissions than imported fossil fuels such as petrol. Similarly, this research suggests that using strategies for efficient use of *NR* lowers *EF*, improving the sustainability of the ecosystem. The inverse association suggests that Pakistan is using strategies to manage the use of *NR* to achieve sustainability efficiently. This suggests that *NR* rent-seeking is safe for Pakistan's environment, culminating in pollution prevention actions shown by the results. This is possible because *NR* earnings may be utilized as a reward to further improve Pakistan's environmental sustainability without harming quality. The results match those of Balsalobre-Lorente *et al.* (2018), who showed that *NR* minimize pollution.

The findings indicate a negative correlation between *UP* and *EF*; a 1% rise in *UP* boosts the quality of Pakistan's environment by 8.74%, suggesting that an increase in urban populations' buying power is associated with a heightened demand for renewable energy and subsequently reduced pollution scales (Nathaniel, 2021). This pertains to the appropriate usage of ecologically useful land, specifically in managing overexploitation. Furthermore, urbanization can generate beneficial effects and potentially enhance the benefits of economies of scale. This is primarily due to the improved accessibility of public services such as piped water, healthcare facilities, efficient waste management systems and environmentally sustainable structures. These factors contribute to the overall convenience and viability of constructing, operating and maintaining urban settlements (Charfeddine and Khediri, 2016). The findings of our study are consistent with prior research conducted by Ulucak and Khan (2020) and Zhou *et al.* (2022).

**Table 5: NARDL outcomes**

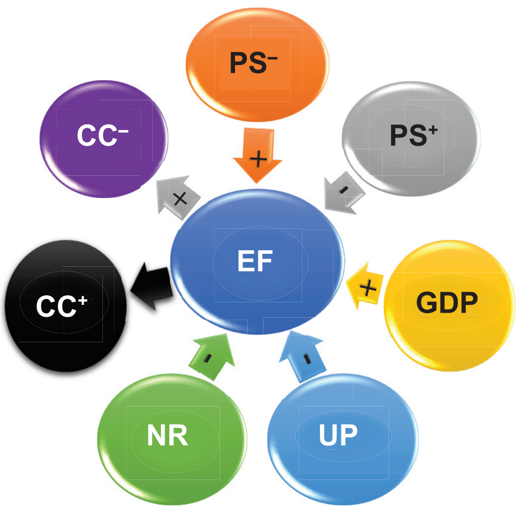
| | **Coefficient** | **Standard error** | ***p*-value** |
|---|---|---|---|
| **Long-run results** | | | |
| ***PS+*** | 0.0040*** | 0.0004 | 0.0000 |
| ***PS–*** | –0.0097*** | 0.0014 | 0.0002 |
| ***CC+*** | –0.0016 | 0.0075 | 0.8401 |
| ***CC–*** | 0.0481** | 0.0157 | 0.0152 |
| ***NR*** | –0.0807*** | 0.0152 | 0.0011 |
| ***UP*** | –8.7410*** | 1.0128 | 0.0001 |
| ***EG*** | 0.6175*** | 0.1463 | 0.0039 |
| ***C*** | –5.8502*** | 0.7336 | 0.0001 |
| **Short-run results** | | | |
| ***PS+*** | 0.0015 | 0.0012 | 0.9053 |
| ***PS–*** | –0.0043* | 0.0023 | 0.0987 |
| ***CC+*** | –0.0046 | 0.0221 | 0.8398 |
| ***CC–*** | 0.1072** | 0.0383 | 0.0266 |
| ***NR*** | –0.0358 | 0.0258 | 0.2085 |
| ***UP*** | –140.8943** | 40.8888 | 0.0108 |
| ***EG*** | 0.6284 | 0.5009 | 0.2500 |
| **CointEq(–1)** | –0.6911*** | 0.2868 | 0.0004 |

Note: ***, ** and * specify significance at 1%, 5% and 10%, respectively.
Source: Authors' own calculation

Furthermore, there is a positive association between *EG* and increasing *EF*. More specifically, it can be shown that a 1% increase in *EG* leads to a corresponding growth of *EF* by approximately 0.61% in the long run. This phenomenon is potentially feasible because heightened levels of economic activity need significant energy intake, leading to the deterioration of environmental conditions by releasing pollution into the atmosphere. Empirical data indicate that Pakistan is now experiencing economic growth at the expense of environmental degradation. Since growing countries usually overlook the possible detrimental effects of economic success on the ecosystem in their early stages of development, the findings seem reasonable for Pakistan (Khan, 2019). The present outcome supports the prior outcomes shown by Nathaniel (2021). Furthermore, this is unavoidable as rising *EG* necessitates high energy consumption, degrading environmental quality by raising atmospheric emissions.

The short run, also illustrated in Table 5, shows that a 1% increase in *PS* negative shock is correlated with a 0.0043% decrease in environmental quality. A 1% decline in *CC* negative shock is correlated with a 0.10% increase in environmental quality. The findings for *NR* are negative but insignificant. Similarly, *UP* significantly negatively affects *EF* in the short run. Finally, a 1% increase in *EG* raises *EF* by 0.62%, but it is insignificant. The findings in Table 5 highlight that there are certain deviations between the short-term outcomes and the long-term asymmetric outcomes achieved by the utilization of the NARDL estimate approach. Additionally, it is intriguing that the lag error term holds substantial importance in terms of indicating the pace of adjustment, with statistical significance noticed at the 1% level. This shows that an annual rate of 0.69% corrects any deviation from the long-term trajectory in the short term. Figure 3 offers a visual description of the study outcomes.

**Figure 3: Graphic representation of study results**




Source: Authors' own elaboration

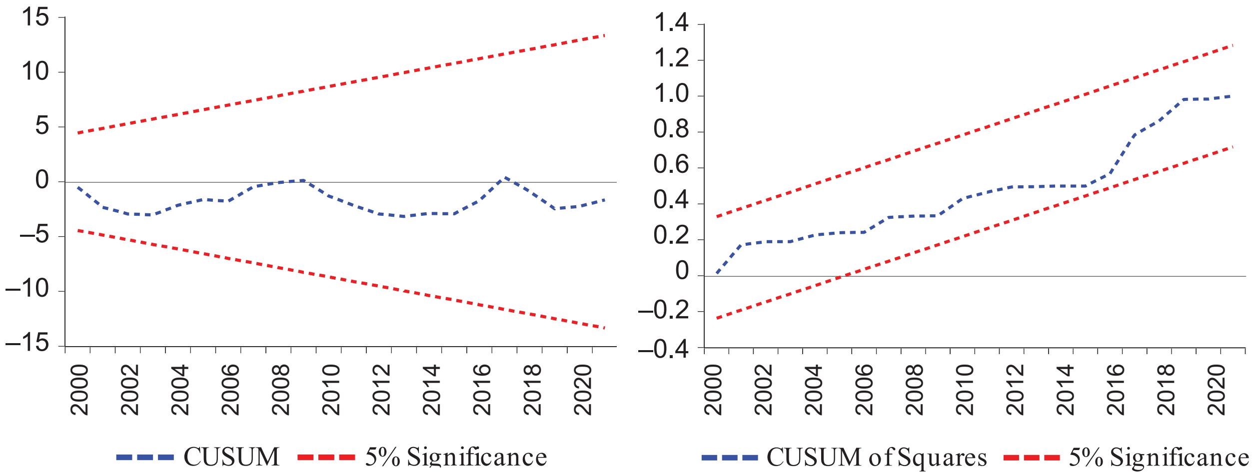
In addition, we perform a range of stability assessments and present the findings of the diagnostic tests in Table 6. The normality test specifies that the residuals have a normal distribution. The LM test indicates that there is no serial correlation. The Ramsey RESET test provides empirical evidence supporting the absence of multicollinearity. Finally, the heteroscedasticity test determines that the data in the chosen model exhibit homoscedasticity. Furthermore, recursive residuals, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests are used to validate reliability of the long-run factors. This validation can be seen in Figure 4. Based on the observed results, the calculated factors remain consistent over the given time. This is evident because the blue lines for CUSUM and CUSUMSQ consistently fall within the 5% crucial lines, indicating the model robustness.

**Table 6: NARDL diagnostic tests**

| Tests | *F*-statistics | *p*-value |
|---|---|---|
| **Serial correlation LM** | 3.9541 | 0.1439 |
| **Heteroscedasticity** | 1.2351 | 0.3879 |
| **Ramsey RESET** | 2.9109 | 0.1644 |
| **Normality** | 2.1220 | 0.3461 |

Source: Authors' own calculations

**Figure 4: CUSUM and CUSUMSQ**




Source: Authors' own calculations

## 5. Conclusion and Policy Inferences

There are a number of problems that continue to plague Pakistan's economy and environment. These problems include political instability, increased corruption, poor value of institutions linked to social disparities and environmental stress caused by the widely used fossil fuels and traditional techniques. Hence, the main goal of this paper was to look at the asymmetric effects of *PS* and *CC* on Pakistan's *EF*. To accomplish this goal, the time-series data for 1984–2021 and the NARDL technique were used. The study outcomes show that *PS* has a positive and substantial influence on *EF* in the long run. *CC* raise the air quality in the negative shock. However, the long-run effects of *NR* and *UP* lower *EF* in Pakistan. Likewise, *EF* in Pakistan is increasing by the *EG*. The present findings could be used to provide a basis for policies that would enable the Pakistani government to achieve the Sustainable Development Goals.

Certain policy proposals or implications could be put forth in light of these empirical findings. Firstly, the results imply that political instability increases the ecological footprint. Thus, Pakistan must regulate the increasing political conflict to reduce environmental harm. Political stability should improve incomes and understanding of environmental deterioration and climate change. This puts additional political weight on governments to protect the ecosystem. Stronger institutions may reduce corruption and implement strict environmental legislation and penalties for unlawful actions such as forest loss, overfishing and wildlife trading. Besides, to safeguard political stability, the administration should seek agreement of major institutions such as the judiciary, legislators, military and bureaucracy. Additionally, it should build a framework to address the country's declining economic and environmental situation effectively. Secondly, Pakistan should set goals to protect its natural wealth and make the most of its people. The administration must create measures to educate the people about natural resource exploitation to reduce sustainability issues. Last but not least, given that the findings indicate that economic progress leads to a rise in pollution levels, the Pakistani government might continue to achieve significant levels of progress while simultaneously reducing pollution levels by reducing the use of fossil fuels.

The present study is subject to many limitations. Our analysis only focused on the demand-side factors contributing to environmental deterioration, specifically examining Pakistan's ecological footprint. Additional research endeavours may delve into supply-side environmental factors, such as the load capacity factor of Pakistan, to conduct a broader analysis of the interplay between diverse economic, financial, technical and governance factors and their impact on the ecosystem.

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