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**Article**

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**Kontakt/Contact**
ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics
Düsternbrooker Weg 120
24105 Kiel (Germany)
E-Mail: *rights[at]zbw.eu*
https://www.zbw.eu/econis-archiv/

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# Impact of Green Energy Production, Green Innovation, Financial Development on Environment Quality: A Role of Country Governance in Pakistan

**Aamir Inam Bhutta[1], Muhammad Rizwan Ullah[2], Jahanzaib Sultan[3], Ahsan Riaz[3]*, Muhammad Fayyaz Sheikh[3]**

[1]Lyallpur Business School, Government College University, Faisalabad, Pakistan, [2]Lyallpur Business School, Government College University, Faisalabad, Pakistan, [3]Lyallpur Business school, Government College University, Faisalabad, Pakistan.
*Email: ahsanriaz@gcuf.edu.pk

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**ABSTRACT**

The study aims to analyze the contributions of green innovation, green energy production, and financial development to environmental quality with the moderating role of country governance. The study collects data from a panel of five South Asian economies from 2000 to 2018. The paper includes CIPS, a second-generation unit root to test the data's stationarity, and the Westerlund co-integration to investigate the long-term relationship between determinants. The Fully Modified and Dynamic Ordinary Least Square is applied to estimate the long-run coefficient and test the hypothesized relationship between selected determinants. The study finds that green innovation and green energy production negatively (positively) contribute to environmental degradation (environment sustainability). Moreover, financial development has a substantial impact on environmental degradation and sustainability, as per the findings. The study further finds a significant role of country governance in the relationship between green innovation, green energy production, environmental degradation, and environmental sustainability. Furthermore, country governance is improving the link between financial development and environmental degradation, and long-term sustainability.

**Keywords:** Green Innovation, Green Energy Production, Financial Development, Environment Degradation, Environment Sustainability, Country Governance
**JEL Classifications:** Q50, Q56, O39, F64, K32, O13, P18

## 1. INTRODUCTION

Due to the tremendous growth in carbon emissions over the last few decades, the globe has faced a severe problem of global warming. This increase deteriorates environmental quality (EQ) of both developed and developing economies' (Khan et al., 2020). This decline in EQ results in serious economic problems such as poverty, food shortage, inequality, etc. The question of "how to improve EQ" is, therefore, crucial to investigate. Many researchers have conducted studies to reduce environmental degradation (ED) and increase environmental sustainability (ES), but their findings remain inconclusive as a practical knowledge gap exists. To the authors' knowledge, the fundamental flaw in previous studies has been focusing on the contributions of various elements in lowering carbon emissions rather than examining their impact on the environment's long-term viability. Researchers assume that reducing carbon emissions ultimately improves the ES (Ahmed et al., 2021). However, this assumption is not applicable practically, as environmental sustainability and degradation are two different dimensions of Environmental Quality (Ahmed et al., 2021). Therefore, the present study investigates the contributions of different factors (green energy, green innovation, and financial

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development) in two different dimensions of EQ, named ED and ES, with the moderating role of country governance (CG).

Green energy contributes significantly to reducing GHG emissions because it is an environmentally benign energy source that reduces negative externalities from the manufacturing process (Anwar et al., 2021). Furthermore, It decreases reliance on insufficient sources, i.e., coal, gas, and fossil fuel, to protect the environment from negative externalities (Adebayo and Kirikkaleli, 2021). Many academics agree that renewable energy sources have an essential role in diminishing $CO_2$ emissions (Sohag et al., 2019). They claimed that renewable energies are the cleanest and most cost-effective way to generate electricity (Kaltschmitt et al., 2007).

Besides GEP, green innovation (GIN) is also a critical factor in improving the EQ. It helps to reduce pollution by giving people access to contemporary and innovative technologies (Popp, 2012). In addition to this, GIN can achieve climate change mitigation, improve energy efficiency, and promote ES (Shahzad et al., 2020). For instance, we can save more than 50% of the carbon emissions over a vehicle's lifetime by using environmentally friendly machinery in the industries (Gao et al., 2018). Consequently, the use of environmental/green technologies in industries lessens wastage and improves their energy efficiency. By introducing environment-friendly technologies, the economy will have lesser carbon emissions content, ultimately mitigating the ED and promoting economic sustainability (Gao et al., 2018).

In addition to GIN, financial development (FD) is also a fundamental factor having significant contributions in reducing carbon emissions. Evidence reveals that FD permits the industries to access the advanced machinery types less purposely connected to carbon emissions (Shahbaz et al., 2013). Moreover, FD promotes R&D activities and investments in cleaner technologies, which is fruitful for ES (Shahbaz et al., 2016). The present study, thus, purposes that FD, GIN, and GEP are the significant factors that significantly reduced $CO_2$ emissions and positively contributed to the ES. Furthermore, the study claims that the CG plays an essential moderating function in the connection between GEP, GIN, and FD, and EQ as a country's government makes best of its efforts to promote ES (Ahmed et al., 2021) and adapts such policies that protect the environment (Ahmed et al., 2021).

This research aims to address the following research gaps and shortcomings in the current debate of EQ. First, the study finds that researchers have worked on innovation-environment relations, but their findings are contradictory as some indicated technological innovation as a solution to environmental problems (Sinha et al., 2020; Adebayo and Kirikkaleli, 2021), while others directed it as a determinant of ED (Ahmed et al., 2021). It is thus vital to analyze the role of GIN in ED and ES so that the contribution of technological innovations becomes apparent to the sustainability and deterioration of the environment. Second, after studying the literature, we concluded that the findings of prior researchers on the relation between GEP and environment are also conflicting, and the decisions of the prior researchers regarding the contributions of energy in ED and ES are based on the explicit measure of environment, i.e., $CO_2$ emissions. This study argues that when there is a separate measure for ES, we measure it with carbon emissions, Environmental Degradation (Ahmed et al., 2020).

Third, the study finds that "How does financial development contribute to environmental sustainability?" is still less focused on the available knowledge as only a few studies (Ahmed et al., 2020) explore the contributions of FD in EQ. Fourth, the study investigates the significant moderating role of CG in the affiliations between GEP, GIN, FD, and EQ with the help of solid theoretical supports. However, as far as we recognize, the moderating role of CG has not been empirically tested by prior researchers. Fifth, we believe that no one has explored the effect of GEP, GIN, and FD on both dimensions of EQ (ED and ES) by integrating CG as a moderating factor, especially in the context of selected South Asian countries. Hence, the gaps mentioned above and shortcomings motivate the authors to investigate the influence of GEP, GIN, and FD on EQ of South Asian countries by incorporating CG as a moderating factor for the following reasons.

Problems like air pollution, global warming, water crises, poverty, and food scarcity are pervasive in South Asian economies that continuously deteriorate EQ.

Climate change is one of the most prominent reasons for all the problems faced by the region. The prime cause of change in the climate in South Asia is the rise in the absorption of GHGs (greenhouse gases). Due to the rapid increase in industrialization and other anthropogenic activities, the absorption of major GHGs, $CO_2$ is constantly increasing in South Asia. Pakistan and India are the foremost contributors to the emission of $CO_2$ in this region. Maldives is the highest contributor in terms of per capita $CO_2$ emission. Among others, air pollution is also a significant problem in South Asia, with almost the whole population defenseless to an intimidating level of gritty stuff of nearly "2.2 microns" in extent. South Asia is predicted to face a 6-7 C' warm-up by the end of the 21$^{st}$ century. The high rate of deforestation is another significant threat to the quality of the environment in this region as it is constantly extracting resources from its natural resource base, causing deterioration in EQ. After analyzing the region of South Asia's environmental situation, the current study suggests that it is necessary to explore the factors that significantly contribute to the EQ. It is also crucial to test the contributions in both the dimensions of EQ (ED and ES) to suggest important policies for the policymakers to improve the EQ of the region.

## 2. LITERATURE REVIEW

### 2.1. Theoretical Framework

The study uses ecological modernization theory, porter hypothesis, economic theory, core-macro economic theory, and environmental governance to justify the significant contributions between the variables of interest.

#### *2.1.1. Ecological modernization theory*

According to ecological modernization theory, environmental challenges can be mitigated by utilizing the latest or contemporary technologies that achieve a specific output level while using minimal energy. Green innovations are strongly associated with environmental policy, such as climate change mitigation and environmental sustainability (Ling et al., 2017).

#### *2.1.2. Porter's hypothesis*

The importance of GIN is further shown by Porter's theory. Green innovation, according to the theory, helps economic development while also addressing environmental issues. As a result, the current investigation anticipates a significant relationship between GIN and EQ.

#### *2.1.3. Core macro-economic theory*

Renewable energy is critical to the ES, according to core macroeconomic theory. The hypothesis demonstrates that energy produced from renewable sources is critical for reducing climate change and ES (Sohag et al., 2019). It is claimed that producing and using cleaner energy reduces reliance on insufficient sources (such as crude oil and fossil fuels) and removes harmful consequences from the manufacturing method, enhancing EQ (Alper and Oguz, 2016). As a result, the idea argues that GEP and EQ have a direct correlation.

The economic theory stresses the importance of capital. According to the view, capital is critical in encouraging long-term development. The current study postulated that FD enhances EQ because it allows the country to access developed and innovative machinery less associated with carbon dioxide emissions (Memon et al., 2020), which ultimately improves EQ (Adams and Klobodu, 2018). Thus, based on the economic theory, the present study expects significant relations between FD and EQ.

The theory of environmental governance demonstrates that the compelling government plays a substantial part in improving EQ. The pioneers of the environmental governance theory indicate the positive relationship between government effectiveness and EQ (Ahmed et al., 2021). They argue that the country's governance makes the best of its efforts to protect the environment by detaching the economic growth for the negative externalities (Ahmed et al., 2021). Therefore, the present study expects that country governance plays a moderating role in GEP, GIN, FD, and EQ relations.

### 2.2. Green Innovation and Environment Quality

The present study considers GIN as equivalent to environmental/technological innovation. Technological innovation-environment nexus remains a highly debated area among researchers, and numerous researchers have analyzed the role of technological/green innovation in EQ. Their findings, however, do not come to a definitive conclusion. For example, the first group of researchers concluded a negative association between technical innovation and carbon emissions and that technological origination is essential in increasing EQ (Adebayo and Kirikkaleli, 2021). Cheng et al. (2021) stated that technological or green innovations are the most effective approach to deliver the best, most efficient, and cleanest utilization of resources while reducing carbon emissions. Villanthenkodath and Mahalik (2020) investigated the influence of technical innovation in lowering carbon emissions in India from 1980 to 2018. The study discovered that combining the ARDL technique with technological improvements reduces carbon emissions significantly.

Jin et al. (2019) discovered a negative correlation between technological advances and ED as well. They observed that the rise in environmental technologies leads to an increase in ES. According to Song et al. (2020), environmental innovation has a crucial influence in reducing GHG emissions, enhancing ES. According to Sohag et al. (2015), technological revolutions tend to minimize GHG emissions by increasing the efficiency of production elements. However, the second strand of researchers has indicated the significant contributions of technological innovation in increasing GHG emissions. For instance, Khattak (2020) analyzed the role of technological innovation in the deterioration of EQ and concluded that technical innovation plays a positive role in increasing carbon emissions. Ahmad et al. (2021) also indicated that technological innovation significantly increases the level of GHG emissions for the case of Malaysia.

After studying the above works, it is depicted that researchers have extensively worked on the innovation-environment nexus. However, they could not reach a significant conclusion as some researchers indicated technological innovation as a solution to environmental problems, while others indicated it as a determinant of ED. Therefore, it is crucial to analyze the role of GIN in ED and ES. Following a review of the literature, it is predicted that:

$H_{1a}$: There is a strong association between environmental degradation and green innovation.
$H_{1b}$: There is a strong association between environmental sustainability and green innovation.

### 2.3. Green Energy Production and Environmental Quality

In this study, green energy production and consumption are equal to the production and consumption of renewable/cleaner energy sources. Various scholars have studied the impact of sustainable energy on EQ. For example, Khan et al. (2020) demonstrated that the development and consumption of renewable energy sources reduce GHG emissions while also improving EQ. As a result, the study found that renewable energies play a favorable influence on ES. Patlitzianas et al. (2007) investigated the function of renewable energy production in GHG emissions and found that it plays a considerable influence in lowering GHG emissions.

According to Panwar et al. (2011), renewable energy has a considerable impact on ES. Nathaniel and Khan (2020) looked at the influence of renewable and non-renewable energy sources in the deterioration of EQ in MENA nations from 1990 to 2016 and found that non-renewable energy sources played a beneficial and essential role in the environment. Renewable energy sources are environmentally pleasant and do not contribute to GHG emissions, according to the study. In contrast to the previous researchers, several have stated that renewable energy production significantly influences rising carbon emissions. Çıtak et al. (2020), for instance, looked examined the impact of renewable energy and natural gas usage on the degradation of the ten most populous states in the United States. In some states, authors discovered that renewable energy and natural gas use had a beneficial impact on GHG emissions, whereas, in others, they discovered that renewable energy consumption had a negative impact. Nathaniel and Khan

(2020) have mentioned the importance of renewable energy in declining ASEAN economies' EQ.

After evaluating the literature mentioned above, we concluded that previous research findings on the green energy and environment relationship are contradictory, as some writers claim a beneficial function for renewable energy while others claim a detrimental impact. Even some of the researchers have indicated a trivial role of renewable sources of energy in the environment. Moreover, researchers have measured the environment's quality, degradation, or sustainability either with GHG or carbon emissions, and their decision is based on this explicit measure of the environment. For example, if the production or consumption reduces carbon\ GHG emissions, they said that the factor positively contributes to environmental quality/sustainability. On the contrary, if the results showed the positive sign of coefficient, they conclude that the factor positively contributes to ED. We have different measures for ES and ED (Ahmed et al., 2020). Therefore, a single measure should not be used for ED and ES. Hence, it is essential to analyze the role of renewable/green energy in ED and ES. Following a review of the literature, it is hypothesized that:

$H_{2a}$: There is a strong association between green energy generation and environmental degradation.
$H_{2b}$: There is a strong association between green energy production and environmental sustainability.

### 2.4. Financial Development and Environmental Quality

The Researchers indicated that FD is very crucial for the sustainability of the environment. They argued that with the help of a sufficient amount of capital, we could quickly get access to the advanced machinery having less significant contributions to the GHG emissions. Jalil and Feridun (2011) explored the influence of FD, growth, and energy on pollutants and discovered that FD harmed climate change. They also discovered that growth and energy play a key role in carbon emissions. Tamazian et al. (2009) used panel data from Brics countries to investigate the finance-growth-environment nexus and found that FD and growth positively affect environmental conservation. A negative association between FD and ED was also observed by Ahmed et al. (2021) and Rahman et al. (2020). Diallo and Masih (2017) analyzed the correlation between FD, energy use, and environmental protection in the United Arab Emirates. According to the conclusions of the study, FD plays a significant influence in lowering GHG emissions. Simultaneously, energy consumption raises the level of GHG emissions. Li and Ouyang (2019) investigated the influence of foreign direct investment (FDI) and human capital in China's carbon emissions and discovered a positive relationship between the two factors. They concluded that FD is one of the most critical aspects of increasing EQ. Ahmed et al. (2021) also discussed the beneficial effects of FD on EQ. FDVEP is a critical pillar of ES, according to the study.

After reviewing the above literature, we propose that the relation between FD and the environment remains highly debated among previous researchers. Many researchers have investigated the role of FD in carbon emissions and concluded that FD tends to reduce carbon emissions which in turn improves the ES. Therefore, to the scholars' knowledge, the impact of FD on ES has yet to be examined. The question of "How does FD contribute to the ES?" is yet unanswered. This research aims to add to the existing knowledge by examining the role of FD in ED and ES. Following a literature review, it is postulated that:

$H_{3a}$: There is a strong association between financial development and environmental degradation.
$H_{3b}$: There is a strong association between financial development and environmental sustainability.

### 2.5. Moderating Role of Country Governance

The government of a country makes the best of its efforts for the progress of its country. Every government knows that the deterioration of the environment adversely affects the country's development (Halkos and Paizanos, 2013). Therefore, the government of every country tries to make or adapt such policies that protect the environment (Ahmed et al., 2021). Renewable energy production, technological innovation, and financial development are all proved to cut emissions. However, their contributions become more strengthen in the presence of adequate governmental quality. For instance, the government provides subsidies to encourage the installment of renewable projects or encourage investment in renewable industries, which positively contributes to the ES (Schaffer and Bernauer, 2014). The government also provides tax credits to the investors at the stage of installation and production of renewable energies (Huang et al., 2012). The government also imposes a new tax to discourage the production and consumption of conventional energy, which reduces GHG emissions and preserves the environment.

Furthermore, an efficient government increases financial market competition by carefully privatizing and liberalizing overseas markets to increase access and depth (Shahbaz et al., 2016; Almed et al., 2021). An effective government also invests capital in installing advanced and environmentally friendly machinery less significant to GHG emissions (Sohag et al., 2019). As a result, the current research posits that governance influences the link between GEP, GIN, FD, and EQ. As a result, it is proposed that:

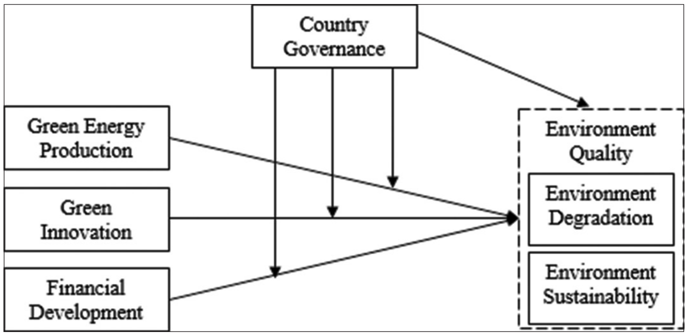
$H_{4a}$: There is a strong association between country governance and environmental degradation.
$H_{4b}$: There is a strong association between country governance and environmental sustainability.
$H_{5a}$: The association between green innovation and environmental degradation is strongly moderated by country governance.
$H_{5b}$: The association between green innovation and environmental sustainability is strongly moderated by country governance.
$H_{6a}$: The association between green energy production and environmental degradation is strongly moderated by country governance.
$H_{6b}$: The association between green energy production and environmental sustainability is strongly moderated by country governance.

$H_{7a}$: The association between financial development and environmental degradation is primarily moderated by country governance.

$H_{7b}$: The association between financial development and environmental sustainability is strongly moderated by country governance.

### 2.6. Research Framework

Figure 1: A research framework




## 3. DATA AND METHODOLOGY

### 3.1. Sources of Data

This research looks at how GEP, GIN, and FD affect EQ in South Asian nations like Pakistan, Nepal, Sri Lanka, India, and Bangladesh. Due to the non-availability of data, Bhutan, Afghanistan, and the Maldives were excluded. The role of CG as a moderator is also investigated to determine empirical results of data collected from 2000 to 2018 of selected countries. Data are acquired from various sources, including OECD statistics for GEP, International Energy Statistics (IES) for GIN, and World Development Indicators (WDI) for the rest of the variables.

### 3.2. Measurement of Variables

| Variables | Measurement | Citation |
|---|---|---|
| Dependent variables | | |
| Environmental quality (EQ) | The study uses EQ as the primary outcome variable. This variable has two dimensions; environment degradation (ED) and environment sustainability (ES) | |
| Environment degradation (ED) | ED is measured by "per capita $CO_2$ emission | (Ozturk and Al-Mulali, 2015) |
| Environment sustainability (ES) | While ES is measured by "national adjusted net savings (excluding certain emission damages) | (Ganda, 2019) |
| Independent variables | | |
| Green energy production (GEP) | GEP is energy produced from sustainable sources such as solar, wind, geothermal, biomass, or biofuel. It is calculated using the share of electricity generated by renewable power plants in total electricity generated by all types of plants | (Hao et al., 2020) |
| Green innovation (GIN) | GIN refers to the innovation in such technologies involved in waste-recycling, energy-saving, emission reduction, and corporate environmental management. This variable is measured by the "share of patents at environmental-related technologies | (Shahzad et al., 2020) |
| Financial development (FD) | Improvements in capital distribution, trade expansion, risk management, money supply, and potential investments are all referred to as FD. Liquid liabilities (% of GDP), money supply (percentage of GDP), and domestic private credit to the banking sector are the three criteria used to construct this factor (percentage of GDP) | (Batuo et al., 2018) |
| Moderating variable | | |
| Country Governance (CG) | CG is a broad notion, comprises individual rights, government regulation and services, control of corruption, and law. The study develops an index based on the efficacy of government, political stability, voice and accountability, corruption control, and regulatory excellence | (Fukumi and Nishijima, 2010) |

### 3.3. Functional Form of Variables

The study uses the following econometric models:

ED=f (GIN,GEP,FD,CG)---- Model 1

ED=f (GIN,GEP,FD,GC,GIN*CG,GEP*CG,FD*CG)---- Model 2

ES=f(GIN,GEP,FD,CG)---- Model 3

ES=f(GIN,GEP,FD,CG,GIN*CG,GEP*CG,FD*CG)---- Model 4

Where ED is environmental degradation, ES is environmental sustainability, GIN is green innovation, GEP is green energy production, FD is financial development, CG is country governance, and GIN*CG, GEP*CG, FD*CG are interaction terms.

### 3.4. Econometric Techniques

#### *3.4.1. Cross section dependency (CSD)*

The current study is focused on a set of economies in South Asia. CSD, on the other hand, typically affects panel data. According to Hsiao and Pesaran (2008), disregarding the problem of CSD leads to skewed and misleading results. CSD results are also used to choose unit-root tests (either first-generation or second-generation) and co-integration approaches. As a result, the current study relies on the Breusch and Pagan (1980) and Pesaran (2004) tests to assess the significance of CSD.

### *3.4.2. Panel unit-root test*

After evaluating the CSD problem, the study uses CIPS derived by Pesaran (2007), a second-generation unit root test, to observe stationarity and order of integration in the data. The test is founded on the cross-sectional augmented dickey fuller (CADF) model, which tracks the impact of common causes using the cross-sectional lagged average of people yt. When CSD is evident, CIPS considers the CSD problem and provides accurate and efficient results.

### *3.4.3. Co-integration test*

To see if there is a long-term correlation between factors, co-integration procedures are applied. Various co-integration strategies continue to be criticized by several researchers. Not all co-integration tests, like not all panel unit root tests, are appropriate for evaluating variables' long-term affiliation under the essential cross-section reliance assumption. In order to determine the long-run association among research determinants, the current study used Westerlund and Edgerton (2007) co-integration test, which is well-known and widely discussed.

Westerlund and Edgerton (2007) is a newly established co-integration test that is preferred to Pedroni (1999) and Kao (1999) co-integration tests since it addresses structural breaks. This method is likewise resistant to the CSD problem, and it employs the bootstrapping property to address it. It also produces effective results when the sample size is minimal. Investigating co-integration between recommended factors under the null hypothesis of "no-error correction" solves standard factor limitation. This test confirms that the error correction series included in order 1 are correct. Westerlund and Edgerton (2007) use four test statistics, two of which are based on group-mean test and panel test statistics. According to the alternative hypothesis for the group, testing at least one panel variable must be cointegrated, while the panel must be cointegrated according to the alternative hypothesis for panel test statistics. As a result, the null hypothesis is rejected, suggesting that the variables have a long-term association/co-integration. Equation 1 mentioned the specifications of the Westerlund and Edgerton (2007) test:

$$\Delta EQ_{it} = \beta_{0i} + \sum_{i=1}^{q} \varphi_i \Delta X_{i,t-i} + \gamma_i ECM_{i,t-i} + e_{it} \qquad (1)$$

Where: EQ is environment quality; X is the vector of explanatory variables, such as GIN, FD, GEP, and CG; $\gamma_i$ Is the value of the speed adjustment of error-term. If $\gamma_i = 0$, The conclusion is that there is no error correction, implying that variables are not cointegrated $\gamma_i < 0$ specified that co-integration among factors.

### *3.4.4. Estimation techniques*

The OLS estimator delivers biased, conflicted, and inconsistent findings in the presence of co-integration, the coefficients of cointegrating vectors are estimated using fully modified least square (FMOLS) and dynamic least square (DOLS) models in this study. FMOLS and DOLS are valuable methods for obtaining consistent LR parameter estimates. Moreover, both (FMOLS and DOLS) approaches to utilize the "*heteroskedastic standard errors*" as a result, the results are free of the problem of heteroscedasticity because they allow the fitting of a model with residuals. (Yang et al., 2019).

FMOLS and DOLS provide reliable estimates of parameters and deal with CSD, heterogeneity, and endogeneity.

The FMOLS coefficient is expressed in Equation 2.

$$\beta^*_i = \left(X_i' X_I\right)^{-1} (X_i' y^*_i - T\Upsilon) \qquad (2)$$

Where: $y_i$* is the converted form of independent variables, ϒ is the coefficient for autocorrelation correction, and *T* denotes the time period.

To explain the mechanism of FMOLS estimators, consider the following regression:

$$y_{it} = \alpha_i + x_{it} B + u_{it} \quad i = 1,\ldots,N;\ t = 1,\ldots,T \qquad (2.1)$$

Where: $y_{it}$ and $x_{it}$ are integrated of the same order; $y_{it}$ = (1 x 1) matrix comprises dependent variable.

B= = ($k \times 1$) slope vector; $u_{it}$ = error term that is assumed to be integrated of order zero; $x_{it}$ = vector of independent variables, where:

$$x_{it} = x_{it-1} + \varepsilon\_it \qquad (2.1.1)$$

$y_{it}$ and $x_{it}$ are cointegrated, i.e., a system of cointegrated regressions are:

$$\hat{\varepsilon}_{it} = \rho\hat{\varepsilon}_{it} + \hat{u}_{it} \qquad (2.1.1.1)$$

Kao and Chiang (2000) demonstrated that residuals might be anticipated, and after serial correlation, the FMOLS estimator was produced, resolving the issue of endogeneity caused by the OLS estimator. It is defined as:

$$\hat{\beta}_{FM} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}\left(x_{it} - \overline{x}\right)\right]^{-1}\left[\sum_{i=1}^{N} \left(\sum_{t=1}^{T}\left(x_i - \overline{x}\right)\hat{y}_{it}^{+} + T\hat{\Delta}_{\varepsilon\mu}^{+}\right)\right] \qquad (2.2)$$

$\hat{\Delta}_{\varepsilon\mu}^{+}$ = Serial autocorrelation term

$\hat{y}_{it}^{+}$ = Transformed from to correct the endogeneity.

The estimators of DOLS are obtained from equation 3.

$$Y_{it} = \alpha_i + X_{it}'\delta + \sum_{j=-q_1}^{j=q_2} L_{ij}\Delta X_{it+j} + \mu_{it} \qquad (3)$$

Where: X is the independent variables such as GEP, GIN, FD, and CG; $L_{ij}$ Is the lead or lag coefficients of predictors at first difference. Equation 3.1 shows the expression of DOLS coefficients.

**Table 1: Descriptive statistics**

| Particulars | FD | ES | ED | CG | GEP | GIN |
|---|---|---|---|---|---|---|
| Mean | 0.1599 | 23.6883 | 10.9969 | 0.0985 | 3.0098 | 2.2303 |
| Median | 0.1995 | 23.4407 | 10.9054 | 0.2372 | 3.4341 | 2.1927 |
| Maximum | 1.1837 | 26.9790 | 14.6941 | 0.5647 | 4.6069 | 3.8747 |
| Minimum | −1.5882 | 20.6658 | 7.8490 | −1.7698 | −2.6757 | 0.0392 |
| Std. Dev. | 0.3482 | 1.5850 | 2.0271 | 0.4384 | 1.4689 | 0.7643 |
| Skewness | −1.1542 | 0.5206 | 0.3176 | −2.7515 | −1.3260 | −0.0701 |
| Kurtosis | 10.5673 | 2.6317 | 2.0748 | 10.1713 | 4.7723 | 2.8061 |
| Jarque-Bera | 27.804*** | 4.828* | 4.985** | 33.454*** | 40.273*** | 0.226 |
| Probability | 0.0000 | 0.0894 | 0.0286 | 0.0000 | 0.0000 | 0.8928 |

Where: *, **, *** indicates the level of significance at 10%, 5%, and 1% respectively

**Table 2: Test of cross-sectional dependency**

| Variables | Breusch-Pagan LM | Peseran CD | Decision |
|---|---|---|---|
| FD | 19.0543*** | 8.5939** | "Cross-section dependence" |
| ES | 14.0002*** | 12.1145*** | "Cross-section dependence" |
| ED | 12.1249*** | 11.9016*** | "Cross-section dependence" |
| CG | 19.3291*** | 13.7623*** | "Cross-section dependence" |
| GEP | 10.6300*** | 6.7102** | "Cross-section dependence" |
| GIN | 16.7221*** | 11.3572*** | "Cross-section dependence" |

Where: "**, *** indicates the level of significance at 10%, 5%, and 1% respectively"

$$\hat{\beta}_{DOLS} = \sum_{i=1}^{N} (\sum_{i=1}^{N} z_{it} z'_{it})^{-1} \left( \sum_{t=1}^{T} z_{ij} \hat{y}_{it}^{+} \right) \quad (3.1)$$

Where: $z_{it} = \left[ X_{it} - \bar{X}_i, \Delta X_{i,t-q}, \ldots\ldots, \Delta X_{i,t+q} \right]$ is the vector of independent variables and $\hat{y}_{it}^{+}$ $(\hat{y}_{it}^{+} = y_{it} - \bar{y}_i)$ is the dependent variable of the study.

## 4. EMPIRICAL RESULTS

### 4.1. Descriptive Statistics

The Jarque-Bera test's significant p-values confirm that the data of FD, ES, ED, CG, and GEP are not distributed normally, indicating a problem of cross-sectional dependency in the data [Table 1].

### 4.2. Cross-Sectional Dependency (CSD)

Breusch-Pagan LM suggests the null hypothesis of cross-sectional independence/no cross-sectional dependence, and Pesaran CD tests show the problem of CSD in data. Breusch-Pagan LM and Pesaran CD [Table 2] reveal that the null hypothesis is rejected at 1 and 5% significance levels, indicating that the data has a CSD problem.

### 4.3. Second Generation Unit Root Tests

After detecting the CSD problem, the study investigates integration and static features using CIPS, a second-generation unit-root test. The test's null hypothesis is "non-stationary series." CIPS results are shown in Table 3, which reveals that none of the predicted variables is stationary at the level (depicted by insignificant test statistics). All variables become stationary at the first difference when the null hypothesis of "non-stationary series" is rejected at a level of 5%, suggesting that all variables are integrated of order 1, i.e., I (1).

### 4.4. Correlation Matrix

After examining the stationary properties of the data, the study employs a correlation matrix to confirm that the data for the current investigation are free of the problem of multicollinearity. Table 4 presents the results of the correlation coefficients, which show that there is no problem of multicollinearity in the data because the coefficient of correlation among any two variables is less than 0.80.

**Table 3: Second generation unit-root test**

| Variables | CIPS | | Decision |
|---|---|---|---|
| | Level | First difference | |
| ES | −1.607 | −3.94** | I (1) |
| ED | −1.226 | −3.67** | I (1) |
| GIN | −1.66 | −4.44** | I (1) |
| GINGP | −1.35 | −3.74** | I (1) |
| FD | −2.23 | −3.14** | I (1) |
| INSQL | −2.01 | −3.07** | I (1) |

Where: ** indicates the level of significance at 5%

**Table 4: Correlation matrix**

| Variables | FD | ES | ED | CG | GEP | GIN |
|---|---|---|---|---|---|---|
| FD | **1** | | | | | |
| ES | 0.2069 | **1** | | | | |
| ED | −0.1721 | 0.1857 | **1** | | | |
| CG | 0.1203 | 0.0828 | −0.0023 | **1** | | |
| GEP | 0.4121 | 0.1668 | −0.3761 | −0.1521 | **1** | |
| GIN | −0.1640 | 0.2130 | −0.2055 | −0.0169 | 0.2072 | **1** |

### 4.5. Test of Co-Integration

Keep in mind the stationary properties and some econometric issues (i.e., non-normality and CSD) in the data. The study applied the Westerlund co-integration test to check the long-run association among variables. The test is applied to model 1 and model 3. The test is not applied to model 2 and model 4 because these models contain interaction terms, as reported in Table 5. The significant test statistics of *Gt, Ga, Pt,* and *Pa* indicate the significant cointegrating association between the factors. This suggests that all the variables move together for 2000-2018 in selected South Asian countries.

**Table 5: Test of Co-integration**

| Model 1 | Gt | Ga | Pt | Pa | Decision |
|---|---|---|---|---|---|
| Statistic | −3.856** | −5.932*** | −8.154*** | −9.745*** | Co-integration exists |
| R.P.V | 0.025 | 0.000 | 0.001 | 0.000 | |
| **Model 3** | **Gt** | **Ga** | **Pt** | **Pa** | |
| Statistic | −4.119*** | −2.949** | −6.374*** | −10.294*** | Co-integration exists |
| R.P.V | 0.003 | 0.045 | 0.002 | 0.000 | |

**Table 6: Hypotheses testing**

| Panel A (DV: ED) | | | | | | |
|---|---|---|---|---|---|---|
| | Panel A1: FMOLS | | Decision | Panel A2: DOLS | | Robustness |
| Variables | Model 1 | Model 2 | | Model 1 | Model 2 | |
| Constant | 0.6734** (0.0263) | 0.3455*** (0.0003) | | 0.2644*** (0.0034) | 0.5343** (0.0254) | |
| GIN | −0.1136*** (0.0021) | -0.0631** (0.0451) | H1a: ☑ | −0.0911** (0.0434) | −0.0613* (0.0634) | ☑ |
| GEP | −0.2993*** (0.0000) | −0.3917*** (0.0000) | H2a: ☑ | −0.3201** (0.0024) | −0.3841*** (0.0019) | ☑ |
| FD | 0.3311*** (0.0002) | 0.2142*** (0.0000) | H3a: ☑ | 0.2934* (0.0971) | 0.2421* (0.0734) | ☑ |
| CG | −0.3531*** (0.0003) | −0.7187*** (0.0052) | H4a: ☑ | −0.0638** (0.0483) | −0.5523** (0.0264) | ☑ |
| GIN*CG | -- | −0.1867*** (0.0076) | H5a: ☑ | -- | −1.7303* (0.0998) | ☑ |
| GEP*CG | -- | −0.4609*** (0.0000) | H6a: ☑ | -- | −0.4003** (0.0373) | ☑ |
| FD*CG | -- | −1.8662*** (0.0076) | H7a: ☑ | -- | −0.1759** (0.0243) | ☑ |
| R-squared | 0.7697 | 0.8946 | -- | 0.7893 | 0.8223 | -- |
| Adj. R-squared | 0.7470 | 0.8643 | | 0.7364 | 0.8023 | |
| **Panel B (DV: ES)** | | | | | | |
| | Panel B1: FMOLS | | Decision | Panel B2: DOLS | | Robustness |
| Variables | Model 3 | Model 4 | | Model 3 | Model 4 | |
| Constant | 0.1634** (0.0263) | 0.1034** (0.0254) | | 0.3585** (0.0434) | 0.2564* (0.0864) | |
| GIN | 0.2798*** (0.0066) | 0.1174*** (0.0034) | H1b: ☑ | 0.3253*** (0.0004) | 0.3371** (0.0101) | ☑ |
| GEP | 0.1343** (0.0435) | 0.4822*** (0.0000) | H2b: ☑ | 0.3858* (0.0674) | 0.2013* (0.0522) | ☑ |
| FD | 0.2444*** (0.0014) | 1.6130*** (0.0000) | H3b: ☑ | 0.1484*** (0.0011) | 0.4545** (0.0015) | ☑ |
| CG | 0.1534*** (0.0096) | 0.5233*** (0.0000) | H4b: ☑ | 0.2244*** (0.0035) | 1.6534*** (0.0003) | ☑ |
| GIN*CG | -- | 1.8140*** (0.0000) | H5b: ☑ | -- | 0.9739** (0.0310) | ☑ |
| GEP*CG | -- | 0.3894** (0.0166) | H6b: ☑ | -- | 0.8258*** (0.0023) | ☑ |
| FD*CG | -- | 0.2664*** (0.0193) | H7b: ☑ | -- | 1.8734** (0.0352) | ☑ |
| R-squared | 0.6346 | 0.7936 | -- | 0.7073 | 0.8037 | -- |
| Adj. R-squared | 0.6045 | 0.7654 | | 0.6745 | 0.7934 | |

Where: "**, *** indicates the level of significance at 10%, 5%, and 1% respectively, DV: dependent variable, ED: environmental degradation, ES: environment sustainability"

### 4.6. Hypotheses Testing

The study uses FMOLS and DOLS to estimate the coefficient of variables after establishing the long-run connection between modeled variables. The hypotheses are accepted or rejected based on the findings of the FMOLS regression, and DOLS is used to assess the results' robustness. Table 6 summarises the FMOLS and DOLS findings. Table 6 is divided into two main panels, Panel A and Panel B. Panel A reports the long-run coefficients of models 1 and 2, while Panel B reports the long-run coefficients of models 3 and 4. However, these panels are further divided into sub-panels, i.e., Panel A1, Panel A2, Panel B1, and Panel B2. Panel A1 and B1 report the results of FMOLS, while Panel A2 and B2 report the outputs of DOLS.

In model 1 of Panel A1, the coefficient of GIN, GEP, and CG is negative, while the coefficient of FD is positive, indicating the negative (positive) impact of GIN, GEP, and CG (FD) on ED. The result implies that a 1-unit increase in FD tends to increase 0.3311 units of ED, while 1-unit inclination in GIN, GEP, and CG cause to reduce 0.1136, 0.2993, and 0.3531 units of ED, respectively. Results of model 2 in panel A1 are also like the findings of model 1. Thus, H1a, H2a, H3a, and H4a of the study are accepted. However, this relationship is significantly influenced by the inclusion of CG as a moderating factor, as the coefficients of interaction terms (GIN*CG, GEP*CG) in model 2 are significant. Comparing the interactions terms of GIN*CG and GEP*CG with the coefficient of GIN and GEP in model 1, the impact becomes more prominent.

Result exhibits that a 1-unit rise in CG tends to increase the impact of GIN and GEP on ED by 0.0171, and 0.1616 units, respectively. Results conclude that CG plays an enhancing role in the relationship between GIN, GEP, and ED. Thus, H5a and H6a are also accepted. On the contrary, when we compare the interaction term of FD*CG with the coefficient of FD in model 1, we can see that the impact of FD on ED becomes negative, which states that a 1-unit increase in CG will reverse the impact of FD on ED by 1.5351 units. The result implies that CG plays an antagonistic role in the relationship between FD and ED. Hence, H7a of the study is also accepted. The results of models 1 and 2 of Panel A2 are robust with the findings of models 1 and 2 of Panel A1.

In model 3 of Panel B1, GIN, GEP, FD, and CG coefficients are positive and significant. Result states that a 1-unit rise in GIN, GEP, FD, and CG improves 0.2798, 0.1343, 0.2444, and 0.1534 units of ES. Similarly, the coefficients of GIN, GEP, FD, and CG in model 3 of Panel B2 exhibit a positive relationship between these variables.

Thus, H1b, H2b, H3b, and H4b are accepted. Results show that the positive association between the chosen factors becomes more favorable when CG is added into the model as a moderating factor. For instance, comparing the results of model 3 with the interaction terms of model 4, the impact of GIN, GEP, FD become more apparent on ES. The result shows that a 1-unit increase in CG tends to increase the influence of GIN, GEP, FD on ES by 1.5342, 0.2551, and 0.022 units, respectively. Results conclude that CG enhances the nexus between GIN, GEP, FD, and ES. Hence, H5b, H6b, and H7b are also accepted. The results of models 3 and 4 of Panel B2 are robust with the findings of models 3 and 4 of Panel B1.

## 5. DISCUSSION AND CONCLUSION

The current study examined the effects of GIN, GEP, and FD on ED and ES. For the analysis, the researchers analyzed data from a panel of South Asian economies from 2000 to 2018. The researchers used the CIPS unit root and the Westerlund co-integration tests to assess the data's static properties to assess factors' long-term associations. To determine the long-run coefficient and assess the projected connection between components, FMOLS and DOLS were utilized.

The study discloses that GIN negatively contributes to the ED while positively contributes to the ES. The justification behind this relationship is that GIN is an innovation that extensively reduces the cost of alleviating carbon emissions by advancing more economical and outperforming technologies with less significant contributions in GHG emissions (Du and Li, 2019). GIN also observes smidgen and precludes pollution at the source while confirming that the whole process of production has a minimal environmental impact (Xu and Li, 2021). In addition, GIN contains capacity innovation that involves pollution hindrance, waste recycling, and energy-saving techniques, which reduces the adverse environmental effects and promotes ES (Wang et al., 2019). Results are aligned with ecological modernization theory, the porter hypothesis, and past researchers (Wang et al., 2019; Paramati et al., 2020). The study further found an enhancing role of country governance in the relationship between GIN, ED, and ES, which is in line with the theory of environmental governance. The possible justification behind this relationship is that the government makes the best of its efforts to adopt policies that protect the environment from the negative externalities (i.e., GHG emissions) to promote ES (Ahmed et al., 2021). Moreover, the adaptation of advanced, cleaner, or green technologies is not possible without adequate country governance support (Loiter and Norberg-Bohm, 1999). The government provides a sufficient budget for adopting advanced technologies to mitigate the adverse climate effects and promote ES.

Second, the study found a negative (positive) impact of GEP on ED (ES), which supports the core-macro economic theory. It implies that GEP is a renewable energy source that is good for the environment. that substantially reduces the adverse environmental effects by substituting the production of energy from unclean sources (i.e., fossil fuels, gas, and petroleum, etc.) to cleaner sources (i.e., solar, wind turbines, etc.) (Venetsanos et al., 2002). In addition, energy production through cleaner/renewable sources improves EQ by decreasing air pollution and the emissions of greenhouse gases. Accordingly, the economic growth induced by incorporating these renewable energy sources is sustainable as it does not degrade natural resources (Alola et al., 2019). Moreover, renewable energy sources do not produce any lethal gases; instead, they are considered eco-friendly sources that reduce adverse environmental effects and promote ES. Results of the present study are supported by previous authors (Sarkodie et al., 2020). The study further reveals the significant enhancing role of CG on the energy-environment nexus. The study argues that the government invests in different renewable energy projects to promote energy production through cleaner or greener sources that significantly reduce carbon emissions (Schaffer and Bernauer, 2014). Moreover, the government considers different policy tools to promote GEP, especially in the power sector, which reduces GHG emissions from the environment and encourages ES (Ahmed et al., 2020). Results are aligned with environmental governance theory.

Finally, the study found the positive impact of FD on both dimensions of EQ, hence supporting economic theory. The study also discovered that CG provokes the link between FD and ED while strengthening the association between FD and ES. The possible justification behind this relationship is that only access to financial resources does not reduce GHG emissions, but the use of these financial resources in a sustained manner is essential for reducing the GHG emissions from the environment (Ahmed et al., 2020). For example, there is a need to access advanced and clean technologies, cleaner energies, etc., to reduce adverse environmental effects, which is impossible without effective government intervention. The government's intervention is critical because, without CG, FD increases come from an unsustainable economic increase, resulting in a considerable increase in $CO_2$, which damages the EQ. The involvement of CG reverses these adverse environmental impacts by extending the financial infrastructure that ultimately improves the resource competencies (Adams and Klobodu, 2018).

Moreover, CG encourages sustained economic activities that lead towards a substantial reduction in the level of GHG emissions (Güngör et al., 2019). However, the possible justification behind the positive relationship between FD and ES is that only access to financial resources does not reduce carbon emissions until or unless they are used sustainably. However, access to financial resources helps promote ES by reducing poverty, inequality, and food insecurity. In addition to GHG emissions, these are prominent factors undermining ES (Wang and Dong, 2019). FD helps to reduce these factors and hence stimulates ES. The involvement of CG strengthens this impact as the explicit aim of effective governance is to reduce poverty, inequality, provide sufficient access to basic needs, and uphold ES. The findings are consistent with previous research (Jalil and Feridun, 2011; Shahbaz et al., 2013) and environmental governance theory.

This study recommends the policymakers and the government of South Asian countries to impose severe monitoring channels and financial rules regarding environmentally friendly finance to improve the quality of the environment through R&D. Such environmentally friendly technical equipment not only preserves South Asian nations' international capacities but also ensures the environment's long-term viability. A less polluting growth process would be possible if the selected countries switched from conventional to cleaner energy sources. The government's investment in industry and agriculture is critical for supporting technological innovation and the development of renewable energy sources.

The study further recommends taking initiatives to promote green technological innovation in South Asia by restructuring financial markets. The government authorities should impose a carbon tax on the production and utilization of carbon-emitting technologies to encourage investment in the production of low-carbon technologies. Accordingly, a set of rules and regulations of government against the problems causing environmental degradation needs to be implemented. In addition, it is also essential to promote green energy production in selected countries by boosting the investment in new projects of renewable energy. The regulatory authorities should stimulate the private departments to raise green energy production by sponsoring. Tax credits may be arranged for investors at the installation and production stages to amplify green energy production at large. Carbon taxes should be imposed to shift the traditional sources of energy to cleaner ones. In the end, the study suggests that the policy-making authorities focus on the quality of country governance while framing policies regarding environmental quality. The quality of governance strengthens the organizations and allows them to work effectively. Effective functioning delivers proper regulations, property rights, and laws, which, if tracked systematically, reduce $CO_2$ emissions, ultimately improving the environment quality.

There are certain limitations to this study that future researchers can explore. First, the study used CG as a moderating variable by creating the index of six different indicators. Future researchers can use its different indicators as different moderating factors to see the more prominent moderation effect. Second, the study measured ED with carbon emissions; researchers in this field can replicate this work using alternative proxies. (i.e., $NO_2$, $SO_2$, Methane dioxide)/or by creating the indexes of different proxies. Third, this research is focused on a group of selected South Asian countries; future studies should focus on other emerging markets and cross-country comparisons.

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