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Renewable Energy Use and Ecological Footprints Mitigation: Evidence from Selected South Asian Economies

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Abstract: Fossil fuel-dependency has induced a trade-off between economic growth and environmental degradation across the developing nations in particular. Against this backdrop, this study aims to evaluate the impacts of renewable energy use on the ecological footprints in the context of four South Asian fossil fuel-dependent nations: Bangladesh, India, Pakistan, and Sri Lanka. The econometric analysis involves the use of recently developed methods that account for cross-sectional dependency, slope heterogeneity, and structural break issues in the data. The results reveal that renewable energy consumption reduces the ecological footprints while nonrenewable energy use boosts the ecological footprints. The results also confirm the validity of the environmental Kuznets curve and pollution haven hypotheses for the panel of the South Asian nations. Besides, foreign direct investment inflows are found to degrade the environment while higher institutional quality improves it. Furthermore, unidirectional causalities are run from overall energy use, economic growth, and institutional quality to ecological footprints. At the same time, bidirectional associations between foreign direct investment inflows and ecological footprints are also ascertained. The overall findings highlight the pertinence of reducing fossil fuel-dependency, enhancing economic growth, restricting dirty foreign direct investment inflows, and improving institutional quality to ensure environmental sustainability across South Asia.

Keywords: renewable energy; ecological footprints; environmental sustainability; cross-sectional dependency; slope heterogeneity; structural breaks; sustainability; environment; South Asia; fossil fuels

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1. Introduction

The majority of the South Asian economies have conventionally been overwhelmingly reliant on fossil fuels for meeting their respective energy demands. Consequently, the relatively larger South Asian countries like India, Bangladesh, Pakistan, and Sri Lanka produce a large portion of their total electricity outputs from domestic and imported fossil fuels [1]. However, although such monotonic fossil fuel-dependency has significantly contributed to the economic growth of these nations, it has simultaneously resulted in unprecedented degrees of environmental problems across South Asia [2,3]. Under such circumstances, protecting the environment has become necessary to ensure environmental sustainability within this region [4,5]. However, South Asia's macroeconomic policies have traditionally focused on promoting economic growth without emphasizing protecting the environment. The contemporary growth policies should be aligned with the environmental welfare objectives since economic growth cannot be sustained without ensuring environmental sustainability in tandem.

Among the several macroeconomic factors, the persistent growth in the fossil fuel combustion levels is hypothesized to be a significant factor that has degraded South Asia's environment. Despite having the intention, these nations have not been able to phase out their predominant reliance on fossil fuels [6]. Similarly, the shares of renewable electricity in these nations' respective electricity outputs have remained significantly low compared to other similar developing nations across the globe [7,8]. However, keeping the objective of environmental sustainability into consideration, it is recommended that these fossil fuel-dependent South Asian nations gradually upscale their renewable energy consumption levels.

Enhancing renewable energy use is imperative for the fossil fuel-dependent South Asian nations in order for them to achieve the 2030 Sustainable Development Goals (SDG) agenda of the United Nations. Although the SDGs are broadly conceptualized to ensure economic, social, and environmental sustainability, this study explores the environmental impacts of the transition from nonrenewable to renewable energy resources explicitly. As opposed to the combustion of fossil fuels, the use of renewable energy resources to generate electricity, especially hydroelectricity, is asserted to reduce human ecological needs [9,10]. Accordingly, renewable energy adoption can be considered an effective means of inhibiting human activity-induced environmental hardships. Similar environmental impacts of renewable energy use can also be expected in the South Asian context, especially considering Nepal's hydroelectricity generation capacity [7]. Nepal can be a source of hydroelectricity for the fossil fuel-dependent South Asian nations. As a result, these nations can benefit by importing hydroelectricity from Nepal to reduce their dependency on fossil fuels. Therefore, it is crucially important to examine the impacts of renewable energy use on South Asia's environmental quality.

Against this backdrop, this study aims to explore the renewable energy use–environmental quality nexus in the context of four fossil fuel-dependent South Asian countries: Bangladesh, India, Pakistan, and Sri Lanka. The empirical analysis is structured as per the theoretical underpinnings of the environmental Kuznets curve (EKC) hypothesis, which postulates economic growth to initially degrade the environment while improving it later on [11–13]. However, the relationship between economic growth and environmental quality is said to be determined by several variables, including energy. Hence, apart from renewable energy, this study also aims to identify the other macroeconomic factors that can effectively ensure environmental sustainability in South Asia. Achieving environmental sustainability is also necessary from the understanding that the South Asian countries have ratified the Paris Agreement. As a result, these nations are committed to reducing their respective fossil fuel consumption-induced greenhouse gas emissions. However, it is to be noted that the nations are yet to mitigate their emission levels. Instead, the emission figures have amplified following the ratification of the agreement [6,14]. Bangladesh, Pakistan, and India are among the ten topmost polluted nations worldwide [15]. Moreover, in 2019, 30 out of the 40 most polluted global cities belonged to these three South Asian countries [16]. Therefore, these adverse environmental trends motivate us to conduct this study.

This study contributes to the relevant literature in threefold ways. Firstly, this study contributes to the limited literature that has assessed the validity of the EKC hypothesis using the per capita ecological footprint (EF) figures to proxy for environmental quality in the South Asian context. The preceding EKC studies on South Asia have conventionally quantified environmental quality in terms of the carbon dioxide (CO_2) emission levels [17–19]. However, using CO_2 emissions does not cover the multidimensional aspects of environmental adversities experienced across South Asia. This is because environmental deterioration within this region is not confined to merely air pollution [3]. As a result, EFs are relatively better environmental quality indicators in South Asia since the EF considers the other vital forms of environmental degradation [20–22]. Besides, among the recent studies that have considered EF to model the EKC hypothesis in South Asia [23,24], the critically important role of renewable energy use on the EF has been overlooked. Along this line, this study aims to bridge this literature gap since renewable energy adoption is expected to be crucial from the perspective of attaining environmental sustainability in South Asia.

Secondly, this study contributes to the EKC literature by applying the third-generation econometric methods to ascertain the stationarity and the cointegrating properties of the variables used in this study. These methods, along with handling cross-sectionally dependent heterogeneous panel datasets, are also robust in accounting for structural break problems. The existing studies have predominantly used the first- and second-generation techniques, which do not accommodate the structural break issues within the estimation processes. The third-generation methods are yet to be extensively used for examining the EKC hypothesis for South Asia. It is pertinent to control the structural break issues since the South Asian nations have experienced various macroeconomic shocks, which could play vital roles in influencing the South Asian countries' macroeconomic aggregates. To the best of the authors' knowledge, no previous EKC hypothesis study for South Asia has considered the third-generation unit root and cointegration methods.

Thirdly, this study further contributes to the South Asian EKC hypothesis literature by applying the augmented mean group (AMG) regression estimator proposed by Eberhardt and Teal [25]. This method is robust to handling cross-sectionally dependent and heterogeneous panel datasets. The method also addresses the slope endogeneity concerns within the econometric model. Furthermore, the AMG estimator, as opposed to the other conventionally used panel data regression techniques, predicts the elasticities for each cross-sectional unit. Such country-specific analysis is critically vital for flexible policymaking purposes. Although various regression techniques have been used in the EKC literature concerning South Asia, very few studies have employed the AMG estimator to address the data's issues, as mentioned above.

The remainder of the paper is structured as follows. Section 2 provides an understanding of the EF features and justifies its use as a proxy for environmental sustainability. Moreover, the trends in the EF of the South Asian nations are also explained in this section. A review of the relevant literature is presented in Section 3. The empirical models and the attributes of the dataset used in this study are explained in Section 4. The econometric techniques are described in Section 5, while Section 6 reports and discusses the econometric analysis results. Finally, Section 7 concludes with several policy takeaways.

2. An Overview of the Ecological Footprints

Measuring environmental quality only in terms of the volume of greenhouse gases emitted into the atmosphere is not enough to reflect the multidimensionality of the environmental hardships [26]. Thus, Wackernagel and Rees [27] introduced a more comprehensive measure of environmental quality in the form of the EFs. The EFs provide a platform to contrast the human needs for ecological resources and the natural ecological capacities to meet these demands and absorb the waste generated in the process [28]. Six types of bioproductive land and sea surfaces required to meet the human-ecological needs are considered in the EF calculation. These include croplands, pasture lands, fishing bodies, forest products, built-up lands, and lands for curbing CO_2 [29]. The total EF can be classified into three segments: the EF of consumption, the EF of production, and net EF embodied in international trade. Moreover, according to the nature of human ecological demand, six types of EFs are estimated: cropland footprints, grazing land footprints, forestland footprints, fishing grounds footprints, built-up land footprints, and carbon footprints. The total EF figures are given as the sum of these six footprints [27].

The trends in the total per capita EF figures and the degrees of ecological deficit of the selected South Asian economies are reported in Table 1. The figures portray that the overall environmental quality in these countries has substantially aggravated between 1990 and2014. Among the four South Asian nations considered in this study, the per capita EF of Sri Lanka increased the most (1.74 times), followed by Bangladesh, India, and Pakistan. Moreover, all these four nations' miserable environmental conditions can further be understood from the deteriorating trends in their respective per capita ecological deficits. Over the 1990–2014 period, the ecological deficits of Bangladesh, Sri Lanka, India, and Pakistan have surged by 3.4-, 2.9-, 2.2-, and 1.5-fold, respectively. Besides, it is evident that the growth rates of the South Asian economies' ecological deficits have outpaced the corresponding growth rates of their respective EF figures. This further reflects the aggravation of the environmental conditions across South Asia, which consequently became the motivation for this study.

Table 1. The ecological footprints trends in the major fossil fuel-dependent South Asian countries.

Panel A: Total Ecological Footprints (Global Hectares of Land Per Capita)				
Year	**Bangladesh**	**India**	**Pakistan**	**Sri Lanka**
1990	0.49	0.78	0.76	0.85
2000	0.57	0.86	0.84	1.20
2010	0.74	1.07	0.85	1.32
2014	0.81	1.17	0.83	1.49
Panel B: Ecological Deficit (Global Hectares of Land Per Capita)				
Year	**Bangladesh**	**India**	**Pakistan**	**Sri Lanka**
1990	0.12	0.33	0.30	0.35
2000	0.19	0.42	0.38	0.72
2010	0.34	0.63	0.46	0.82
2014	0.40	0.72	0.44	1.00

Source: Global Footprint Network [2].

3. Literature Review

The EKC hypothesis postulates an inverted U-shaped relationship between economic growth and environmental quality. As per the theoretical underpinnings of this hypothesis, economic growth is initially associated with the aggravation of environmental well-being; however, later on, economic growth is also believed to reinstate environmental well-being [30–32]. Grossman and Krueger [33] have pioneered the empirical studies on the EKC hypothesis. The authors measured environmental quality in terms of sulfur dioxide and smoke emissions in Mexico. However, the findings in that study could not statistically authenticate the EKC hypothesis. Subsequently, the EKC hypothesis has been explored using various environmental indicators. These studies have conventionally quantified environmental quality in terms of the CO_2 emission levels [34–36], which led to the documentation of equivocal evidence regarding the EKC hypothesis's validity. Hence, these contrasting findings in the literature imply that economic growth does not guarantee environmental improvement.

However, since CO_2 emissions do not consider the multidimensional aspects of environmental degradation, the contemporary studies on the EKC hypothesis have used the EF as an alternative indicator of environmental well-being. As per the EKC hypothesis's theoretical underpinnings, the nonlinearity of the economic growth–EF nexus can be explained as economic growth initially increasing the EF (synonymous to environmental deterioration) while reducing the EF later on (synonymous to environmental improvement). Analogous to the CO_2 emission-induced EKC hypothesis narrative, the ambiguous relationships between economic growth and EFs were also reported in the EKC hypothesis narrative.

Among the studies that have validated the EKC hypothesis for EFs, Aydin and Turan [37] explored the EKC hypothesis in Brazil, Russia, India, China, and South Africa (i.e., the BRICS nations). However, the EKC hypothesis was found to hold only for India and South Africa. Similarly, Pata [38] also found evidence of the EKC hypothesis for EF holding for the United States. Identical findings were reported in other country-specific studies by Bulut [39] for Turkey, Selim and Rivas [40] for Uruguay, and Mrabet and Alsamara [41] for Qatar. On the other hand, using panel datasets, Saqib and Benhmad [42] opined that the EKC hypothesis was held in the context of 22 European nations. Similarly, in a recent study on the Association of Southeast Asian Nations (ASEAN) states, Kongbuamai et al. [43] also validated the EKC hypothesis to verify the inverted U-shaped nexus between economic growth and EFs. Identical findings were put forward by Charfeddine and Mrabet [44] for 15 the Middle East and North African (MENA) countries and also by Ulucak and Bilgili [26] for high, middle, and low-income countries. In contrast, several preceding studies have also refuted the authenticity of the EKC hypothesis for EFs. Among these, Pata and Caglar [45] stated that the economic growth–EF nexus in China depicts a U-shaped relationship; thus, the EKC hypothesis does not hold for China. In another relevant study, Yang et al. [46] also found evidence of the U-shaped association between economic growth and EF in the context of China and India. Similarly, Destek and Sinha [47] for 24 OECD (Organization for Economic Cooperation and Development) countries, Mikayilov et al. [48] for Azerbaijan, and Ozcan et al. [49] for Turkey also refuted the EKC hypothesis. Apart from economic growth, EFs are believed to be influenced by a wide array of macroeconomic aggregates, including energy consumption.

The Literature on EF and Energy Use

Since energy use is often associated with economic growth, it can be expected to have an environmental impact, as well. Hence, several studies have investgated the impacts of energy use on the levels of EFs. In a study by Nathaniel [50], the author argued that higher levels of energy consumption boost the EF figures of Indonesia, both in the short and long run. In another relevant study on 38 IEA (International Energy Agency) countries, Khan and Hou [51] found per capita energy consumption to be positively correlated to the EF levels. Similar findings were highlighted by Ahmed et al. [52] for the Group of Seven (G7) countries. Therefore, these aforementioned studies tend to have highlighted the adverse environmental impacts of energy use. Although these studies predominantly assessed the impacts of total energy consumption on the EF, several recent studies have disaggregated total energy use into renewable and nonrenewable energy consumption to ascertain the energy-specific impacts on EFs.

In line with the hypothesis of the augmentation of renewable energy resources into the national energy system to ensure environmental sustainability, several existing studies have probed into the renewable energy consumption–EF nexus. Among these, Naqvi et al. [53] found statistical evidence of higher renewable energy consumption to reduce the EF in the context of the high- and upper-middle-income countries. However, in the cases of the lower-middle- and low-income countries, no statistically significant impacts of renewable energy use on the EF were ascertained. The authors also found unidirectional casualty running from renewable energy use to EFs for the high- and upper-middle-income panels only, while no causal association in this regard was found for the lower-middle- and low-income panels. Hence, the authors argued that it is easier for the relatively developed economies to ensure environmental sustainability through promoting renewable energy use. Similarly, Destek and Sinha [47] also found renewable energy use to be effective in reducing the EF of selected OECD countries. Similar findings appeared in the studies by Alola et al. [54] for 16 European Union countries and Sharma et al. [55] for developing countries from Asia.

Conversely, in a recent study on the 15 highest carbon-emitting economies, Usman et al. [56] found renewable energy use to be detrimental to environmental sustainability. The authors argued that higher renewable and nonrenewable energy use boost EFs. However, compared to nonrenewable energy, the marginal impacts of renewable energy consumption on EFs were seen to be relatively lower. Thus, the authors stated that renewable energy is a relatively better means of achieving environmental sustainability. On the other hand, Nathaniel and Khan [57] claimed that renewable energy use does not influence the EFs of selected ASEAN states. However, higher consumption of nonrenewable energy was found to be responsible for higher levels of EFs. Similarly, the country-specific results also portrayed the ineffectiveness of renewable energy in influencing the EF. In Malaysia, Vietnam, and Thailand, the positive nexus between nonrenewable energy consumption was established. The heterogeneous impacts of renewable and nonrenewable energy use on the EF were also highlighted by Nathaniel et al. [58]. The authors found that renewable energy consumption could not influence the EFs of the MENA countries as a whole. However, only in Israel and Jordan cases, higher renewable energy consumption was associated with lower EF levels. On the other hand, nonrenewable energy was found to increase the EFs of the MENA countries as a whole and also for Iran, Algeria, Oman, Tunisia, Yemen, and the United Arab Emirates. Hence, the equivocal findings documented in the aforementioned studies suggest that promoting renewable energy use does not guarantee a reduction in the EF. Therefore, it is crucial to examine the relationship in different countries.

4. Empirical Model and Data

The econometric analysis conducted in this paper is structured as per the theoretical underpinnings of the EKC hypothesis. Accordingly, the per capita EFs of the selected South Asian countries are expressed as a quadratic function of economic growth, the squared term of economic growth, renewable energy use, foreign direct investment (FDI), financial development, and institutional quality. The baseline model used in this study can be specified as follows:

$$\mathrm{lnEFPC_{it}} = \delta_0 + \delta_1 \mathrm{lnYPC_{it}} + \delta_2 (\mathrm{lnYPC_{it}})^2 + \delta_3 \mathrm{lnRECPC_{it}} + \delta_4 \mathrm{lnFDI_{it}} + \delta_5 \mathrm{lnFD_{it}} + \delta_6 \mathrm{lnPOLITY2_{it}} + \varepsilon_{it} \quad (1)$$

where i, t, and ε denote the individual cross-sections (countries), the time (years), and the error term, respectively. Here, δ_0 and $\delta_k (k = 1, \ldots 6)$ are the intercept and the elasticity parameters to be predicted. The outcome variable lnEFPC stands for the natural logarithm of per capita EFs of the South Asian countries. Higher per capita EF figures are synonymous to lower environmental quality, while lower per capita EF values would improve environmental quality [27]. The EF figures are measured in terms of global hectares of bioproductive land per capita. The explanatory variables lnYPC and $(\mathrm{lnYPC})^2$ abbreviate the natural logarithms of real GDP per capita level and its squared term, respectively. The real GDP per capita figures, measured in terms of constant 2010 US dollars, are used as a proxy for the economic growth level of the South Asian countries. As per the EKC hypothesis, the positive and negative signs of the predicted elasticity parameters δ_1 and δ_2 would validate the inverted U-shaped nexus between economic growth and EF [42,44], thus validating the EKC hypothesis. The variable lnRECPC stands for the per capita renewable energy consumption levels measured in kilograms of oil equivalent. Since renewable energy resources are environmentally friendly, higher renewable energy consumption can reduce the EF. Thus, the predicted elasticity parameter δ_3 can be hypothesized to have a negative sign [54,55]. The variable FDI abbreviates the percentage share of net foreign direct investment (FDI) inflows in the respective South Asian countries' GDP. The inclusion of FDI into the EKC model is based on assessing the pollution haven hypothesis (PHH), which advocates FDI inflows degrading the environment. If higher FDI inflow shares increase the EF figures, then the PHH can be claimed to hold, whereby the sign of the predicted elasticity parameter δ_4 can be expected to be positive [59]. In contrast, a positive sign for δ_4 would validate the pollution halo effect [60].

Besides, the EKC analysis also controls for the level of financial development within the South Asian economies. The impacts of financial development on environmental quality have received equivocal mentions in the literature [61]. It is argued that financial development stimulates environmental degradation by boosting the demand for natural resources. In contrast, financial development could also improve environmental quality by financing environment-friendly projects. In Model (1), FD abbreviates financial development, which is proxied by the percentage share of credit extended to the private sector in the GDP. The impacts of financial development on the environment have been acknowledged to be ambiguous. Hence, the sign of the predicted elasticity estimator δ_5 can either be positive [62] or negative [63]. Finally, in line with the notion of strengthening institutional quality to safeguard the environmental resources, the EKC analysis is controlled for the quality of institutions within the South Asian economies. The variable POLITY2 refers to the polity index, which acts as a proxy for institutional quality by assigning scores based on the autocratic and democratic environments within the South Asian economies. A higher value of the POLITY2 index indicates better institutional quality and vice versa. In line with the understanding that better quality of institutions is likely to promote environmental welfare, the sign of the elasticity parameter δ_6 can be expected to depict a negative sign [64].

To check the robustness of the findings, especially in reducing fossil fuel-dependency to ensure environmental sustainability, the per capita renewable energy consumption variable is replaced with the per capita nonrenewable energy consumption figures to re-estimate the EKC model. The modified model can be expressed as:

$$\text{lnEFPC}_{it} = \delta_0 + \delta_1\text{lnYPC}_{it} + \delta_2(\text{lnYPC}_{it})^2 + \delta_3\text{lnNRECPC}_{it} + \delta_4\text{lnFDI}_{it} + \delta_5\text{lnFD}_{it} + \delta_6\text{lnPOLITY2}_{it} + \varepsilon_{it} \quad (2)$$

where lnNRECPC refers to the natural logarithm of per capita nonrenewable energy consumption figures of the South Asian economies. The nonrenewable energy consumption figures are also measured in terms of kilograms of oil equivalent per capita. As opposed to renewable energy resources, the nonrenewable resources comprise environmentally unfriendly fossil fuels. Hence, although the predicted elasticity parameter δ_3 in Model (1) was hypothesized to depict a negative sign, it is expected to be positive in Model (2). This assumption is in line with the understanding that nonrenewable energy consumption attributes to environmental degradation, whereby the EF can be anticipated to rise [58].

Annual frequency spanning across 1990 and 2014 is used in the EKC analysis. The data for real GDP per capita, renewable and nonrenewable energy consumption per capita, net FDI inflows, and access to credit for the private sector are sourced from the World Development Indicators database of the World Bank [6]. The EF per capita figures are retrieved from the Global Footprint Network database [2], while the POLITY2 scores are sourced from the PolityIV project. Table 2 provides the descriptive statistics for the variables and reports the variance inflation factor (VIF) scores. The VIF analysis shows no multicollinearity concern in both the models since the VIF scores of all the explanatory variables and the mean VIF scores are below 10.

Table 2. Descriptive statistics and variance inflation factor analysis.

Panel A: Descriptive Statistics							
Variable	**Min**	**Max**	**Mean**	**St. Dev.**	**Skewness**	**Kurtosis**	**Obvs.**
lnEFPC	−0.779	0.395	−0.166	0.281	−0.311	2.648	100
lnYPC	6.018	8.162	6.889	0.516	0.559	2.763	100
lnRECPC	4.422	5.812	5.208	0.451	−0.985	2.256	100
lnNRECPC	3.463	6.001	5.019	0.585	−0.889	2.019	100
FDI	0.004	3.668	1.024	0.767	0.830	2.129	100
FD	8.821	52.387	28.164	9.904	0.648	2.195	100
POLITY2	−6	9	5.15	4.164	−1.672	2.177	100
Panel B: Variance Inflation Factor analysis							
Model (1)				Model (2)			
Variable	VIF	1/VIF	Mean VIF	Variable	VIF	1/VIF	Mean VIF
lnYPC	2.88	0.347	1.99	lnYPC	1.53	0.656	1.53
lnRECPC	2.51	0.399		lnNRECPC	1.73	0.578	
FDI	1.66	0.603		FDI	1.71	0.584	
FD	1.77	0.565		FD	1.60	0.626	
POLITY2	1.14	0.878		POLITY2	1.07	0.933	

5. Methodology

Cross-sectional dependency (CSD) is a major issue in panel data analysis. Close economic, geographic, and cultural associations between the countries included in the data can be attributed to CSD issues. As a result, a particular macroeconomic shock can induce similar impacts on multiple cross-sectional units (countries). Ignoring such CSD issues could lead to the estimation of biased and inconsistent stationarity and cointegrating properties [65]. Hence, following Murshed et al. [66,67], the Pesaran [68] CSD test is used to check for CSD. This method is chosen because of its capacity to handle datasets with small cross-sectional units and finite time dimensions. The Pesaran [68] CSD test statistic is estimated under the null hypothesis of cross-sectional independence and can be specified as:

$$CD = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\, \hat{\rho}_{ij}^{2} \rightarrow N(0,1) \quad (3)$$

Table 3 reports the results from the CSD analysis. The statistical significance of the Pesaran [68] test statistics, at a 1% significance level, reject the null hypothesis of cross-sectional independence, thereby affirming the existence of the CSD concerns in the data. This finding is justified because the selected South Asian nations are connected in terms of geographic location, international trade, culture, and similarity in policies pursued. Besides, these nations are also members of the South Asian Association for Regional Cooperation (SAARC). Furthermore, the CSD issues could also be because of all these four nations traditionally being fossil fuel-dependent and net importers of oil [6].

Table 3. The results from the Pesaran [68] cross-sectional dependency analysis.

Variable	CSD-Statistic	Probability	Decision
lnEFPC	19.230 ***	0.000	CSD exists
lnYPC	70.441 ***	0.000	CSD exists
lnRECPC	46.260 ***	0.000	CSD exists
lnNRECPC	51.270 ***	0.000	CSD exists
FDI	22.221 ***	0.000	CSD exists
FD	130.231 ***	0.000	CSD exists
POLITY2	35.230 ***	0.000	CSD exists

Note: *** denotes statistical significance at 1% level.

Apart from the CSD analysis, it is also essential to check for slope heterogeneity issues since the slope coefficients can vary across the cross-sectional units. Overlooking the slope heterogeneity problems is also said to generate biased elasticity estimates. In this study, although the selected South Asian countries are connected in several aspects, there are some differences across these nations. These nations vary in several macroeconomic aggregates, including the per capita EF figures and renewable energy consumption shares [2,6]. Thus, slope heterogeneity concerns can be expected. Therefore, following Chang et al. [69] and Li et al. [70], the slope homogeneity test of Pesaran and Yamagata [71] is used in this study. This method involves the estimation of two test statistics ($\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj.}$) under the null hypothesis of homogeneous slope coefficients across the cross-sectional units. The results from the Pesaran and Yamagata [71] test for both Models (1) and (2) are reported in Table 4. The statistical significances of the $\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj.}$ statistics, at a 1% significance level, reject the null hypothesis, affirming the existence of slope heterogeneity issues in the data.

Table 4. The results from the Pesaran and Yamagata [71] slope homogeneity analysis.

	Model (1)		Model (2)	
Test	Statistic	*p*-Value	Statistic	*p*-Value
$\widetilde{\Delta}$	21.133 ***	0.000	19.300 ***	0.000
$\widetilde{\Delta}_{adj}$	21.778 ***	0.000	19.832 ***	0.000

Note: *** denotes statistical significance at 1% level.

The problems of CSD and slope heterogeneity are considered when choosing the appropriate unit root, cointegration, regression, and causality estimation methods.

5.1. Panel Unit Root Analysis

The first-generation methods, such as the Im et al. [72] panel unit root estimators, do not account for the CSD issues in the data. Hence, the use of the first-generation methods becomes inappropriate in the context of cross-sectionally dependent panel datasets. Thus, to account for the limitations of the Im et al. [72] method, Pesaran [73] introduced the cross-sectionally augmented Im–Pesaran–Shin (CIPS) second-generation panel unit root estimator. This method is believed to predict consistent and reliable stationarity properties in the presence of CSD issues in the data [74]. The CIPS test statistic is derived from a generalized regression model that can be expressed as:

$$\Delta y_{it} = \partial_i + \delta_i y_{i,\, t-1} + c_i\, \overline{y}_{t-1} + \sum_{j=0}^{s} d_{ij}\, \Delta\overline{y}_{t-j} + \sum_{j=1}^{s} \delta_{ij} \Delta\overline{y}_{i,t-j} + e_{it} \tag{4}$$

where Δ denotes the first difference operator; $\overline{y}$ and $\Delta\overline{y}$ refer to the cross-sectional mean values of lagged levels and first differences, respectively, at time T for all individual cross-sectional units [73]. From Equation (4), the CIPS test statistic is estimated as follows:

$$\text{CIPS}\,(N,T) = N^{-1} \sum_{i=1}^{N} t_i(N,T) \tag{5}$$

where $t_i(N,\ T)$ are the *t*-statistics for δ_i.

Although the second-generation panel unit root tests account for the CSD concerns, they cannot correct the structural break issues in the data. Since the selected South Asian economies have weathered major macroeconomic shocks, such as the Asian financial crises of 1998, and have also experienced several episodes of natural calamities and terrorism incidents, it is justified to accommodate the potential structural break issues within the stationarity analysis. Thus, the Bai and Carrion-i-Silvestre [75] third-generation panel unit root estimation technique was introduced, which can simultaneously account for the CSD, slope heterogeneity, and structural break problems in the data [76]. This method estimates three test statistics, i.e., Z, Pm, and P, to ascertain the stationarity purposes. For comparability purposes, this study uses all the three aforementioned panel unit root estimators. The test statistics under these methods are commonly predicted under the null hypothesis of nonstationarity of the concerned panel series against the alternative hypothesis of stationarity.

5.2. Panel Cointegration Analysis

Much like the first-generation panel unit root methods, the first-generation panel cointegration estimators such as the Kao et al. [77] technique fail to account for the CSD concerns. Therefore, Westerlund [78] introduced a second-generation method for ascertaining the cointegrating properties in the context of cross-sectionally dependent panel datasets. In this method, the dependency across the cross-sectional units are corrected by employing a bootstrapped approach to estimate the standard errors of four test statistics, i.e., G_t, G_a, P_t, and P_a. Among these, G_t and G_a are group-mean test statistics that are predicted under the null hypothesis of non-cointegration against a relatively flexible alternative hypothesis of cointegration among the panel series in at least one of the cross-sectional units. In contrast, the two panel-mean test statistics P_t and P_a are predicted under a stricter alternative hypothesis of cointegration among the panel series in all the cross-sectional units.

However, the Westerlund [78] technique does not account for the structural break issues. Consequently, to address this limitation of the second-generation methods, the third-generation panel cointegration techniques were introduced. Among these, the Banerjee and Carrion-i-Silvestre [79] panel cointegration estimator is the latest method of ascertaining the cointegrating properties by controlling for CSD, slope heterogeneity, and structural breaks in the dataset. Another advantage of this method is that it predicts the test statistics for both the panel and the individual cross-sectional units. For comparability purposes, all the three aforementioned panel cointegration methods are used in this study.

5.3. Panel Regression Analysis

A significant limitation of the conventionally used panel data regression estimators such as the generalized method of moments (GMM), random effects (RE), fixed effects (FE) is that these methods presume the slope coefficients to be homogeneous for all the individual cross-sectional units. However, such an assumption is unrealistic given that there are certain country-specific heterogeneities in the characteristics across the cross-sectional units [80,81]. Thus, these panel regression estimators are not applicable for handling cross-sectionally dependent panel datasets, as in this current study. Therefore, following Nathaniel and Iheonu [82] and Le [83], the AMG estimator of Eberhardt and Teal [25] is used to predict the long-run elasticities of per capita EF. This method is robust in accounting for both CSD and slope heterogeneity concerns in the data. The AMG estimator tackles the CSD issues using a "common dynamic process" [25]. Besides, the AMG estimator also has a couple of more favorable features. Firstly, the AMG estimator is efficient in handling endogeneity issues, irrespective of the variables being stationary or cointegrated or not [84]. Secondly, the AMG estimator predicts the elasticities for both the panel and the individual countries included in the panel dataset [85]. Identifying the country-specific outcomes is extremely important for adopting flexible policies to keep the South Asian economies' unique features. However, the AMG estimator does not predict the short-run elasticities.

5.4. Panel Causality Analysis

The conventionally used Granger [86] causality analysis assumes slope homogeneity and does not account for the slope heterogeneity issues in the data. Hence, in keeping the slope heterogeneity concerns in the panel dataset considered in this study, the Dumitrescu–Hurlin [87] panel causality technique is used to ascertain the causal associations between the EF and the other explanatory variables. The CSD is accounted for using a bootstrapped approach. In contrast, the slope heterogeneity issue is accounted for, allowing the causal associations to vary across the individual cross-sectional units. In contrast to the Granger [86] approach, which predicts the test statistic against the alternative hypothesis of causality between a pair of stationary variables existing across all the cross-sectional units, the Dumitrescu–Hurlin [87] allows for causality between a pair of stationary variables in at least one of the cross-sectional units. The Z-bar statistic under the Dumitrescu–Hurlin [87] approach can be expressed as:

$$\overline{Z}_{N,T}^{HNC} = \frac{\sqrt{N}}{\sqrt{Var\left(\widetilde{W}_{i,T}\right)}}\left[W_{N,T}^{HNC} - E\widetilde{W}_{i,T}\right]. \tag{6}$$

The econometric analyses were conducted using the STATA15 and Gauss software applications.

6. Results and Discussion

This section begins by analyzing the results found from the panel unit root analysis reported in Table 5. The findings are reasonably homogeneous across the three alternative methods used in this study. The statistical significances of the test statistics reject the null hypothesis of nonstationarity, thus affirming the stationarity of the respective panel series. Although Im et al. [72] and Pesaran [73] suggest the variables lnYPC and lnRECPC to be stationary at both level and first difference, the Bai and Carrion-i-Silvestre [74] method affirms a common order of integration among the variables at the first difference. Since the Bai and Carrion-i-Silvestre [74] method is more robust to handling CSD, slope heterogeneity, and structural break issues, we consider and prefer the order of integration ascertained under this approach. The confirmation of the stationarity of the variables cancels out the possibility of the elasticity estimates being spurious. The cointegration analysis follows the unit root analysis.

Table 5. The results from the panel unit root analysis.

Test	Im et al. [72]	Pesaran [73]	Bai and Carrion-i-Silvestre [74]		
Variable	**W-t-bar stat.**	**CIPS stat.**	**Z stat.**	**Pm stat.**	**P stat.**
Level, I(0)					
lnEFPC	−0.389	−2.012	−0.901	−1.130	43.650
lnYPC	1.018	−3.054 **	0.880	−1.300	42.440
lnRECPC	−1.987 **	−2.279	0.750	−1.140	42.170
lnNRECPC	1.072	−2.151	−1.021	−1.200	42.850
FDI	−1.086	−1.854	1.130	−1.210	37.281
FD	0.217	−1.919	−0.780	−0.880	42.590
POLITY2	0.198	−2.190	−0.760	−0.930	41.120
1st Difference, I(1)					
ΔlnEFPC	−6.442 ***	−4.677 ***	−1.700 *	3.100 ***	68.790 ***
ΔlnYPC	−4.063 ***	−4.288 ***	−1.840 **	2.980 ***	63.190 ***
ΔlnRECPC	−7.148 ***	−5.297 ***	−2.570 ***	2.980 ***	70.890 ***
ΔlnNRECPC	−7.162 ***	−4.545 ***	−2.190 ***	2.120 **	62.210 ***
ΔFDI	−6.432 ***	−4.669 ***	−1.870 **	1.990 **	55.640 **
ΔFD	−3.940 ***	−4.072 ***	−2.200 ***	1.970 **	61.510 ***
ΔPOLITY2	−5.275 ***	−4.385 ***	−1.910 **	2.890 ***	65.950 ***

Note: The optimal lag selection was determined by the Akaike information criterion (AIC); ***, ** and * denote statistical significance at 1%, 5%, and 10% significance levels, respectively.

Table 6 reports the results from the panel cointegration analysis. The statistical significances of the test statistics under all three cointegration methods reject the null hypothesis of non-cointegration, thus affirming the cointegrating relationships between the respective models' variables. Hence, it can be said that there are long-run relationships between EFs, economic growth, renewable energy use, nonrenewable energy use, FDI inflows, and financial development in the context of the four fuel-dependent South Asian economies considered in this study. The confirmation of the long-run cointegrating relationships fulfills the prerequisite for estimating the long-run elasticities of EFs. Hence, the regression analysis follows the cointegration analysis.

Table 6. The results from the panel unit root analysis.

Panel A: Kao et al. [77] Cointegration Analysis		
Model	***t*-Statistic**	**Probability**
(1)	−3.118 ***	0.001
(2)	−4.121 ***	0.000

Panel B: Westerlund [78] Cointegration Test				
Model	**Gt**	**Ga**	**Pt**	**Pa**
(1)	−2.835 ***	−16.918 ***	−5.340	−15.400 ***
(2)	−2.758 ***	−16.010 **	−5.121	−15.121 ***

Panel C: Banerjee and Carrion-i-Silvestre [79] Cointegration Test				
Panel/Country	**Model (1)**	**Model (2)**	**Significance Level**	**Critical Value**
Panel	−6.15 ***	−5.95 ***	1%	−2.92
Bangladesh	−4.40 ***	−4.90 ***	5%	−2.82
India	−7.45 ***	−5.20 ***		
Pakistan	−2.90 **	−3.98 ***		
Sri Lanka	−5.60 ***	−7.40 ***		

Notes: The optimal lag selection is based on the AIC; the test statistics are predicted considering trend; *** and ** denote statistical significance at 1% and 5% levels, respectively.

Table 7 reports the long-run elasticity estimates from the AMG [25] regression analysis in the context of Model (1). The results validate the EKC hypothesis for the panel of the selected South Asian economies. The positive and negative signs of the elasticity parameters attached to lnYPC and (lnYPC)ˆ2 affirm this claim. Hence, it can be said that economic growth initially increases the per capita EF in these countries, but it eventually improves the environmental quality by reducing the EF later on. Therefore, economic growth can be referred to as both the cause and solution to the environmental adversities in the South Asian countries of concern. This finding is parallel to those put forward by Kongbuamai et al. [43] for ASEAN countries. The similarity of the findings can be attributed to the fact that the ASEAN states are predominantly fossil fuel-dependent like the four South Asian countries considered in this study. However, the country-specific findings seem to reveal heterogeneity. The EKC hypothesis is found to hold only for Sri Lanka, while for India and Pakistan, the relationship between economic growth and EF is found to be U-shaped. On the other hand, the elasticity estimates for Bangladesh show that economic growth monotonically increases the EF. These contrasting findings can be explained in Sri Lanka having a significantly higher per capita GDP level than the other three nations. Hence, in line with the EKC hypothesis's theoretical framework, it can be said that the comparatively higher per capita national income level may have enabled Sri Lanka to achieve the threshold growth level, beyond which the economic growth–environmental adversity trade-off can be phased out.

Table 7. The long-run elasticity estimates in the context of Model (1).

Model (1): lnEFPC = f [lnYPC, (lnYPC)^2, lnRECPC, FDI, FD, POLITY2]					
	Panel	**Bangladesh**	**India**	**Pakistan**	**Sri Lanka**
Variables					
lnYPC	2.297 ***	1.161 **	−5.355 **	−9.327 ***	6.262 ***
	(0.844)	(0.800)	(1.140)	(2.224)	(1.857)
(lnYPC) ^{2}	−0.124 **	0.137 **	0.430 ***	0.671 **	−0.389 ***
	(0.062)	(0.68)	(0.081)	(0.335)	(0.122)
lnRECPC	−0.598 ***	−0.801 **	−0.648 ***	−1.198 ***	−1.208 ***
	(0.175)	(0.400)	(0.132)	(0.230)	(0.388)
FDI	0.016 ***	0.038 **	0.019 *	0.310 ***	0.021
	(0.004)	(0.020)	(0.011)	(0.117)	(0.020)
FD	0.182	0.103	−0.105	0.008	0.113
	(0.132)	(0.089)	(0.093)	(0.007)	(0.199)
POLITY2	−0.202 ***	−0.190 ***	−0.107 ***	−0.202 ***	−0.137 ***
	(0.038)	(0.032)	(0.042)	(0.081)	(0.028)
Constant	−7.276	4.805	19.467 ***	−28.821 **	−23.657 ***
	(13.521)	(4.343)	(5.244)	(14.410)	(6.990)

Notes: The robust standard error are reported within the parentheses; ***, **, and * denote statistical significance at 1%, 5%, and 10% significance levels, respectively.

As far as the impacts of renewable energy consumption on the EF are concerned, the panel elasticity estimates show that higher consumption of renewable energy reduces the EF figures of the selected South Asian nations. Besides, this finding is homogeneous for both the panel and the country-specific elasticity estimates. However, the country-specific estimates show that the marginal impacts are relatively higher for Pakistan and Sri Lanka cases. This could be because the shares of renewables in the aggregate final energy consumption figures of Pakistan and Sri Lanka have traditionally been higher than the corresponding renewable energy shares of Bangladesh and India. Hence, these findings highlight the importance of enhancing renewable energy use to attain environmental sustainability in South Asia. Moreover, the contrasting country-specific findings imply that enhancing the renewable energy consumption shares is equally vital in enhancing the environment's quality. Thus, it is critically important for these fossil fuel-dependent South Asian countries to adopt renewable energy technologies to resolve their environmental woes gradually. The environmental welfare impacts of renewable energy use were also documented in the studies by Destek and Sinha [47] and Sharma et al. [55] for OECD and Asian countries, respectively.

Besides, FDI inflows are found to dampen the environment's quality across the selected South Asian countries. The negative signs of the elasticity parameters attached to *lnFDI* indicate that as the share of net FDI inflows in the GDP increases, it tends to boost the EF figures. Thus, the PHH can be claimed to hold for the panel of the selected South Asian nations. In this regard, the country-specific results show that FDI inflows exert similar adverse environmental impacts for the cases of Bangladesh, India, and Pakistan. However, in Sri Lanka, FDI inflows cannot statistically explain the nation's EF figures' variations. This implies that Sri Lanka has probably managed to attract environmentally friendly FDI compared to the relatively dirty-FDIs flowing into the other three nations. Thus, it is critically important for the South Asian economies to restrict dirty FDI inflows to safeguard their environmental attributes. The results are similar to those highlighted by Khan et al. [59] for China, India, and Pakistan.

On the other hand, the elasticity estimates show that financial development cannot explain the changes in the selected South Asian nations' EF figures. Besides, this finding is homogeneous for both the panel and country-specific analyses. Similarly, Baloch et al. [61] also found financial development to be ineffective in influencing India's environmental quality. Furthermore, the elasticity estimates reveal that enhancing the institutional quality exerts favorable environmental outcomes for the selected South Asian nations. The negative signs of the statistically significant elasticity parameters attached to POLITY2 affirm this claim. This finding is factual for both the panel and the country-specific cases, highlighting the relevance of improving institutions' existing qualities to protect the ecological reserves across South Asia. Since most of these nations have low institutional quality concerns, this finding could strengthen the associated institutions, especially those directly and indirectly authorized to safeguard South Asia's ecological reserves.

Although the elasticity estimates in the context of Model (1) statistically certified the positive environmental impacts of renewable energy use in South Asia, it is also pertinent to evaluate nonrenewable energy's environmental impacts for relevant policymaking purposes. Hence, for robustness check of the findings, Model (1) is re-estimated by replacing the renewable energy consumption levels by the nonrenewable energy consumption levels.

The long-run elasticity estimates in the context of Model (2) are reported in Table 8. It can be seen that higher consumption of nonrenewable energy boosts the concerned South Asian nations' EF. The positive sign of the statistically significant elasticity parameter attached to lnNRECPC affirms this claim. The positive nexus between per capita nonrenewable energy use and EF is also homogenous for the whole panel and the individual South Asian economies considered in this study. However, compared to Pakistan and Sri Lanka, the marginal adverse environmental impacts of nonrenewable energy use are relatively more remarkable in Bangladesh and India. This can be credited to the fact that the shares of nonrenewable energy use in Bangladesh and India's aggregate energy consumption levels have been significantly greater than those of Pakistan and Sri Lanka throughout the study period. Thus, the elasticity estimates from Model (2) support the corresponding elasticity estimates from Model (1) to highlight the importance of enhancing renewable energy use to attain environmental sustainability in South Asia. The adverse environmental impacts of nonrenewable energy use were also found in the studies by Nathaniel and Khan [57] for the ASEAN states, Usman et al. [56] for high carbon-emitting nations, and Nathaniel et al. [58] for a panel of MENA countries.

Furthermore, the other elasticity estimates across both models validate the EKC hypothesis and highlight the positive and negative nexuses between FDI inflow and EF and between institutional quality and EF. Once again, financial development is found to be ineffective in explaining the variations in the EF figures of the concerned South Asian nations. In line with these findings, the elasticity estimates found in this study can be referred to as robust across the two alternative models considered in this study.

Table 8. The long-run elasticity estimates in the context of Model (2).

Model (2): lnEFPC = f [lnYPC, $(\text{lnYPC})^2$, lnNRECPC, FDI, FD, POLITY2]					
	Panel	**Bangladesh**	**India**	**Pakistan**	**Sri Lanka**
Variables					
lnYPC	2.611 ***	2.653 **	−4.357 ***	−12.150 ***	4.200 ***
	(0.750)	(1.102)	(1.230)	(3.900)	(1.101)
$(\text{lnYPC})^2$	−0.096 ***	0.325 ***	1.187 ***	1.908 **	−0.350 **
	(0.028)	(0.120)	(0.340)	(0.450)	(0.176)
lnNRECPC	0.330 **	1.350 **	0.948 ***	0.672 **	0.528 ***
	(0.165)	(0.501)	(0.230)	(0.236)	(0.210)
FDI	0.021 ***	0.089 **	0.030 **	0.380 ***	0.050
	(0.009)	(0.035)	(0.014)	(0.115)	(0.039)
FD	0.135	0.122	−0.128	0.068	0.201
	(0.990)	(0.101)	(0.103)	(0.054)	(0.160)
POLITY2	−0.247 ***	−0.207 ***	−0.169 **	−0.189 ***	−0.208 **
	(0.075)	(0.069)	(0.085)	(0.101)	(0.105)
Constant	−4.370	7.810 ***	9.980 ***	−24.850 **	−20.560 ***
	(4.643)	(2.560)	(4.230)	(12.420)	(5.120)

Notes: The robust standard error are reported within the parentheses; *** and ** denote statistical significance at 1% and 5% significance levels, respectively.

Finally, Table 9 reports the causal associations between the variables that are ascertained using the Dumitrescu–Hurlin [87] approach. The results reveal a unidirectional causality running from lnRGDPPC to lnEFPC. This implicates that economic growth influences the EF levels of the concerned South Asian economies. Thus, this finding supports the corresponding elasticity estimate, and it certifies economic growth to be both the cause and solution to the environmental problems in South Asia. This finding is parallel to Destek and Sarkodie [88] for newly industrialized economies, including India. Besides, unidirectional causalities stemming from renewable and nonrenewable energy consumption to EF are also ascertained from the causality analysis. Therefore, it can be said that the overall energy consumption levels of the South Asian economies influence their levels of EF. Thus, considering the corresponding elasticity estimates, it is ideal for these economies to reduce their fossil fuel-dependencies and adopt renewable energy technologies to ensure environmental sustainability. Wang and Dong [89] also found unidirectional causality running from renewable energy use to EF for the case of Sub-Saharan African nations while Usman et al. [56] found unidirectional causality running from nonrenewable energy use to EF in the context of 15 most carbon-emitting nations, which included India as well.

Table 9. The results from the Dumitrescu–Hurlin [87] panel causality analysis.

Null Hypothesis	Z-Bar Tilde Stat.	Probability	Causality	Direction
lnYPC $\nrightarrow$ lnEFPC	5.486 ***	0.000	Unidirectional	lnYPC $\rightarrow$ lnEFPC
lnEFPC $\nrightarrow$ lnYPC	1.280	0.400		
lnRECPC $\nrightarrow$ lnEFPC	7.289 ***	0.000	Unidirectional	lnRECPC $\rightarrow$ lnEFPC
lnEFPC $\nrightarrow$ lnRECPC	1.990	0.300		
lnNRECPC $\nrightarrow$ lnEFPC	3.015 ***	0.000	Unidirectional	lnNRECPC $\rightarrow$ lnEFPC
lnEFPC $\nrightarrow$ lnNRECPC	1.271	0.400		
FDI $\nrightarrow$ lnEFPC	3.741 ***	0.000	Bidirectional	FDI $\leftrightarrow$ lnEFPC
lnEFPC $\nrightarrow$ FDI	2.380 ***	0.000		
FD $\nrightarrow$ lnEFPC	0.910	0.600	No causality	FD $\neq$ lnEFPC
lnEFPC $\nrightarrow$ FD	1.100	0.500		
POLITY2 $\nrightarrow$ lnEFPC	4.330 ***	0.000	Unidirectional	POLITY2 $\rightarrow$ lnEFPC
lnEFPC $\nrightarrow$ POLITY2	1.001	0.200		

Note: $\nrightarrow$ denotes does not Granger cause; the optimal lag selection is based on the AIC; the probability values are estimated using 5000 bootstrapped replications; *** denotes statistical significance at 1% significance level.

The causality estimates also find bidirectional causal associations between FDI inflows and EF. This interdependency between FDI inflows and EF could be explained in this way: Not only do dirty FDI inflows degrade the environment, but the deteriorating trends in the EFs could also send a signal to the foreign investors to outsource production of environmentally unfriendly goods and services from the South Asian economies. Thus, restricting inflows of such dirty FDI and simultaneously reducing the EF is critically important for these nations. Zafar et al. [90] reported similar feedback causations between FDI inflows and EF in the United States context. On the other hand, no causal association between financial development and EF could be statistically established in this study. This further supports the corresponding elasticity estimates being used to clarify why financial development could not explain the variations in the EF figures. Finally, a unidirectional causality stemming from POLITY2 to lnEFPC is found, which implies that institutional quality does play a crucial role in ensuring environmental sustainability across the selected South Asian nations. This finding is parallel to the result found by Charfeddine and Mrabet [44] in the context of selected MENA countries.

7. Conclusions

Fossil fuel-dependency is a common feature of developing countries. However, such monotonic reliance on nonrenewable energy resources results in multidimensional environmental adversities to which the South Asian fossil fuel-dependent nations are no exception. Under such circumstances, undergoing replacing fossil fuels with renewable energy alternatives has been acknowledged as means to ensuring environmental sustainability without compromising economic development. Against this backdrop, this study aimed to evaluate the impacts of renewable energy use on the EF of four South Asian nations that have traditionally been fossil fuel-dependent: Bangladesh, India, Pakistan, and Sri Lanka. The analysis was conducted under the EKC hypothesis framework controlling for energy use, FDI inflows, financial development, and institutional quality concerning these nations between 1990 and 2016. The econometric methodology involved relatively latest methods robust to handling CD, slope heterogeneity, and structural break issues in the data.

The overall findings revealed that higher renewable energy use mitigates the EFs of the South Asian nations of concern. In contrast, nonrenewable energy consumption was found to be associated with higher levels of EFs. Besides, these findings were homogeneous for both the panel and the country-specific analyses. Moreover, the EKC hypothesis was authenticated for the South Asian panel and only for Sri Lanka. On the other hand, the PHH was also confirmed. Furthermore, the better institutional quality was predicted to reduce the EF in South Asia. Finally, the causality estimates revealed unidirectional causalities stemming from economic growth, renewable energy use, nonrenewable energy use, and institutional quality to the EF. At the same time, FDI inflows and EF were found to be bi-directionally associated.

In line with these findings, the following policy recommendations can be suggested. Firstly, since renewable and nonrenewable energy consumption was found to exert opposing impacts on the EF, it is pertinent for the South Asian economies to gradually phase-out their monotonic dependency on fossil fuels. In this regard, the traditional fossil fuel-dependent South Asian countries should augment renewable resources into their respective energy mix. However, given the technological and infrastructural limitations, enhancing the share of renewables in the total energy consumption profile may not be an easy task for these nations. Therefore, along with enhancing the renewable energy consumption levels, traditional fossil fuels should be replaced with relatively less dirty alternatives. These fuels can be expected to act as transitionary fuels before these nations can overcome the factors that have inhibited South Asia's renewable energy sectors' expansion. Secondly, since the EKC hypothesis was found to hold, it is imperative for South Asian nations to expedite their respective economic growth rates to attain the threshold growth level. However, the expansionary economic policies should boost renewable energy consumption while simultaneously reducing fossil fuel use. Thus, it is pertinent for these economies to ensure complementarity between their respective economic and environmental development policies. Thirdly, the financial globalization policies need to be restructured to restrict the inflows of dirty FDIs into South Asia. The concerned governments should adopt relevant policies to prevent the South Asian nations from turning into pollution havens. Finally, enhancing the institutions' quality is imperative for safeguarding South Asian nations' ecological reserves. In this regard, improving the democratic environment, enhancing accountability, increasing political transparency, and controlling corruption could be some of the policy interventions expected to improve the existing institutions' quality.

As far as the future research scope is concerned, this study can be extended by assessing the impacts of renewable energy use on other environmental quality indicators. Besides, the possible heterogeneous impacts of renewable energy on the different components of the EF can also be studied. Moreover, this study can be further extended by controlling other vital macroeconomic aggregates that can address South Asia's environmental welfare concerns.

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Abbreviations

SDG	Sustainable Development Goals
EKC	Environmental Kuznets curve
EF	Ecological footprint
CO_2	Carbon dioxide
AMG	Augmented mean group
BRICS	Brazil, Russia, India, China, and South Africa
ASEAN	Association of Southeast Asian Nations
MENA	The Middle East and North Africa
OECD	Economic Cooperation and Development
IEA	International Energy Agency
G7	Group of Seven
YPC	Real gross domestic product per capita
RECPC	Renewable energy consumption per capita
FDI	Foreign direct investment
PHH	Pollution haven hypothesis
FD	Financial development
POLITY2	Polity Index
NRECPC	Nonrenewable energy consumption per capita
VIF	Variance inflation factor

CSD	Cross-sectional dependency
SAARC	South Asian Association for Regional Cooperation
CIPS	Cross-sectionally augmented Im–Pesaran–Shin
GMM	Generalized method of moments
RE	Random effects
FE	Fixed effects

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