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Research Article

Unfolding the Role of Economic Variables on SDGs and Ecological Footprint in SAARC Economies since 2000-2021

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Abstract

The paper describes the importance of overall score of sustainable development goals (SDG) and mitigation of ecological footprint in SAARC economies the basis of real variables. Adoption of renewable energy for independence on energy needs, economic growth and consideration of the globalization for sustainability plays a crucial role on SAARC economies. Moreover, some prior work has also examined this issue, but the focus was more on the ecological footprint as an indicator of sustainability of the economy. This study examines the two key elements of the works in this area. Firstly, ecological footprint and secondly, overall score of sustainable development goals as impacted by renewable energy consumption, economic growth and globalization in SAARC economies from 2000 to 2021. Use of advanced econometric approaches, namely Panel-Corrected Standard Errors (PCSE), Feasible Generalized Least Squares (FGLS), and Driscoll-Kraay estimators, are used to handle the heterogeneity and cross-sectional dependence which are common in panel data in order to guarantee error free results. The most significant observations of this study are: Firstly, renewable energy consumption have double-edged causation on ecological footprint and overall score of sustainable development goals in SAARC economies. Secondly, globalization reduces ecological footprint and increases overall score of SDG. Finally, economic growth increases ecological footprint and reduces overall score of SDG. These observations are aligned with PCSE, FGLS and Driscoll-Kraay estimation at 1% level of significance. Further, a significant number of explanatory variables have a unidirectional relationship on ecological footprint and overall score of SDG except renewable energy consumption. Further as revealed by the Dumitrescu-Hurlin panel causality test which indicates a need to take action in order to improve overall score of SDG and mitigate ecological footprint SAARC economies to harness renewable energy resources through investment on R&D and green technologies in substantial manner.

Keywords: Ecological Footprint, Sustainable Development Goals (SDGs), Renewable Energy Consumption, Globalization, SAARC Economies

1. Introduction

Global issues like biodiversity loss and climate change are addressed by the Sustainable Development Goals (SDGs) of the UN, however reaching these goals requires policy coherence, with trade-offs and synergies arising [1]. However, adaptation in 2015, the SDGs seek to achieve equilibrium between economic, social, and ecological objectives while addressing every country and improving sustainability. A social environments approach is vital for analyzing and sustaining development [2].While carbon emissions restrict SDG coupling coherence in high-middle-income and high-income nations, they greatly enhance it in low and low-middle-income countries, with regional differences [3]. Although, boost energy research and development spending, recycle, employ energy-efficient technologies, embrace sustainable supply strategies, boost afforestation, and preserve the environment. Future research should look at how municipal regulations affect EF and take trash reduction and car recycling into account [4]. Although, global warming is shown by consumption-based emission accounting, but emissions associated with the consumption of goods and services and their effects on the SDGs, particularly in the SAARC region, are not given enough consideration [5]. Nonetheless, as income rises, additional funds can be allocated to renewable energy projects and strict regulations for sustainable resource use, expanding the share of renewable energy in the energy mix [6].

In order to improve national economy and integrate with the global economy, stimulate the diffusion of energy-efficient technologies, and encourage active engagement in international climate change negotiations, globalization and REC are crucial [7]. Although, renewable energy has a lot of potential, mainstream adoption is hampered by high installation costs. Biofuels are discouraged by environmentalists, who also transmit subpar technologies to developing countries [8].Though, the sustainable development goals are impacted by the environmental degradation challenge resulting from global economic expansion. Given that the OECD is a prominent organization for economic cooperation, it is crucial to look at its initiatives to advance ecological protection [9]. However, stricter environmental laws result in greater environmental pressure, exacerbate non-compliance, and multiply domestic production footprints. In contrast to import footprints, domestic production footprints can be reduced by refraining from non-compliance action [10]. While, non-renewable energy promotes economic growth but raises ecological footprint, renewable energy detrimental effects on ecological footprint both reduce and increase with urbanization. Urbanization eases environmental pressures and stimulates economic growth. Furthermore, depending on the income level, renewable energy does not necessarily reduce the ecological impact [11, 12].

Stronger environmental laws and a greater use of renewable energy sources can result from greater democratic accountability. After all, using freedom of opinion and data general understanding of resource conservation and ecological sustainability can be raised through communication efforts, better decision-making, and public involvement in the creation and application of regulations [13]. Additionally, boosting renewable energy through rigorous environmental standards, microcredit, technological subsidies, and promotion of environmentally beneficial behavior. In order to reduce CO_2 emissions and promote environmentally friendly production methods, it also suggests financial development [14].In spite of the regulation, significance of green entrepreneurship in sustainable development, highlighting the requirement for focused laws and incentives to solve environmental issues unique to a given industry. According to this, infrastructure investments should enable SMEs to include sustainability-driven techniques while taking economic considerations into account and guaranteeing that green technologies are accessible [15]. However, countries to meet the SDGs, development issues must be prioritized. Deflationary fiscal policies and supply-side measures can ease trade imbalances, boost economic efficiency, lower inflation, and preserve export competitiveness [16].

The Green Economy addresses human rights, livelihood preservation, social support equality, safe working conditions, and labor prevention. It falls under sustainable development, emphasizing countries responsible for ecological crises and climate change taking the most responsibility in addressing these issues [17]. Although, digitalization and globalization can accelerate the achievement of the SDGs, but issues with fair access and possible drawbacks call for a nuanced strategy to handle these difficulties [18]. However, development of initiatives to encourage green investment and financing, provide tax benefits, and stimulate partnerships between commercial and governmental sectors. This include influencing resources, substituting firms for one another, and involving the private sector in environmental decision-making [19]. Moreover, one of the main causes of environmental pollution and greenhouse gas emissions that impede sustainable development is human activity. In green cities, transportation, especially road transportation, has the biggest influence on greenhouse gas emissions [20]. Although, those regions with limited access to renewable energy sources must be the primary focus of planning and understanding off-grid and grid extension programs. SDG 7, which asks for universal access to modern energy services, and the 2030 Agenda of the UN Assembly are not well covered in the literature [21]. This study examines the impact of globalization, renewable energy use, and economic growth on the ecological footprint and sustainable development goals in eight South Asian Associations for Regional Cooperation (SAARC).

This study fills the gaps in current knowledge and offers policy insights. The study focuses on a total score of sustainable development goals, especially important for SAARC countries dealing with urbanization and resource depletion. Firstly, it incorporates these variables into two models, providing a comprehensive picture of their overall effects. Secondly, the study uses sophisticated economics approaches, such as Panel-Corrected Standard Errors (PCSE), Feasible Generalized Least Squares (FGLS), and Driscoll-Kraay estimators, to ensure cross-regional reliance and structural differences. Thirdly, the study concludes by offering policy recommendations, emphasizing the adoption of renewable energy to reduce ecological footprints, creating trade policies for environmental sustainability, and applying urban planning techniques that consider the environmental effects of growing urbanization and economic expansion. The remaining paper is organized as follows: Section 2 provides reviews recent empirical literature on the topic, details sampling, variables, and strategy, presents results, and concludes with policy insights. Section 3 details with the sampling, variables, and empirical strategy. Section 4 display the estimation along with an in-depth discussion. Finally, Section 5 explain the heteroscedasticity is strengthened by its dependency and diversity. Policy recommendations include adopting renewable energy, creating trade policies for environmental sustainability, and incorporating urban planning techniques to consider environmental effects of urbanization and economic expansion.

2. Review of Literature

Globalization, utilization of renewable energy, economic expansion, trade liberalization, and urbanization have all had a significant impact on ecological footprint and the overall score of sustainable development goals impact of different regions. This association has gained attention in the current academic discourse due to the pressing global mandate to combat climate change. The empirical research in this area has produced a range of results, primarily because of differences in methodology, variables chosen, and the countries' developmental phases. This review critically analyzes how the consumption of renewable energy, economic growth, and globalization affect environmental sustainability by combining knowledge from a wide range of scholarly sources. Further, study of Zhong et al. [22] show that explores the relationship between environmental degradation, energy efficiency, and health expenditures in SAARC countries from 2000 to 2020. Results show that emissions and energy intensity increase health expenditures, while energy efficiency and sustainable development reduce them. Bidirectional causality exists between health expenditures and sustainable development, while unidirectional causality links energy efficiency, intensity, and emissions to health expenditures. Çakmak and Acar [23] examines environmental laws, economic growth, and ecological footprints in Bangladesh, India, Pakistan, and Sri Lanka (1990–2016), using OECD, World Bank, and Global Footprint Network data. Advanced econometric methods validate the Environmental Kuznets Curve, showing strict regulations and renewable energy reduce footprints, while non-renewable energy and FDI degrade environmental quality. Sadiq, Khan, and Khan [24] assesses SDG progress in seven South Asian nations using SDG-based, Beyond-GDP, and GDP-based methods. Data from international databases, normalized via min-max, show India and Pakistan lagging, while Bhutan and the Maldives excel. It prioritizes SDG-based rankings for funding and policy, emphasizing integrated social, environmental, and economic sustainability.

However, Akram et al. [25] investigates emissions in SAARC nations (1972–2024) using CS-ARDL, linking fossil fuel use, urbanization, and industrialization to increased emissions. Renewable energy reduces emissions. Recommends renewable energy transition, sustainable urban development, and regional cooperation to balance economic growth and environmental sustainability for SDGs. Although, Ali et al. [14] use of DEA assesses economic, environmental, and social efficiency in SAARC and G-8 nations (2000–2021) using WDI data. G-8 outperforms SAARC economically (0.682 vs. 0.414), both are socially efficient (>0.980), with similar environmental scores (0.712 vs. 0.724). Recommends resource efficiency, renewable energy, and global cooperation for sustainability. Moreover, H. Akram et al. [25] examines carbon emission regulations' impact on SAARC nations' environmental sustainability (1990–2018) using World Bank and BP data. Non-linear ARDL and Dumitrescu-Hurlin tests show GDP growth and fossil fuels hinder sustainability, while REC, FDI, and economic complexity enhance it. Recommends renewable energy and policy shifts for SDGs. Similarly, Shakoor and Ahmed [26] analyzes economic growth and environmental SDGs in SAARC nations (excluding Afghanistan, 2000–2020) using Panel ARDL (PMG) and World Bank/UN data. SDGs 11, 12, and 15 support long-term growth, while SDGs 7 and 13 hinder it due to transitional costs. Balancing sustainability and economic strategies is crucial. Although, Rahman et al. [27] study (1972–2015) examines consumption-based emissions (CBE) impact on SDGs in SAARC nations using Eora, ADB, Polity IV, and WDI 2020 data. MRIO-based CBE shows 62.39% emissions from household consumption, with India highest (37.27%) and Nepal lowest (0.61%). FMOLS and Granger causality reveal CRW's significant impact and unidirectional CBE-GDP link. Recommends policies targeting consumption patterns and renewable energy for sustainable growth. At the current time, Dogan, Majeed, and Luni [12], [28], [29] empirical study from (1990–2017) analyzes unemployment, ecological footprint (EFP), and energy in

South Asia using World Bank and Global Footprint Network data. Second-generation panel methods (CIPS, CADF, Westerlund, FMOLS, DOLS) show income and non-renewable energy increase EFP, while unemployment, renewable energy, and population growth reduce it. Unidirectional causality exists between EFP, energy types, and income. Recommends policies for renewable energy, green jobs, and balancing ecological sustainability with economic growth. Further, Gautam, et al. [30], [31], [32] study examine state-wise energy consumption pattern, growth scenario and impact of economic variable on renewable energy production in India. As well as, Singh. et al. [33] panel study examine from (2000–2022) analyzes SAARC nations' ecological footprint (EF) using time-trend analysis and econometric models. Industrialization, inflation, GDP per employed person, greenhouse gas emissions, and age dependency ratio increase EF, while life expectancy, technical improvements, digitalization, and renewable energy reduce it. Recommends policies promoting digitalization, innovation, and renewables to balance ecological sustainability and economic growth, aiding SAARC nations in environmental preservation.

Prior studies indicate the substantial influence of globalization and economic expansion on growing ecological footprints; nevertheless, the outcomes of trade openness and renewable energy's moderating impacts have varied by location. Furthermore, thorough assessments that integrate these aspects holistically to comprehend their cumulative implications on environmental sustainability are conspicuously lacking. The findings' generalizability is limited by the tendency of current research to concentrate on individual components either alone or within particular regional contexts. By concentrating on the SAARC countries and employing ecological footprints and the total score of sustainable development goals as dependent variables, our study seeks to close these gaps and offer a more thorough assessment of the environmental impact on the sustainability and ecological indices.

3. Methodology

3.1. Data and Variables

This study employs annual longitudinal data from 2000 to 2021 to observe the impact of renewable energy consumption, gross domestic product, globalization on sustainable development goal and ecological footprints in SAARC (Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka) economies. However, Maldives is excluded in the data due to unavailability of its ecological footprint data and selection of time period 2000 because of SDG data started at this year and REC data not available after 2021. The explained variables are SDG and EF. The explanatory variables include renewable energy consumption, gross domestic product, globalization. Moreover, these variables were preferred for their noteworthy stimulus on environmental results and SDG index. Renewable energy consumption reduces reliance on fossil fuels and reduces GHG emissions, positively impacting the environment that leads to improve SDG index [28], [29], [34].Further, Environmental degradation can be negatively impacted by economic growth in a variety of ways. For example, a greater GDP may result in more pollution or make it possible to invest in cleaner technologies as well as increment of SDG index [10], [35].

Table 1. Variable, symbols, measurement unit and source.

Variable	Code	Measurement	Source
Ecological footprint	EF	Global hectares (Gha)	Global Footprint Network
Globalization	GLO	KOF Globalization Index	KOF Swiss Economic Institute
Economic growth	EG	GDP, constant 2015 UD$	WDI
Renewable energy consumption	REC	% of total final energy	WDI
Sustainable development goal	SDG	Overall SDG score	Sustainable Development Report

Nevertheless, to make sure that globalization helps green technologies and sustainable practices, policymakers should change the rules for trade and investment. Strong institutions will help balance economic growth with environmental responsibility by encouraging foreign direct investment (FDI) that is good for the environment [36]. Data were obtained from authentic source such as the Global Footprint Network, World Development Indicator (WDI), Sustainable Development Report and KOF Swiss Economic Institution. All data details information sources, measurement unit and symbols are depicted in Table 1.

3.2. Model specification

Construction of empirical studies by [37], [38] and [39], this study forward their vision by exhaustively analyzing the effect of renewable energy consumption, economic growth and globalization on sustainable development goal and ecological footprint. All variables are log-transformed to improve relative elasticity estimation, reduce heteroscedasticity, and control data volatility, giving in more reliable and robust estimations than linear specification. In Model I, shows the ecological footprint is the outcome variable, in the equation (1) express the linear interaction of the its inputs variables represented:

$$lnEF_{it} = \alpha_0 + \alpha_1 lnEG_{it} + \alpha_2 lnREC_{it} + \alpha_3 lnGLO_{it} + \mu_{it} \ldots\ldots\ldots\ldots\ldots (1)$$

where EF represent ecological footprint, EG express economic growth, REC denotes for renewable energy consumption, and GLO represent globalization, for to are the coefficient of the input variables, and show the error term of the model. In Model II, represnt the sustainable development goal overall score is response variable, the linear relationship between the variables denoted in the equation (2), as repesent below:

$$lnSDG_{it} = \beta_0 + \beta_1 lnEG_{it} + \beta_2 lnREC_{it} + \beta_3 lnGLO_{it} + \epsilon_{it} \ldots\ldots\ldots\ldots (2)$$

where SDG denotes sustainable development goal overall score, is the error term and to are coefficients. The subscript i and t represent country and time, subsequently, where i = 1,.....,N signifies a country number and t = 1,.....,T express the time duration.

3.3. Econometric strategy

3.3.1 Unit root test and multicollinearity

To investigate stationarity, we obtained second generation unit root test for given likelihood of CSD in the study. Categorically, we employ the Cross-sectional Augmented Dickey-Fuller (CADF) and Cross-sectional Im-Pesarn-Shin (CIPS) tests. Moreover, the CIPS test incorporate CSD by addressing cross-sectional averages of lagged levels and first differences, which consistent with a more robust estimation of longitudinal data stationarity. It can be represented as follow:

$$\Delta y_{it} = \alpha_i + \eta_i y_{i,t-1} + \delta_1 \bar{y}_{t-1} + \sum_{j}^{k} \delta_{ij} \Delta \bar{y}_{i,t-j} + \sum_{j=0}^{k} \Delta \bar{y}_{i,t-j} + \epsilon_{it} \ldots\ldots\ldots\ldots (3)$$

where represent the first order deference, is the cross-sectional average of y_{t-1}, and is the error term. Because the two tests are connected, the CIPS test can be estimated as:

$$\text{CIPS} = N^{-1} \sum_{i=1}^{n} \text{CADF}_{I} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where is the stastical value of t is the CADF.

3.3.4 Cross-section dependence test

Given the nations co-ordination and linked attributes among SAARC countries, cross-sectional dependence (CSD) is probably, possibly biasing analysis and inferences. Avoiding CSD can takes to unreliable and unstable results [40]. To estimate CSD, we use the [41] test. The Pesaran CD test, reliable for both large and small longitudinal data, it is measured such as:

$$CD=\sqrt{\frac{2T}{N-1}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\sigma_{ij}} \text{ ....(5)}$$

where T is the time period, N is the number of cross sections, and is the smaple calculation of the two-by-two correlation of the error term. The study additionally Lagrange Multiplier (LM) statistic for CSD test given by [42]. This test checks the null hypothesis, which express no cross-section dependence, another side alternative hypothesis, asserts the three are existence of cross-section reliance. The hypothesis is constructed such as:

$$H_0: p_{ij} = p_{ij} = cor\left(\mu_{it}, \mu_{jt}\right) = 0 \text{ for } j \neq i$$
$$H_a: p_{ij} = p_{ij} = cor\left(\mu_{it}, \mu_{jt}\right) \neq 0 \text{ for some } j \neq i$$

If there is a statically significant variation of the CSD estimation from zero, then the null hypothesis of no CSD is not accepted, otherwise vice versa.

3.3.5. Slop heteroscedasticity test

For robust estimation ignoring of slope heteroscedasticity could lead to destructive regression estimation, this study identifies the existence or extinct of heteroscedasticity in the slope coefficients by using the [43] test. This test can be measured by below given excretion:

$$\bar{\Delta} = \left(\frac{N^{-1}\bar{S}-k}{\sqrt{2k}}\right) \qquad (6)$$

where is the average of the separate slope coefficient, and k is the number of input variables. This test ascertains ith slope coefficient statistically significant every cross-section, which shows the importance of heteroscedastic panel determinants. For the less sample are cared by using the biased adjusted version of test statistics:

$$\bar{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\bar{S}-(\bar{Z}_{iT})}{\sqrt{Var\,(\bar{Z}_{iT})}}\right) \qquad (7)$$

where = K, = $\frac{2k(T-K_1)}{T+1}$. The null hypothesis of this test assume that every slope coefficient is homogeneous, which they are constant every cross-sectional unit.

3.3.6. Test for cointegration

To examine long-run correlation, we use the [44] and [45] longitudinal cointegration tests. The Pedroni test, in contrast with regular cointegration tests, combines panel-specific fixed effects and longitudinal trends, permitting the autoregressive (AR) coefficient to differ among panels. This test offers both intra-dimensional and inter-dimensional statistics, so strengthening the robustness of our study. The Pedroni test is express such as:

$$Y_{it} = \alpha_i + \delta_{it} + \beta_i X_{it} + \in_{it} \qquad (8)$$

where is the outcome variable, are the input variables, are seperated fixed effects, and obderve inevitable trends. The null hypothesis of no cointegration is not accept if estimated statistics are significant. The [45] test, further substantiate while according to heteroscedasticity and CSD, consider accordingly principles.

3.3.7. PCSE and FGLS estimation

This study utilize two advanced econometric methods to examine the long-term estimates: the PCSE methos, developed by [46], and the FGLS methos, firSt introduce by and further reintroduce by [47]. The PCSE method is specifically robust for asymmetrical error constructs. It is well-design for longitudinal panel, as empirically studies by and [48], these are considered on dataset with large number of cross-section unit and comparatively small time period (N>T). Although, the FGLS method consist of both cross-section cointegration and heterogeneity in the longitudinal data, which satisfy a rigorous examination of longitudinal specific statistical deviations.

3.3.8. Driscoll-Kraay standard errors

When we deal with CSD, cointegration, and heterogeneity, then this study employs Driscoll-Kraay standard errors (DKSE), which gives reliable results even in the above problems in the data. The variance-covariance matrix with DKSE is express such as:

$$Var(\widehat{\beta}) = (X'X)^{-1}\left(\sum_{t=1}^{T}\sum_{s=1}^{T}\omega_{ts}\right)(X'X)^{-1} \quad (9)$$

where denotes the covariance between errors at period t and s.

3.3.9 Dumitrescu-Hurlin causality test

There are numerous advantages to complementing longitudinal data models with time series approaches for causality testing. Cross-sectional data can be used to examine possible influences [49]. In this aspect, the [50] panel causality test is employed to identify the direction of causality among variables, suppose to that some cross-sections in the longitudinal may be directional linkages, but not compulsory everyone. Moreover, for heteroscedastic panels, the Dumitrescu Hurlin panel causality test is useful for both N<T and N>T. Employing this methos, the study estimates the causative interconnection among economic growth, sustainable development goal overall score, globalization, ecological footprint, and renewable energy consumption. The test procedure estimated such as:

$$y_{it} = \alpha_{it} + \sum_{i=1}^{k}\theta_i^{(k)}\, y_{i,t-k} + \sum_{i=1}^{k}\delta_i^{(k)}\, y_{i,t-k} + \epsilon_{it} \quad (10)$$

where and elucidates lag and slope statistics that change across sets, k describes the lag orders and it followed to be the constant for every cross-section's unit, and represent individual effects that are deliberate to be fixed in the time period. However, the null hypothesis proposes that there is no homoscedastic causation every cross-section, while the alternative hypothesis suggests that at least one causal connection among the varibles, the null and alternative hypothesis for examining the Dumitrescu-Hurlin panel connection is writen such as:

$$H_0: \delta_i = 0\forall_i = 1, \ldots, N \quad (11)$$

4. Results and Discussion

4.1. Descriptive Summary and Pairwise Correlation Estimates

Table 2 shows a descriptive summary and pairwise correlation estimates of the variables. The summary shows that average lower value (3.789) of globalization and highest values (24.733) are economic growth. However, sustainable development goal and globalization show comparative stable trend, with lower standard deviation of 0.165 and 0.246, respectively. Further, higher values of standard deviation 2.116 and 1.73 of economic growth and ecological footprint respectively. Here, all the variable has 154 observations of the data. In the Table 2 Panel B display the correlation analysis of among the variables. Moreover, positive relationship between economic growth (0.973) and globalization (0.701), negatively related with renewable energy consumption (-0.495) . Further, SDG are also positively related with economic growth (0.147), renewable energy consumption (0.489), and globalization (0.530). Additionally, economic growth has positive with globalization (0.82) and negatively associated with renewable energy consumption (-0.423). Furthermore, renewable energy consumption and globalization (-0.199) negative correlation. This gives a summary of increment of economic growth and globalization lead to ecological footprint increase and increment of renewable energy consumption shrink the ecological footprint. Then, SDG increase with increase of economic growth, renewable energy consumption and globalization.

Table 2. Descriptive summary and correlation estimates.

Panel A: Descriptive Summary					
Variable	Obs	Mean	Std. Dev.	Min	Max
lnEF	154	17.688	1.73	14.759	21.122
lnSDG	154	4.019	0.165	3.55	4.247
lnEG	154	24.733	2.116	20.438	28.653
lnREC	154	3.887	0.474	2.534	4.522
lnGI	154	3.789	0.246	3.155	4.124
Panel B: Correlation Analysis					
Variables	(1)	(2)	(3)	(4)	(5)
(1) lnEF	1				
(2) lnSDG	0.003	1			
(3) lnEG	0.973	0.147	1		
(4) lnREC	-0.495	0.489	-0.423	1	
(5) lnGI	0.701	0.53	0.82	-0.199	1

4.2. Unit root and cross-sectional dependence test

This the first step of the longitudinal data analysis and to check the CSD study employ [41] test. Table 3 display the cross-sectional dependence test results. The outcomes show that all variables are cross-sectional dependence between SAARC nations. The null hypothesis indicates that no cross-sectional dependence and it is not accepted due to all variables are significant at 1% level. For, analyses the stationarity test study utilized second generation unit root test the CIPS and CADF, because of basic unit root test unable to investigate the CSD between the parameters, [51]. The unit root test show that lnEF and lnREC are not stationary at level I(0) on the both CIPS and CADF test. Although, lnEF, lnSDG and lnGI are stationary at level I(0) on 5% level of significant on both CIPS and CADF test. Moreover, all the variable are significant at level 1% on the first difference (I(I)). It means all variables are integrated over time.

Table 3. Cross-sectional dependence and Unit root test.

Variable	CD Test	CIPS I (0)	CIPS I (1)	CADF I (0)	CADF I (1)
lnEF	20.042***	-2.53**	-5.351***	-2.11***	-9.794***
lnSDG	20.892***	-2.422**	-4.847***	-1.855**	-8.42***
lnEG	21.005***	-1.51	-4.163***	0.904	-5.825***
lnREC	16.680***	-1.385	-4.519***	1.024	-7.525***
lnGI	17.270***	-2.802***	-4.268***	-2.843***	-6.842***

Note: ***, **, * express that significance level at 1%, 5%, and 10%, correspondingly.

4.3. Cointegration Test

This study utilizes Kao and Pedroni test for long run cointegration between variables. In the Table 4, show that Pedroni test shows that Model I and II, null hypothesis assumes there are no cointegration is rejected on the basis of every given method. This is express in the probability values of PP and ADF statistics values are less then 1% level of significance. Similarly, the Kao test of cointegration incorporate heteroscedasticity and cross – section dependence, merge with Pedroni test results, gives the clear information and confirm the cointegration of the series. Although, the results indicate the rejecting the null hypothesis of there are no cointegration overall score of SGD and ecological footprint and its explanatory variables. The validation of long run cointegration of the variables needs to estimates the long-run elasticities of both the models.

Table 4. Kao and Pedroni long run cointegration test.

	Model I: EF		Model II: lnSDG	
	Statistic	p-value	Statistic	p-value
Pedroni test for cointegration				
Modified Phillips-Perron t	1.1162	0.1322	1.8242	0.0341
Phillips-Perron t	-3.5986	0.0002	-2.0769	0.0189
Augmented Dickey-Fuller t	-4.2575	0.0001	-1.7642	0.0388
Kao test for cointegration				
Modified Dickey-Fuller t	-1.813	0.0349	-1.935	0.0265
Dickey-Fuller t	-0.9426	0.1729	-1.6249	0.0521
Augmented Dickey-Fuller t	0.8975	0.1847	0.4254	0.3353
Unadjusted modified Dickey-Fuller t	-2.4133	0.0079	-1.96	0.025
Unadjusted Dickey-Fuller t	-1.2065	0.1138	-1.6353	0.051

Slop heteroscedasticity test

To, analyze the slop coefficient are homoscedastic or heteroscedastic distributed or not. For this test the study applies the [43] test. However, null hypothesis of slope homoscedasticity for both models no accepted. Consequently, if slope coefficient is homoscedastic then it affects regression output and gives inaccurate hypothesis estimation. Although, the robust econometric methods utilized for remain slope heteroscedastic and cross-sectional dependence models.

Table 5. Heteroscedasticity test results

	Model I: lnEF		Model II: lnDSG	
H0: coefficient slopes are homogeneous				
	Statistic	P-value	Statistic	P-value
	10.873	0.00	10.077	0.00
$\tilde{\Delta}$ Adjusted	12.369	0.00	11.464	0.00

4.4. PCSE, FGLS and Driscoll-Kraay S.E results.

Additionally, renewable energy consumption is the first step to improvement of economic and environmental condition i the SAARC nations. Here, results show that 1% increase of renewable energy consumption -0.192 % reduction of ecological footprint and 0.168 % increment of SDG overall score of the SAARC economies, and this is significant at 1% level on the three models. This show that transition on renewable energy SAARC economies have a huge potential to achieve SDG goals in the near future. These results are consistent with [39] for sub-Saharan Africa region, [52] in India, [53] in USA, [54] Middle East and North Africa region, [55] from developing countries. For SAARC economies, some countries face many drastic natural climatic variabilities, but investment in renewable energy gives a right direction for sustainable development and reduce energy dependence and increase ecological and environment biodiversity.

Table 6. Results from the PCSE, FGLS, and Driscoll-Kraay estimators (Model I: lnEF).

	PCSE			FGLS			Driscoll-Kraay S.E		
	Coeff.	std. err.	z-stat.	Coeff.	std. err.	z-stat.	Coeff.	std. err.	z-stat.
lnEG	0.958***	0.013	68.83	0.958***	0.019	48.05	0.958***	0.015	60.14
lnREC	-0.192***	0.027	-7.1	-0.192***	0.051	-3.7	-0.192 ***	0.044	-4.34
lnGI	-1.90***	0.149	-12.67	-1.900***	0.158	-12	-1.900***	0.17	-11.14
Constant	1.935***	0.25	7.71	1.935***	0.42	4.6	1.935***	0.18	10.7
Obs.	154			154			154		
R2	0.976						0.976		
Countries	7			7			7		

Note: ***, **, * denote significance levels at 1%, 5% and 10%, respectively. Coeff. and std err. are the coefficients and standard errors, respectively.

Table 7. Results from the PCSE, FGLS, and Driscoll-Kraay estimators (Model II: lnSDG).

	PCSE			FGLS			Driscoll-Kraay S.E		
	Coeff.	std. err.	z-stat.	Coeff.	std. err.	z-stat.	Coeff.	std. err.	z-stat.
lnEG	-0.038***	0.005	-7.49	-0.038***	0.006	-5.78	-0.038***	0.002	-14.67
lnREC	0.168***	0.016	10.26	0.168***	0.017	9.74	-0.168***	0.197	8.56
lnGI	0.690***	0.046	14.72	0.690***	0.052	13.07	0.690***	0.368	18.76
Constant	1.696***	0.050	33.87	1.696***	0.140	12.09	1.696***	0.045	37.12
Obs.	154			154			154		
R2	0.711						0.711		
Countries	7			7			7		

Note: ***, **, * denote significance levels at 1%, 5% and 10%, respectively. Coeff. and std err. are the coefficients and standard errors, respectively.

However, the finding shows that globalization have negatively effect on ecological footprint and positively effect on SDG overall score in SRRAC economies. Clearly show that 1% increase in globalization -1.90% decrease of ecological footprint and

0.690% increase of SDG overall score of the SAARC nations, and these are consistent in 1% level of significant for three models. The results suggest that globalization leads to achieve sustainable development goals and green growing economies of the SAARC. These findings aligned with the previous empirical studies [36] in six SAARC economies, [56] in European countries, [57] in South Asia's, [58] in developed countries, and [59] in BRICS countries. They report the Reducing reliance on fossil fuels, promoting modern technology and renewable energy, and enacting investment regulations to support sustainable practices are all ways to slow down globalization.

4.5. Panel causality test

The PCSE, FGLS and Driscoll-Kraay S.E models give elasticity coefficient for the long-run relationship between variables. Moreover, policy makers perspective needs of causal effects used for effective regulation implementation. Although, these results do not identify the causal association between explain and explanatory variables. Furthermore, this study utilized the [50] causality estimation to analyze the causal association among variables. Table 9 express the output of causality estimation. The ecological footprint has unidirectional causality between economic growth and globalization. Specifically, ecological footprint affects economic growth performance and globalization activity of the economy. Nevertheless, renewable energy consumption cause of reduction of ecological footprint in the economy that leads to long-run sustainable and flourishing economic growth. Similarly, in the SDG overall score unidirectionally causality with economic growth and globalization index. Furthermore, SDG overall score and REC have bidirectional causality, consistent with simultaneous effect on both the variables in the economic development.

Table 8. Dumitrescu–Hurlin causality test results.

Model I: Ecological footprint			
Null Hypothesis:	W-Stat.	Z bar- Stat.	Direction of causality
lnEF does not homogeneously cause lnEG	7.0807***	8.9878	Unidirectional
lnEG does not homogeneously cause lnEF	1.0792	-0.0692	
lnEF does not homogeneously cause lnREC	0.845	-0.4225	Unidirectional
lnREC does not homogeneously cause lnEF	3.6369***	3.7907	
lnEF does not homogeneously cause lnGI	2.9495***	2.7533	Unidirectional
lnGI does not homogeneously cause lnEF	0.4183	-1.0665	
Model I: Ecological footprint			
lnSDG does not homogeneously cause lnEG	6.5191***	8.1402	Unidirectional
lnEG does not homogeneously cause lnSDG	1.3371	0.3201	
lnSDG does not homogeneously cause lnREC	4.5618***	5.1865	Bidirectional
lnREC does not homogeneously cause lnSDG	3.1942***	3.1227	
lnSDG does not homogeneously cause lnGI	4.9546***	5.7794	Unidirectional
lnGI does not homogeneously cause lnSDG	0.7526	-0.562	

Note: *** and ** denote significance levels at 1% and 5%, respectively.

Additionally, these results consist with [36] study reveal that environmental degradation may impact financial systems, potentially leading to reduced investment or financial priorities. Globalization impacts Institutional quality index, financial devolvement (FD), industrialization, and GDP, with bidirectional causality between FD and institutional quality, renewable energy usage, and GDP. Although, the study reveals a unidirectional causality from economic globalization index to ecological footprint consumption (EFC), bidirectional causality between social globalization index and EFC, and no causality between political globalization index and EFC [56]. Moreover, [60] estimates express the causality between institution quality, and population size is unidirectional, while bi-directional and inversely related, affecting the ecological footprint and inverted load capacity factor.

5. Conclusion

The SAARC nations work on to balance sustainable development goals with controlling ecological footprints to tackle climate change. Strategies include renewable energy consumption and understanding globalization's effects, as many have embraced globalization, causing environmental impacts. Thus, The study examined the impact of globalization, renewable energy consumption, and economic growth on ecological footprint and sustainable development goals in SAARC nations from 2000 to 2021 using PCSE, FGLS, and Driscoll-Kraay S.E estimators. Moreover, In the first step the study analysis revealed cross-sectional dependence and rejected the slope coefficient homogeneity null hypothesis, confirming variables' mixed order of stationarity, i.e. I(0) and I(I), through second-generation unit root tests like CADF and CIPS. Although, the study used Kao and Pedroni cointegration tests to verified long-term relationships between sustainable development goals, ecological footprint, and explanatory variables, and the Dumitrescu–Hurlin test employed to determine causal relationships. However, the analysis exhibit that economic growth in SAARC nations is non-renewable-intensive, resulting in a higher ecological footprint and a decrease in sustainable development goals, indicating that economic growth mechanisms are needs transformative change for sustainable future. Although, Renewable energy consumption significantly reduces ecological footprint and improves sustainable development goals by reducing reliance on fossil fuels consumption effect on mitigating the ecological footprint, indicating its potential to enhance overall sustainable development goal scores. Further, estimates shows that globalization in SAARC countries has a mixed effect on environmental outcomes, reducing ecological footprint and lowering emissions, and also increasing sustainable development goals. Neverthless, the Dumitrescu-Hurlin causality test exhibits that unidirectional relationships between renewable energy consumption, economic growth, and globlization with ecological footprint in SAARC nations. Additionally, Economic growth and globlization have a unidirectional causal link to sustainable development goals, while renewable energy consumption has a bidirectional causality.

To improvement of sustainable development goal overall score and minimize environmental degradation, SAARC nations should adhere to the following policies: Firstly, place primarily investments in renewable energy technologies and reduce dependence on nonrenewable energy. This will contribute harness ample renewable resources, which provides a sustainable and clean energy supply. Secondly, making environment friendly rules for fossil fuel-based companies those are responsible for environment deterioration. By enforcing these laws industries adopt environmentally friendly technologies for sustainability of environment. Thirdly, developing policy for engagement of maniple local bodies for practicing green technologies and proper implementation of reuse, recycle and decrease practice. This type of project delivers real remedy for mitigate environmental deterioration. Fourthly, awareness of new developed technologies i.e. (solar energy, electric vehicles, and energy efficient gadgets) to general public leads to simultaneous acceleration of adoption and mitigation for betterment of environment degradation. Lastly, timely conducting environment assessment practice to evaluate policy implementation efficiency and it reduce effort on further policy making complication. Collaboration with specialized institution delivers a long-term perspective of policy implementation for improvement of sustainable development and lower ecological imprint.

Although the study examines the impact of economic growth, renewable energy consumption, globalization, and ecological footprints on sustainable development goals in South Asian countries (SAARC). However, it has limitations, such as focusing on longitudinal data from 8 countries and a limited set of regressor variables. Other relevant factors like institutional performance, technology advancements, investment in renewable energy, and climate coping measures could be incorporated. Future research could explore different ecological parameters, such as drinking water contamination or agricultural land utilization modification, and use non-stationary frameworks or tolerance outcomes to demonstrate the changes in associations across different economic performance levels.

Declarations

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