



# Revisiting the nexus of ecological footprint, unemployment, and renewable and non-renewable energy for South Asian economies: Evidence from novel research methods



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## ABSTRACT

Given the need to employ novel research methods in the energy-environment nexus, the objective of the present research is to investigate the impacts of real output, unemployment, and renewable and non-renewable energy on ecological footprint under a STIRPAT theoretical framework by applying the second-generation unit root, cointegration, Granger-causality, and long-run estimation methods on the annual data from 1990 to 2017 for South Asian economies. Empirical results show that increases in unemployment and renewable energy decrease ecological footprint while increases in real income and non-renewable energy hurt the environment. This study confirms the adverse effect of renewable energy on environmental degradation as well as the trade-off between unemployment and pollution through multiple robustness and sensitivity checks. In addition, the causality test supports unidirectional causality from income, renewable energy, and non-renewable energy to ecological footprint. Regarding policy perspectives, the governments of the South Asian region should support the deployment of renewable energy through various channels and regulations. The development of technologies that promote sustainable production and consumption play critical roles for reducing the trade-off unemployment and ecological footprint. Further policy suggestions are discussed in the study.

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## 1. Introduction

Human activities are held responsible for climate change and global warming [1–3] and for overusing the earth's biocapacity by 56% [4]. The increasing demand for energy, food, and improved living standards increases pressure on natural resources and biodiversity, enhancing the human footprint on the earth. That is, the increasing pressure on resources to meet increased demands boosts ecological footprint (EFP) which is the ability of land, air, and water to sequester externalities and fulfill human demands of natural resources. When resource consumption is greater than regeneration capacity, it leads to resource depletion [5,6].

Although South Asia has emerged as the fastest-growing sub-region however its growth did not support jobs for the youth as 80%

of the labor force remains engaged in the informal sector. These economies shifted from agriculture to service-based economies and due to surpassing the industrial sector were not able to create enough jobs [7]. The relationship of unemployment with the environment can be explained by analyzing changes in pro-environmental behavior (PEB). The literature offers different reasons to explain unemployment and PEB nexus. Clark et al. [8] argued that PEB can be considered as a reflection of the private provision of a public good. Theoretical models suggest that individuals maximize their utility by trading off some private gain by offering the public good with the private cost. Income plays an important role in these models, and if it falls during unemployment then PEB also influences. Further, the opportunity cost of time changes during unemployment also alters PEB [9]. Employment opportunities increase the stress on biodiversity and resource use due to higher demand for production and consumption and lead to environmental degradation. Therefore, it is important to examine how unemployment contributes to environmental quality [10].

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The population is associated with an increase in ecological footprint due to its dependence on resources to support changing lifestyles. The improved lifestyle boosts consumption of natural resources more than regeneration, leading to an incline in ecological footprint [2,11]. However, if population consumption is sustainable, it supports ecological quality through a decline in footprint. In this respect, Toth and Szigeti [12] reported consumption patterns to be the reason for environmental damage and not the population. Furthermore, communication and awareness about environmental damage can play a pivotal role in sustaining ecological quality [13].

Asian economies face numerous environmental challenges as 4 billion people are exposed to air pollution which is higher than the “World Health Organization (WHO)” guidelines. These challenges, such as land, air, and water pollution, deforestation, and biodiversity loss, are attributed to rapid industrialization and economic expansion [14]. South Asia is the most densely populated region where one-fourth of the world’s population resides, however, land resources to support the population are inadequate in quantity and quality. In the case of India, 45% of cultivable land is arid, semi-arid, or degraded, and a similar situation is faced by Pakistan. South Asian economies also face health hazards, climate change, and biodiversity loss from extensive biomass use for energy [15]. Besides, these economies are vulnerable to extreme weather events including droughts and floods. Although forest cover has increased from 148050.8 to 170801.1 square kilometers (sq. km) between 1990 and 2018 (forest area % of the land area increased from 22.71% to 23.869% between 1990 and 2018), carbon emissions have increased at a faster rate from 127966 (0.318) to 551862 (0.944) kilotons (carbon emissions per capita), during the same period (1990–2018) [16]. Furthermore, 27% population of the region lacks electricity access and 60% of the population depends on biomass for cooking [7]. The energy strategy of India focuses on the deployment of alternative energy sources including nuclear, solar, and wind to ensure efficient resource consumption and environmental sustainability. By ensuring energy efficiency and investment in modern technologies, India aims to mitigate the emission intensity of gross domestic product (GDP) from 33 to 35% by 2030, [17]. To enhance electricity trade, efforts have been initiated to implement the concept of the “South Asian Association for Regional Cooperation (SAARC) Energy ring” based on an interconnected electricity system since 2004, however, the progress is slow. The cross-border power connectivity system helps in costs reduction, supply diversification, using renewable and low carbon energy resources [18] that can help in achieving “Sustainable Development Goal (SDG) 7 and SDG 11” and can help in solving the energy trilemma of ensuring “energy security, affordability, and sustainability”.

Achieving clean energy targets through interconnectedness helps in achieving other SDGs as well including “poverty, hunger, health, water and sanitation, infrastructure, the environmental impact of urbanization, climate change, life underwater and on land”. The energy sector is held responsible for global climate change due to the release of 80% of “greenhouse gas (GHG)” emissions. South Asia will be affected by unmitigated climate change which will affect its water resources, biodiversity, (due to climate change water cycle will change) and causes flash floods [18]. Furthermore, due to climate change, coastal areas of Bangladesh and India are at risk of sea-level rise and storms, and this can lead to the displacement of millions of people and could erode 10% of land in Bangladesh [7].

To ensure environmental sustainability, countries in South Asia are taking measures including the implementation of the “zero defect, zero effect (ZED) model” on the environment by India. The commitments made by South Asian economies in “Conference of the Parties (COP)21” in Paris through “Nationally Determined

Contributions (NDCs)” on emission reduction from business-as-usual levels by 2030 are as follows: Afghanistan, Bangladesh, Sri Lanka, and India will cut emissions by 13.6%, 7%, 5%, and 35%, respectively. Bhutan aims to maintain carbon neutrality as set out in 2009 and is dedicated to retaining 60% of the territory forested. Nepal plans to decrease its dependence on fossil fuels by 50% by 2050 and attain 80% electrification by adopting renewable energy technologies. For Pakistan, no measurable target is available yet. However, it aims to preserve forested area by 40% of the total area of the country [7]. These economies are implementing different environmental regulations to achieve these targets. For example, in 2010 India has established the “National Green Tribunal (NGT)” to expedite the hearing of environmental cases. The government of Bangladesh approved Bangladesh Environment Conservation Act (BECA) in 1995 comprising various environmental laws to conserve the environment. In 2019, the government of Nepal has approved the “environmental protection act, 2076” to address the issues related to climate change.

Economic growth around the globe since WWII has led to improvement in human living standards however this improvement came at the cost of the stability of the earth’s operating system that sustains it. Economic growth is associated with higher income and increased economic opportunities however if growth is based on the extraction and use of natural resources it causes biodiversity loss and increases ecological footprints. India extracted 7.6% (the second highest material extraction) of natural resources (materials) in 2017 after China, and this resource extraction, and processing caused 90% biodiversity loss, water stress, and global GHG emissions. Although global resource use has increased however global material productivity remained stagnant during the last 20 years. Improvements in resource efficiency and sustainable resource management can lead to a decline in resource extraction by 25% and boost the global economy by 8% along with mitigating negative environmental impacts (IRP, 2019).

The EFP of South Asian countries increased from 0.7195 constant per capita in 1990 to 1.0946 by 2017 [19]. The EFP of the region increased from 0.63gha to 1.12gha (global hectares) per person between 1961 and 2017 [19]. The increasing EFP represents a demand and supply gap suggesting overuse of natural resources in South Asia. This reveals that biocapacity (the regenerative capacity of nature; supply) is lower than demand for natural resources [20]. Although the region is rich in natural resources, it faces a biocapacity deficit due to overconsumption that depletes natural resources. Furthermore, the exhaustive use of natural resources has adverse economic (decline in income and increase in commodity prices) and environmental consequences—higher emissions due to decline in forest cover; that support carbon absorption and act as a carbon sink-for the region (ADB & WWF, 2012). Besides, the unemployment rate (% of the total labor force); however, decreased from 4.7794 to 3.8624 over the same period [16]. The total population also increased from 224 million to 351 million between 1990 and 2017. Similarly, the income of the region increased from 654.65 per capita to 1781.7 per capita between 1990 and 2017. Energy sources trend also indicate the pressure on natural resource use as renewable energy consumption shows a decline from 72.205 to 52.918 (% of total energy consumption) between 1990 and 2017. Contrary to this, non-renewable energy dependence increased between 1990 and 2017 from 36.227 to 53.565% of the total. Nevertheless, the role of renewable energy is unclear in the level of emissions among the existing studies [21].

This study is important because South Asia is a region where one-fourth of the population resides and this region suffers from one-third of total global death caused by disasters, and 45% of the world’s flood-affected population lives in Afghanistan, Bangladesh, India, and Pakistan [7], therefore it is imperative to explore how

clean energy can contribute to decline in disasters and control climate change through changing ecological footprints. It is important to examine how renewable energy contributes to ecological sustainability and ensures the implementation of SDGs. South Asia has shown considerable potential in the development of products and processes through “frugal engineering” which can contribute to a decline in emission and natural resource consumption thereby decreasing stress on ecology and supporting sustainability. India has increased its solar energy target five folds from 20 GW (GW) to 100GW by 2022.

Based on the above information and arguments, this research analyzes the relationship between environmental deterioration (ecological quality), real output, unemployment, renewable, non-renewable energy and population by applying multiple reliable and robust panel data estimations on the data from 1990 to 2017 for South Asian countries. The present paper extends the empirical literature in the following manner: First, this research for the first time incorporates unemployment to the energy-environment nexus for South Asian economies, and is among the thin body of literature that focuses on unemployment-energy-environment nexus [22]. Second, this research employs a comprehensive measure of ecological quality represented by ecological footprint as apart from the majority of the existing papers. Third, the study uses a number of unique econometric techniques that consider endogeneity, cross-sectional dependency, and heterogeneity across variables among the economies. Last, this study applies a number of sensitivity analyses as well as robustness checks to confirm the findings from one method to one another. The study is organized as: Section 2 incorporates literature review, section 3 explains data and methodology, section 4 provides results and discussion while section 5 is based on conclusion and policy implications.

## 2. Literature review

Until 1970, the regenerative capacity of the earth was greater than the human's ecological footprint. Changing lifestyles in the 21st century led to the overuse of biocapacity. The mismatch between “economic grammar” and “natures syntax” has resulted because of a decline in natural capital by 40% since the 1990's and an increase in human capital (13%) and produced capital. Biodiversity is required to preserve our health, wealth, and security [4]. It provides “food, fiber, water, energy, medicines, and other genetic materials and regulates climate water quality, pollution, pollination services, flood control, and storm surges” [4]. Biodiversity is affected by factors including loss of forests, water stress, and urbanization which are the result of anthropogenic activities leading to change in land-use practices, increase in rural and urban untreated waste, pollution from industry, mining and agriculture, and energy production and consumption of energy [23]. Biodiversity in the region (Asia and Pacific) is on the decline and the loss of species is about twice the global average even being rich in natural capital. The region has a biocapacity deficit suggesting that the region uses more resources than available, and the shortfall is met through imports of natural resources which has environmental as well as economic implications in the form of rising commodity prices and degradation of natural resources. This loss of biodiversity is resulting from human activities [24]. The increasing gap between ecological footprint and biocapacity results in a decline in the earth's productive capacity, thereby causing climate change, food shortage, and biodiversity loss [2].

To ensure the sustainability of life on earth, research is flourishing to explore the determinants of environmental degradation which result in climate change and threatens human survival. Although the major source of climate change is anthropogenic activities including land-use changes, agriculture, and industry,

however, these are the sources to support human welfare and living standards. Economic growth has been considered as the major culprit behind increasing environmental degradation due to the extraction of finite natural resources. Analyzing the effect of income on ecological footprints Al-Mulali et al. [25] supports the “environmental Kuznets curve (EKC)” hypothesis for upper-middle-income and high-income economies over the span 1980–2008 using fixed effects (FE) and Generalized Method of Moments (GMM) while urbanization contributes to environmental damage through an increase in ecological footprints. Charfeddine [26], used Markov switching technique to analyze the impact of economic growth, and urbanization on the EFP for Qatar over the period 1970 to 2015. The results reveal that a U-shaped relationship exists between EFP and economic growth while electricity consumption and urbanization are associated with higher EFP.

The study of Majeed and Mazhar [27] analyzed the effect of economic growth and financial development on EFP. By using the GMM for 1971–2017 the results revealed that although financial development improves environmental quality through a decline in EFP however economic growth increases EFP. By employing Driscoll-Kraay panel regression, Baloch et al. [28] showed an incline in EFP owing to an increase in income, energy consumption, and urbanization in Belt and Road (BRI) economies from 1990 to 2016. Destek and Sarkodie [29] examined the relationship between economic growth, energy consumption, and financial development within the EKC framework using the augmented mean group (AMG) estimator for “11 newly industrialized economies” from 1977 to 2013. The findings suggested that the EFP increases due to energy consumption. Danish et al. [30], supported an increase in EFP from economic growth using the autoregressive distributed lag (ARDL) approach over 1971 to 2014 for Pakistan controlling for the effect of biocapacity and human capital. Using the ARDL approach, Nathaniel [31] reported an increase in EFP resulting from economic growth, energy consumption, and urbanization in Indonesia between 1971 and 2014. The findings of Majeed & Mazhar [32] provide evidence of inverted U-shaped EKC in upper-income economies while the EKC is not confirmed in middle and low-income economies, using 1st and 2nd generation panel times series for 1961 to 2018.

With higher growth, employment opportunities increase and leads to an increase in the demand for goods and services which are based on natural resources. Therefore, Kashem & Rahman [10], by using fixed and random effects, and pooled mean group (PMG) estimations, revealed an inverse relationship between carbon emissions and unemployment. The environment can be improved at the cost of employment. Similarly, the findings of Anser et al. [33] also supported the tradeoff between environmental quality and unemployment for “Brazil, Russia, India, China, South Africa, and Turkey (BRICST)” during 1992–2016 by employing PMG estimation. Ng et al. [22] report that unemployment and renewable energy contribute to environmental improvement and decline in EFP in 36 “Organization for Economic Co-operation and Development (OECD)” economies for the period 1995 to 2015 using “AMG and Common correlated effect mean group estimator (CCEMG)” approaches. Energy is also considered a major source of environmental quality. The exploration and production of energy adversely affect biodiversity [33]. The energy produced from conventional sources (coal, oil, and gas; natural resources) leads to loss of biodiversity and an increase in ecological footprints. However, if energy is produced from renewable resources which are abundant in nature can lead to sustainable development as it does not deplete and compromises the planet's sustainability.

Dogan et al. [34] examined the influence of non-renewable energy, renewable energy, and urbanization on ecological footprints in Mexico, Nigeria, Indonesia, and Turkey during 1971–2013

using the ARDL approach. The results reveal that EKC exists and non-renewable energy, urbanization leads to higher pressure on the environment while renewable energy contributes to a decline in environmental stress by decreasing EFP. Examining the effect of renewable energy and on EFP for “Brazil, Russia, India, China, and South Africa (BRICS)” economies for 1992–2016, Danish et al. [35] used Fully modified ordinary least squares (FMOLS) and Dynamic ordinary least squares (DOLS). The results reveal that natural resource rent and renewable energy improves environmental quality through a reduction in EFP. Destek and Sinha [36] also support the decline in EFP from renewable energy and trade openness in 24 OECD economies from 1980 to 2014 using mean group estimator within the EKC framework however their findings support the u-shaped association between economic growth and EFP. Jebli et al. [37] analyze the impact of renewable energy on emissions across 102 economies classified according to income level using GMM from 1990 to 2015 and report that renewable energy decreases emissions across all countries except low-income economies. The study of Azam et al. [17] investigated the impact of “renewable energy and nuclear energy” on emission reduction in ten major carbon-emitting countries for the duration 1990–2014 using panel FMOLS and revealed that renewable energy and nuclear energy decreases emissions. Yuping et al. [38] demonstrated emissions mitigating effect of renewable energy in Argentina from renewable energy using the ARDL approach from 1970 to 2018. Danish et al. [39] find that renewable energy contributes to a decline in both consumption and production-based emissions while nuclear energy only decreases production-based emissions for the period 2005–2016 using the Driscoll-Kraay regression method in 15 OECD economies. Nathaniel et al. [40] support the decline in EFP resulting from renewable energy from 1992 to 2016 using CCEMG estimator in BRICS. Saidi and Omri [41] report a decline in carbon emissions from renewable energy use in 15 major renewable energy consumption economies using the FMOLS technique over the period 1990 to 2014. Cui et al. [42] analyze the role of renewable energy and human capital on EFP in 20 economies divided into two sub-panels for 1980 to 2017 using FMOLS and DOLS. Renewable energy boosts EFP in one panel while decreasing it in the other panel. The difference between the two panels is due to the patterns of energy consumption. The higher emission is associated with the panel including China, which is determined to use sustainable energy however its primary energy consumption is based on coal results in emission. Human capital declines EFP in both panels. Usman et al. [43] report a decrease in EFP in resource-rich countries from renewable energy use and globalization from 1990 to 2018 using AMG and CCEMG approaches. Usman and Balsalobre-Lorente [43] also validate the reduction in EFP from renewable energy and natural resource rent in 10 newly industrialized economies from 1990 to 2019 using the AMG approach. Yu et al. [44] show that solar energy decreases emissions in 10 solar energy-consuming economies across different quantiles using the Quantile-on-Quantile approach for 1991 to 2018. Suki et al. [45] also reported a decline in carbon emissions and EFP from renewable energy and technological innovation using bootstrap ARDL for Malaysia from 1980 to 2018. Djellouli et al. [46] also reported a decrease in emissions from renewable energy in 20 African economies using the ARDL approach from 2000 to 2015. However, the study of Nathaniel et al. [47] reported an insignificant impact of renewable energy on EFP for Middle East and North African (MENA) economies using an AMG estimation for 1990 to 2016 controlling for economic growth, non-renewable energy, and urbanization. Economic growth, non-renewable energy, and urbanization contribute to environmental degradation.

Population growth increases human influence on the ecosystem. Population growth leads to an increase in demand for

resources through an increase in agriculture, fishing, industry, and international commerce and results in land transformation affecting Earth's ecosystem. This transformation causes climate change and biological diversity loss. The waste and by-products of human activity result in environmental change [48]. Population expansion increases the demand for goods and services and increases natural resource extraction. To meet increased demands of utilities including food, transportation, housing, and water, natural resource extraction increases which leads to depletion of resources along with climate change and environmental pollution [2]. The conversion of agriculture land and forest to meet housing needs results in deforestation [30]. This decline in forest cover to construct urban areas leads to urban heat island effect (heat accumulation) due to human activities in urban areas. Pan et al. [49] and Apergis & Majeed [50] highlighted that the decision regarding urban settlements is based on the availability of ecosystem services. Thus, population growth influences EFP [33] negatively by affecting the atmosphere, land, and water quality [26] and influences energy and material flow in urban ecological system [51]. A related concept is urban resilience which suggests that people do not welcome environmental and sustainability reforms. However, once they are aware of that their wellbeing is linked with the policy and policy can help to get a relief from the negative effects of environmental degradation they welcomed and accepted environmental policies. The studies such as Chen et al. [13] and Monteiro et al. [52] provided empirical support for urban resilience and environmental policy nexus in the context of health effects of the environmental for Brazil and China, respectively. The issue of unemployment can be managed through nature-based solutions and innovations. Meanwhile, it can be managed by managing “urban resilience” against environmentally friendly policy through communication and awareness.

However, population growth can lead to a decline in EFP through proper use of land, increasing return to scale, provision of improved water, sanitation and health facilities, waste management, environment-friendly infrastructure, which leads to sustainability of the environment and decline in environmental pressures. Furthermore, the provision of better educational facilities increases awareness about environmental conditions and efficient use of resources to avoid exploitation thereby decreasing EFP and supporting improved environmental quality. Along with this, countries use alternative energy sources with growing population to avoid environmental degradation [53]. The empirical literature provides heterogeneous results on the impact of population on environmental quality. The study by Katircioglu et al. [53] examined the role of urbanization, total population, rural population, and income on emissions at the global level within the EKC framework from 1960 to 2013. The results reveal that population growth does not contribute to environmental damage. However, the study of Ahmed et al. [2] suggests that urbanization increases EFP in “Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States (G7)” economies for 1971 to 2014 using “Continuously updated Fully Modified Ordinary Least Square (CUP-FM) and Continuously Updated Bias-Corrected (CUP-BC) approaches”.

### 3. Data and methodology

The study examined the impact of income (GDP), unemployment rate (UNE), renewable energy (REN), non-renewable energy (NREN), and total population (POP) on the EFP in South Asia from 1990 till 2017. The analysis is based on including “Bangladesh, India, Nepal, Pakistan, and Sri Lanka” since the data of non-renewable energy consumption were missing for Afghanistan and Bhutan. The data on EFP “constant per capita” has been derived from the

Global Footprint network (2021). The ecological footprint is a more comprehensive measure of environmental degradation as it accounts for “cropland, grazing, fishing grounds, forestland, carbon footprint, and built-up land”. The data of unemployment total (% of the total labor force), GDP “per capita (constant 2010 US\$)”, renewable energy consumption as a share of “total energy consumption”, non-renewable energy consumption as “a share of total energy consumption measured by fossil fuel energy consumption”, and population is obtained from the World Bank [16]. The dataset under consideration is from 1990 to 2017.

Based on the well-known STIRPAT framework [33,54,55], the model can be specified as follows:

$$EFP = F(GDP, UNE, REN, NREN, POP) \tag{1}$$

After taking natural logarithms to decline the heterogeneity issue [35,56], the model can be rewritten as follows:

$$EFP_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 UNE_{it} + \alpha_3 REN_{it} + \alpha_4 NREN_{it} + \alpha_5 POP_{it} + \epsilon_{it} \tag{2}$$

where *i* represents cross sections (1, 2, 3, 4, 5), and *t* is the time period (1990–2017),  $\epsilon_{it}$  is the error term,  $\alpha_0$  represents intercept,  $\alpha_1, \alpha_2, \alpha_3, \alpha_4,$  and  $\alpha_5$  represents elasticities with respect to real output, unemployment, renewable and non-renewable energy, and population.

The data are first examined for the cross-sectional dependence (CD) using “Breusch- Pagan LM, Pesaran scaled LM, Bias-corrected, and Pesaran CD test”. The confirmation of CD leads to the use of 2nd generation tests which accounts for cross-sectional dependence. The cross-sectional augmented IPS (CIPS) and cross-sectional augmented Dickey-Fuller (CADF) tests account for slope heterogeneity and CD while examining the stationarity of the variables in panel data. Furthermore, the “Westerlund cointegration test” has been used which accounts for CD while examining the cointegration. The long-run association among the variables is examined using “FMOLS and DOLS” estimators that are suitable for cointegrated panels. Stock and Watson [57] introduced the “DOLS technique” produce better results in the presence of cointegration however cross-sectional heterogeneity is not accounted by DOLS. FMOLS accounts for cross-sectional heterogeneity, serial correlation, and endogeneity issues. The results obtained from FMOLS are consistent even in a small sample [58]. The study also examined the long-run relationships with PMG estimator which bounds long-term parameters to remain constant (homogeneity) while intercept, error variance, short-term covariance, and speed of adjustment can vary across countries. Fixed effects (FE) results are reported which consider the correlation between country-specific characteristics and determinants of environmental quality. FE can eliminate the bias problem resulting from the omission of variables that remains fixed over time [25].

**Table 1**  
Summary statistics.

	Observation	Mean	Std. Dev	Min	Max	Ske	Kur
<b>EFP</b>	140	0.881	0.229	0.443	1.540	0.557	3.444
<b>GDP</b>	140	1079.43	756.70	354.25	3860.15	1.904	6.430
<b>UNE</b>	140	4.01	3.10	0.398	14.66	1.355	5.058
<b>REN</b>	140	60.73	17.08	34.74	95.12	0.619	2.236
<b>NREN</b>	140	47.43	21.21	5.05	73.08	-0.787	2.272
<b>POP</b>	140	290	423	17.3	1340	1.513	3.532

Note: Population is in millions.

### 3.1. Descriptive statistics

Table 1 reports summary statistics of the panel of South Asian countries. Table 2 presents the correlation matrix. The ecological footprints have a positive correlation of 0.7990 and 0.2864 with income and unemployment, while a negative correlation of 0.0363, 0.0731 and 0.2354 with renewable energy, non-renewable energy, and total population. Our results are different from Nathaniel et al. [47] as they reported a negative correlation of GDP and a positive correlation of renewable and non-renewable energy with ecological footprints. Due to the high positive correlation of 0.7990 of income with ecological footprints, we used variance inflation factors (VIFs) to examine for possible multicollinearity. The mean VIF is 3.98 suggesting no multicollinearity. The results are presented in Table 10. To examine heteroskedasticity the study used the panel heteroskedasticity LR test. As the *p*-value is 0.0019 therefore rejecting the null hypothesis of homoskedasticity suggesting that heteroskedasticity exists in the residuals.

## 4. Empirical results and discussions

### 4.1. Cross-sectional dependence test

In panel data for employing proper techniques, the CD is analyzed as failure to address the CD may lead to the biased unit and cointegration tests. The study examined CD by applying several tests including “Breusch- Pagan LM, Pesaran scaled LM, Bias-corrected, and Pesaran CD test”. The results obtained from cross-sectional dependence tests are reported in Table 3. All the tests reject the null of cross-sectional independence thereby suggesting that shocks in the economies have spillover effects.

### 4.2. Second-generation unit root tests

The results obtained from 1st generation test become biased if the issue of cross-sectionally dependency persists. In such a situation the tests which account for cross-sectional dependence are employed. The study used CIPS and CADF tests to analyze the order of integration in the presence of CD. CIPS is robust to cross-sectional dependence [59]. EFP, unemployment, “GDP per capita, renewable energy, non-renewable energy, and total population” are difference stationary. The results are reported in Table 4.

### 4.3. Second-generation cointegration test

Table 5 reports the findings from the Westerlund cointegration test which takes account of slope and trend parameters, country-specific short-run dynamics, and CD while examining cointegration. The test provides 4 statistics: “two-panel and two group statistics” and tests for the null of no cointegration. The two-panel statistics ( $P_t$ : panel tau,  $P_a$ : panel alpha) examines the alternate hypothesis of the whole panel being cointegrated, while two group statistics ( $G_t$ : group tau,  $G_a$ : group alpha) examine the alternate hypothesis of at least one unit being cointegrated [58]. Westerlund

**Table 2**  
Correlation matrix.

	EFP	GDP	UNE	REN	NREN	POP
<b>EFP</b>	1.0000					
<b>GDP</b>	0.7990	1.0000				
<b>UNE</b>	0.2864	0.4254	1.0000			
<b>REN</b>	-0.0363	-0.4124	-0.1262	1.0000		
<b>NREN</b>	-0.0731	0.4330	0.2065	-0.8979	1.0000	
<b>POP</b>	-0.2354	-0.0657	0.0682	-0.7169	0.6529	1.0000

**Table 3**  
Cross-sectional dependence results.

	Breusch-Pagan	Pesaran scaled	Bias-corrected	Pesaran CD
<b>EFP</b>	158.4506***	33.1947***	33.1019***	11.9076***
<b>GDP</b>	273.3048***	58.8767***	58.7841***	16.5310***
<b>UNE</b>	86.3048***	17.0623***	16.9696***	-0.9670
<b>REN</b>	208.6641***	44.4226***	44.3300***	14.4056***
<b>NREN</b>	227.121***	48.5612***	48.4685***	15.0429***
<b>POP</b>	255.0547***	54.7959***	54.7033***	15.9684***

“Probabilities \* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01”

**Table 4**  
Unit root results.

	CIPS		CADF	
	Level	1st Difference	Level	1st Difference
<b>EFP</b>	-2.451**	-5.277***	-2.451**	-5.277***
<b>GDP</b>	-2.048	-4.423***	-2.048***	-4.423***
<b>UNE</b>	-0.142	-4.429***	-0.142	-4.429***
<b>REN</b>	-2.021	-5.245***	-2.021	-5.245***
<b>NREN</b>	-1.548	-5.355***	-1.548	-5.355***
<b>POP</b>	-0.844	-1.835	-0.844	-3.658***

“Critical values -2.21, -2.33, -2.57 at 10%, 5%, 1% in CIPS and CADF having -2.210, -2.330, -2.570 at 10%, 5%, and 1% level of significance respectively. Probabilities \* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01”

**Table 5**  
Westerlund panel cointegration results.

Statistics	Values	Z-Values	P-Values	Robust P-Values
<b>Gt</b>	-2.897	-1.536	0.062	0.020
<b>Ga</b>	-3.732	2.327	0.990	0.940
<b>Pt</b>	-6.096	-1.546	0.061	0.040
<b>Pa</b>	-4.401	1.021	0.846	0.660

cointegration is based on error correction and generates P-values based on the bootstrap process that reduces distortion resulting from an asymptotic normal distribution [2]. The test confirms cointegration as the null hypothesis of no cointegration is rejected by  $G_t$  and  $P_t$  at a 5% level of significance. The variables EFP, GDP per capita, unemployment, renewable energy, non-renewable energy, and total population are cointegrated. The confirmation of cointegration indicates the presence of a long-run relationship among the variables.

4.4. Second-generation long-run estimates

In the case of cointegration “FMOLS, DOLS, and PMG” are employed. The results are reported in Table 6. The FMOLS results reveal that GDP per capita increases ecological footprint. A 1% increase in income per capita is associated with a 0.2109% increase in ecological footprint. Higher income is associated with higher economic activities including production and leads to extensive use of

**Table 6**  
Long run findings (EFP).

	Fully Modified OLS		Dynamic OLS		Pooled Mean Group		Fixed effects	
	Coefficients	t-Stats	Coefficients	t-Stats	Coefficients	Z-Stats	Coefficients	t-Stats
<b>GDP</b>	0.2109***	9.9525	0.3299***	8.8188	0.2358***	5.72	0.2095***	7.80
<b>UNE</b>	-0.0175***	-2.0501	-0.0433**	-2.6159	-0.0081	0.652	-0.0227**	-2.06
<b>REN</b>	-0.6166***	-17.8166	-0.3099***	-6.7228	-1.1453***	-9.06	-0.6278***	-14.15
<b>NREN</b>	0.0635 **	-2.8800	-0.0925*	-1.8792	-0.2208***	-2.83	0.0646**	2.48
<b>POP</b>	-0.0175**	-3.7951	-0.0342*	-1.9242	-0.0881	-0.67	-0.1715***	-3.50

Probabilities \* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01.

resources and causes air, water, and land degradation. Our results coincide with the results of Majeed and Mazhar [27], Baloch et al. [28], and Tahir et al. [60]. Our findings are different from Danish et al. [35], who suggested a negative association between income and ecological footprints due to technological development (advancements), and structural transformation.

Unemployment leads to a decrease in ecological footprints. An increase of 1% in unemployment leads to a decline in ecological footprints by 0.0175% respectively. The possible reason behind the inverse association between unemployment and ecological footprints is the employment opportunities are created in pollution-intensive industries which rely on conventional sources of energy and compromise environmental quality. Furthermore, the unemployed population has lower consumption and demand of goods and services due to income constraints which leads to a decline in ecological degradation. Therefore, to ensure environmental sustainability increase in unemployment is required. Kashem & Rahman [10] also provided empirical evidence that an incline in unemployment decreases emissions. Anser et al. [33] also reported a decrease in EFP from unemployment caused by the decline in economic activities thereby reducing environmental stress. Furthermore, Ng et al. [22] also reported a similar finding in OECD economies. They suggested that the negative impact of unemployment on EFP is due to poor environmental quality associated with an increase in higher employment level within the economy. The lack of technological advancement in the industrial sector promotes the use of more labor causing inefficient resource allocation and environmental degradation [22].

Renewable energy is associated with a decline in ecological footprints as it does not deplete the resources. The results suggest that an incline of 1% in renewable energy leads to a 0.6166% decline in ecological footprints. Renewable energy uses naturally replenishing resources which neither degrade nor deplete natural resources and renewable energy minimizes the extraction of finite resources. Therefore, the use of renewable energy enhances environmental quality. Our results coincide with Dogan and Seker [61], Majeed & Luni [5], Anwar et al. [62], who demonstrated the favorable role of renewable energy for the environment in the global panel and high income, upper-middle, lower-middle, and low-income economies. Destek and Sinha [36], Saidi and Omri [41], Jebli et al. [37], Azam et al. [17], Yuping et al. [38], Danish et al. [39], Nathaniel et al. [40], Anser et al. [33], Usman and Balsalobre-Lorente [43], Cui et al. [42], Ng et al. [22], Usman and Balsalobre-Lorente [43], Yu et al. [44], Suki et al. [45], and Djellouli et al. [46] also reported similar findings. Thus, renewable energy contributes to environmental sustainability regardless of the income differences. However, our results contrast with Nathaniel et al. [47]. The authors reported the insignificant impact of renewable energy on ecological footprints in MENA economies as energy consumption is dominated by non-renewables. Furthermore, Luni & Majeed [63] also suggested that renewable energy contributes to environmental quality after a threshold level is achieved. Green innovations not only decrease environmental burden through decline in resource

input and energy use but also support higher employment [64] which is required for South Asian economies.

Non-renewable energy contributes to environmental degradation. A 1% rise in non-renewable consumption increases ecological footprints by 0.0635%. Non-renewable increases ecological footprints through the extraction of natural resources, and the release of externalities in the air, water, and land during production and consumption [63]. Our results are similar to Anser et al. [33], Nathaniel et al. [47], Kang et al. [65], and Destek & Sarkodie [29].

The population leads to a decline in environmental deterioration. A 1% incline in population declines ecological footprints by 0.0175% respectively. This inverse relationship between ecological footprints and population can be justified on the grounds that with an increase in population the awareness about the use of ecological resources increases as people become more aware that waste of resources leads to exploitation and damage to the planet which compromises life sustainability; therefore, the use of resources decreases which leads to decline in ecological footprints. Monteiro et al. [52] revealed that creating awareness about the impact of urban resilience on health and well-being can change the behavior regarding policies and help in improving environmental quality. Thus, awareness regarding the adverse impact of environmental degradation on the living standard can lead to change in behavior and measures taken to ensure ecological sustainability. Our findings are similar to Katircioglu et al. [53] who also supported that an incline in population is not associated with environmental degradation. Our results depart from the findings of Anser et al. [33], Nathaniel et al. [47], and Ahmed et al. [2] who suggested ecological degradation resulting from urbanization.

The robustness of the results is examined by DOLS, PMG, and FE. The results obtained from DOLS, and FE also suggest that unemployment decreases ecological footprints. Income leads to higher ecological footprints while renewable energy contributes to a decline in ecological footprints. Non-renewable and population also contribute to environmental sustainability. Although, in PMG, the coefficient of unemployment is negative but insignificant. The results obtained from the country-specific analysis are reported in the appendix in Table A2.

#### 4.5. Second-generation panel causality results

To examine the causal association among the variables “Dumitrescu & Hurlin (2012)” test has been used. The test is robust to CD and heterogeneity issues (Table A4). The null hypothesis of the test is “there is no homogenous causality” while the alternate hypothesis is that causal relationships are heterogeneous [29].

The results are presented in Table 7. The results obtained suggest unidirectional causality from GDP per capita, to ecological footprint. As South Asian economies experienced growth to support this growth resources are utilized. As these economies are developing, and their resource use is not efficient it leads to higher pressure on the environment through increased demand for resources, infrastructure, and energy. Unidirectional causality is

**Table 7**  
Heterogeneous panel causality results.

	EFP	GDP	UNE	REN	NREN	POP
<b>EFP</b>	—	7.465***	1.189	2.365**	1.735*	4.653***
<b>GDP</b>	−0.039	—	−0.045	−0.826	−0.342	1.476
<b>UNE</b>	0.393	1.126	—	0.526	0.971	3.898***
<b>REN</b>	0.215	0.746	1.827*	—	3.409***	2.483**
<b>NREN</b>	−1.141	−0.770	0.339	−0.879	—	0.041
<b>POP</b>	20.446***	25.933	−0.496	26.442***	3.184***	—

Probabilities \* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01.

observed from renewable energy to ecological footprint. Renewable energy has an adverse effect on the environment as the construction of hydropower dams leads to flooding of the natural environment, disturbs river body ecology and sediment transport along with fish migration [66]. Furthermore, renewable energy leads to overexploitation of forests, and water overuse [67] thereby increasing EFP. Non-renewable energy causes EFP, as non-renewable leads to greenhouse gas emissions, mercury emissions, land and water pollution, waste generation, and affects biodiversity and ecosystems [1]. Furthermore, unidirectional causality is reported from unemployment to renewable energy, non-renewable to renewable energy, total population to unemployment. Bidirectional causality exists between ecological footprint and total population, total population and unemployment, and renewable energy and total population respectively.

#### 4.6. Sensitivity analysis

Table 8 reports the findings of the sensitivity of baseline results to additional control variables. The study controls for the effect of agriculture land (AL, % of land area), forest area (FA, % of land area), gross capital formation (GFC, constant 2010 US\$), and natural resource rent (NRR % of GDP), as they also affect EFP. Even after controlling for these variables the impact of unemployment on EFP is negative and significant. Thus, our findings are consistent and not sensitive to determinants of EFP.

#### 4.7. Robustness check: novel panel quantile regression results

To assess whether the association between income, unemployment, renewable and nonrenewable energy, population, and EFP varies across different levels of EFP, a panel quantile regressions analysis is conducted. The results are reported in Table 9. It is evident from the reported results that the negative impact of unemployment on EFP persists across all quantiles. However, the level of significance drops out at higher quantiles (0.70–0.90). Similarly, the negative impact of renewable energy and population on EFP is also evident across all quantiles. This finding suggests that at higher

**Table 8**  
Sensitivity analysis with additional variables.

	(1)	(2)	(3)	(4)
<b>Dependent Variable: EFP</b>				
<b>GDP</b>	0.199*** (0.0306)	0.243*** (0.0276)	0.198*** (0.0272)	0.188*** (0.0337)
<b>UNE</b>	−0.0207* (0.0114)	−0.0207* (0.0106)	−0.0242** (0.0109)	−0.0216* (0.0123)
<b>REN</b>	−0.645*** (0.0502)	−0.733*** (0.0524)	−0.651*** (0.0455)	−0.653*** (0.0507)
<b>NREN</b>	0.0681** (0.0265)	0.0338 (0.0266)	0.0602** (0.0259)	0.0673** (0.0300)
<b>POP</b>	−0.171*** (0.0491)	−0.411*** (0.0838)	−0.172*** (0.0485)	−0.161*** (0.0498)
<b>AL</b>	0.0854 (0.115)			
<b>FA</b>		−0.254*** (0.0737)		
<b>GCF</b>			0.000711* (0.000361)	
<b>NRR</b>				−0.00757 (0.0130)
<b>Constant</b>	3.710*** (0.896)	9.305*** (1.762)	4.107*** (0.846)	3.976*** (0.897)
<b>Observations</b>	140	140	140	112
<b>R<sup>2</sup></b>	0.942	0.947	0.944	0.941
<b>Adjusted R<sup>2</sup></b>	0.938	0.943	0.939	0.936
<b>F-Value</b>	349.69***	382.23***	359.23***	271.19***

\*Standard errors in parentheses\* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01”

**Table 9**  
Panel quantile regression results.

Variables	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
UNE	−0.032* (0.018)	−0.029** (0.015)	−0.027** (0.012)	−0.025** (0.011)	−0.023** (0.010)	−0.021* (0.011)	−0.019 (0.013)	−0.016 (0.015)	−0.014 (0.018)
GDP	0.198*** (0.045)	0.201*** (0.037)	0.204*** (0.030)	0.206*** (0.026)	0.209*** (0.025)	0.212*** (0.027)	0.215*** (0.031)	0.218*** (0.037)	0.221*** (0.045)
REN	−0.677*** (0.078)	−0.663*** (0.064)	−0.650*** (0.052)	−0.640*** (0.046)	−0.628*** (0.043)	−0.616*** (0.047)	−0.605*** (0.054)	−0.594*** (0.064)	−0.581*** (0.078)
NREN	0.064 (0.049)	0.064 (0.040)	0.065** (0.032)	0.065** (0.028)	0.065** (0.027)	0.065** (0.029)	0.065* (0.034)	0.065 (0.040)	0.065 (0.049)
POP	−0.164** (0.078)	−0.166*** (0.063)	−0.168*** (0.052)	−0.170*** (0.046)	−0.172*** (0.043)	−0.173*** (0.046)	−0.175*** (0.054)	−0.176*** (0.064)	−0.178** (0.078)

“Standard errors in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ ”

**Table 10**  
System GMM results.

	EFP			CFP		
	Coeff.	Sd.Er	z-Value	Coeff.	Sd.Er	z-value
GDP	0.1018***	0.0321	3.17	0.1161*	0.0625	1.86
UNE	0.0107**	0.0052	2.04	0.0053	0.0144	0.37
REN	−0.0851*	0.0450	−1.89	−0.1864**	0.0909	−2.05
NREN	−0.0806***	0.0257	−3.13	−0.0686**	0.0302	−2.27
POP	0.0085	0.0065	1.30	0.0151	0.0143	1.05
EFP <sub>t-1</sub> /CFP <sub>t-1</sub>	0.7900***	0.0568	13.90	0.8659***	0.0526	16.44
Constant	−0.2392	—	—	−0.2132	—	—
AR (1)	0.000			0.000		
AR(2)	0.624			0.128		
Sargan Score	87.21			79.89		
Observations	135			135		
Mean VIF	3.98			3.98		

Probabilities \*  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

levels of EFP an increase in unemployment will not significantly lower the pressure on EFP while renewable energy can lower this pressure.

4.8. Robustness check: GMM results

Furthermore, the study also examined the impact of variables under investigation on ecological footprint using the system GMM to address the issue of endogeneity [68]. The results reveal that model does not suffer from endogeneity. The empirical results reported in the former Tables are still valid with those reported in Table 10. In detail, renewable energy and employment contribute to a decline in EFP and CFP. The results obtained from the “Variance inflation factor (VIF)” are reported in the table below which also suggests the model does not suffer from multicollinearity.

Besides, to confirm whether the effects of selected variables suffer from multicollinearity problem, we have also checked the individual effects of the selected variables (Table A3). First, the effect of GDP per capita is controlled, then the remaining control variables are added one by one in the successive models. The effect of renewable energy turns out to be negative and significant, implying that an incline in renewable energy improves environmental quality by decreasing EFP. In the next model, the effect of non-renewable energy is controlled which shows that an increase in non-renewable energy deteriorates environmental quality by increasing EFP. Note, the impact of renewable energy remains intact, implying that the effect of renewable energy is not sensitive to the control of non-renewable energy consumption. The effects of other variables also remain consistent with the baseline estimations.

5. Conclusion and policy implications

The study examined the impact of income, unemployment, renewable energy, non-renewable energy, and population on ecological footprints. The analysis is based on South Asian economies including “Bangladesh, India, Nepal, Pakistan and Sri Lanka”, from 1990 to 2017. Initially, the data was analyzed for cross-sectional dependence. After cross-sectional dependence, the “cross-sectionally augmented IPS (CIPS), and cross-sectionally augmented Dickey-Fuller test (CADF)” tests were employed to decide the stationarity of the variables. The cointegration was investigated by using “The Westerlund cointegration test”. The long-run association among the variables was analyzed with the help of FMOLS, DOLS, and PMG. Furthermore, to determine causal relationship “Dumitrescu and Hurlin [69] causality test” was employed.

The findings support a decline in ecological footprints resulting from unemployment. The inverse relationship between ecological footprints and unemployment is because a higher rate of employment is associated with higher income that support an incline in demand for goods and services. The increased consumption (of goods and services) can be facilitated with an increase in production that is possible through the extraction of virgin resources (materials). Thus, employment increases pressure on natural resources, thereby increasing ecological footprints while unemployment is associated with a decline in consumption and ecological footprints, respectively. Our findings are like Kashem and Rahman [10], Anser et al. [33], and Ng et al. [22]. Renewable energy declines ecological footprint through decline in extraction of virgin materials thereby enhancing environmental sustainability. The findings coincide with Majeed & Luni [5], Azam et al. [17], Yuping et al. [38], Danish et al. [39], Nathaniel et al. [40], Anser et al. [33], Usman and Balsalobre-Lorente [70], Cui et al. [42], Ng et al. [22], Usman and Balsalobre-Lorente [43], Yu et al. [44], Suki et al. [45], and Djellouli et al. [46] while contradict with Nathaniel et al. [47].

From a policy perspective it can be questioned that for development, improvement in living standards along with increasing human capabilities is important which is undermined by unemployment. However, in this regard use of renewable resources should be promoted which also contributes to the decline in environmental pressures. Renewable energy can support employment along with decreasing ecological footprints, combating climate change, and achieve sustainable development targets of decarbonization and increasing energy access. As renewable resources are replenished naturally, therefore does not compromise the regenerative capacity of the earth. Furthermore, income and non-renewable energy are associated with higher ecological footprints similar to the findings of Anser et al. [33], Nathaniel et al. [47], Kang et al. [65], and Destek and Sarkodie [29]. Population

contributes to a decline in ecological footprints similar with findings reported by Katircioglu et al. [53] however different from Anser et al. [33], Nathaniel et al. [47], and Ahmed et al. [2] as they suggest degraded ecological quality caused by urbanization.

From a policy perspective, such policies need to be implemented which are environment and employment friendly such as nature-based solutions and green innovations. For instance, agroforestry, urban forestry, and community-based ecosystem management, amongst others, can help to preserve the environment as well as these initiatives will create green jobs. The governments of the South Asian region need to support the deployment of clean energy and investment in human skills to enable them to join clean industries. Moreover, educational reforms are required that develop the capacity of works in line with the requirement of green industrialization. Furthermore, increasing awareness among the population regarding the importance of biodiversity and its contribution to sustaining life can help decrease the use of non-renewable resources thereby improving the human-environment relationship. South Asian economies do not have a strong renewable technology to fight against environmental deterioration without damaging the employment status of these economies. Therefore, policymakers should put more efforts and priority on the development of renewable and clean technologies which likely lead sustainable consumption and production, and employment outcomes with the lowest pollution possible. As an example, South Asian countries can promote and subsidy firms and organizations to decline unemployment through research and development projects in clean energy. The promotions and incentives towards renewable energy to handle increased environmental pollution over securing environmentally sustainable development.

**Credit author statement**

**Eyup Dogan:** writings, model, supervision; **Tariq Majeed:** methodology, writings; **Tania Luni:** introduction, literature review.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**APPENDIX**

**Table A1**  
Multicollinearity and Residual diagnostics results

Variables	VIF	1/VIF
<b>GDP</b>	7.40	0.1352
<b>UNE</b>	5.50	0.1817
<b>REN</b>	3.32	0.3010
<b>NREN</b>	2.35	0.4248
<b>POP</b>	1.35	0.7429
<b>Mean VIF</b>	3.98	
<b>Residual diagnostics Test</b>		
Test	Statistics	P-Value
<b>Jarque-Bera</b>	2.5718	0.2839
<b>Hetro-LR Ratio (time)</b>	26.0527	0.0001
<b>Hetro-LR Ratio (CS)</b>	18.97	0.0019

**Table A2**  
Country Specific Analysis

Bangladesh				
Variable	Fully Modified OLS		Dynamic OLS	
	Coefficients	t-Stats	Coefficients	t-Stats
<b>GDP</b>	0.2766*	2.0491	2.4296*	2.0929
<b>UNE</b>	0.0272	0.5185	-0.4759***	-3.3198
<b>REN</b>	-0.6812***	-2.8867	-1.6707***	-3.7652
<b>NREN</b>	-0.3911	-1.4080	-3.3107***	-6.6732
<b>POP</b>	0.1045	0.7212	12.8520***	3.8087
India				
Variable	Fully Modified OLS		Dynamic OLS	
	Coefficients	t-Stats	Coefficients	t-Stats
<b>GDP</b>	0.4985***	6.5852	0.1233	0.6552
<b>UNE</b>	-0.3054**	-2.5693	-1.1586***	-4.1532
<b>REN</b>	-0.4818***	-5.3256	-0.8255*	-1.8245
<b>NREN</b>	0.9293***	3.8145	1.0453	1.3653
<b>POP</b>	-1.6427***	-6.0182	-1.1920	-1.1560
Nepal				
Variable	Fully Modified OLS		Dynamic OLS	
	Coefficients	t-Stats	Coefficients	t-Stats
<b>GDP</b>	0.5573***	5.5593	0.1836	1.3202
<b>UNE</b>	0.2280*	1.9613	0.3253*	2.1079
<b>REN</b>	-3.0015**	-2.3716	-10.6209***	-6.0171
<b>NREN</b>	-0.4027**	-2.7971	-1.1657***	-5.7468
<b>POP</b>	-0.2048	-1.3618	0.9728***	3.8250
Pakistan				
Variable	Fully Modified OLS		Dynamic OLS	
	Coefficients	t-Stats	Coefficients	t-Stats
<b>GDP</b>	0.4351***	3.7583	3.0059***	12.9173
<b>UNE</b>	-0.0124	-1.1603	-0.3146***	-11.3296
<b>REN</b>	-0.2089***	-3.0432	9.8581***	9.6264
<b>NREN</b>	1.3181***	4.7405	9.4433***	7.8299
<b>POP</b>	-0.4095***	-4.5901	0.4179	1.5975
Sri Lanka				
Variable	Fully Modified OLS		Dynamic OLS	
	Coefficients	t-Stats	Coefficients	t-Stats
<b>GDP</b>	0.7241***	4.2930	0.3696	-1.2048
<b>UNE</b>	0.2191***	3.3446	-0.2829	-1.5073
<b>REN</b>	-0.3618*	-1.8744	-2.6291***	-4.0962
<b>NREN</b>	0.1770*	1.9017	-0.4590*	-2.1108
<b>POP</b>	-1.4592*	-1.7318	0.9561**	2.7740

Probabilities \* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01.

**Table A3**  
Additional robustness checks

Variables	Dependent Variable: EFP				
<b>GDP</b>	0.430*** (0.0157)	0.224*** (0.0219)	0.199*** (0.0254)	0.162*** (0.0241)	0.210*** (0.0269)
<b>REN</b>		-0.520*** (0.0471)	-0.520*** (0.0466)	-0.616*** (0.0461)	-0.628*** (0.0444)
<b>NREN</b>			0.0547* (0.0285)	0.0390 (0.0261)	0.0646** (0.0261)
<b>UNE</b>				-0.0472*** (0.00888)	-0.0228** (0.0110)
<b>POP</b>					-0.172*** (0.0490)
<b>Constant</b>	-3.083*** (0.107)	0.431 (0.328)	0.406 (0.325)	1.154*** (0.327)	3.917*** (0.850)
<b>Observations</b>	140	140	140	140	140
<b>R<sup>2</sup></b>	0.848	0.920	0.923	0.936	0.942
<b>Adjusted R<sup>2</sup></b>	0.842	0.917	0.919	0.932	0.938
<b>F-Stats</b>	744.90***	769.51***	524.61***	481.84***	420.98***

Standard errors in parentheses \* p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01.

**Table A4**  
Heterogeneity test

	Delta	p-Value
Adj.	5.321	0.000
	6.144	0.000

The value of delta statistics is large therefore the null hypothesis of slope homogeneity is rejected and it can be stated that slopes are heterogeneous.

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