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Renewable energy development, unemployment and GDP growth: South Asian evidence

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Abstract

Purpose – This study aims to investigate the interplay between renewable energy development, unemployment and GDP growth within Bangladesh, India, Pakistan and Sri Lanka. The research underscores the significant role of renewable energy plays in stimulating economic growth and mitigating unemployment, offering crucial policy insights for sustainable growth in South Asia.

Design/methodology/approach – Utilizing the autoregressive distributive lag (ARDL) framework and Toda Yamamoto causality through the vector autoregressive (VAR) approach, the study analyzes the long-term and short-term impacts of these variables from 1990 to 2019.

Findings – This study reveals a significant co-integration among renewable energy consumption, unemployment and GDP growth in selected South Asian countries. The long-term estimation shows renewable energy consumption influences negatively economic progression in Bangladesh, with no notable correlation with unemployment. In contrast, Sri Lanka demonstrates an optimal relationship among all the variables. Short-run assessments reveal a significant positive relationship between renewable energy consumption and economic growth in India, while an inverse relationship is evident in Pakistan. Moreover, the relationship between unemployment and economic progression, the result shows a negative and significant relationship in India and Sri Lanka.

Research limitations/implications – The study emphasizes the need for policy development concerning renewable energy development, unemployment reduction and sustainable economic growth in South Asia. While limitations exist, future research can expand upon this work by incorporating varied data, additional countries or alternative modeling techniques.

Originality/value – This research offers a unique exploration into the multidimensional impacts of renewable energy consumption, unemployment and economic growth in the South Asian context, an area previously unexplored in such depth.

Keywords Renewable energy, Unemployment, GDP growth, ARDL, Causality test

Paper type Research paper

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1. Introduction

Non-renewable energy is the dominant energy consumption for manufacturing; therefore, the industrial revolution happened worldwide. Therefore, non-renewable energy has continued to be the most popular and accessable energy source over the years. More than 87% of the primary energy consumed worldwide is supplied by non-renewable energy (Sarkodie, Adams, Owusu, Leirvik, & Ozturk, 2020). Global warming is a result of our overreliance on non-renewable energy sources, which has led to significant CO_2 emissions (Abokyi, Appiah-Konadu, Abokyi, & Oteng-Abayie, 2019; Maji, Sulaiman, & Abdul-Rahim, 2019). In contrast, renewable energy sources, including sun, wind, biomass and hydropower do not release CO_2 during production (Carfora, Pansini, & Scandurra, 2019). Whereas non-renewable energy is the primary source of producing the greatest amount of greenhouse gases (GHGs) globally (Appiah, 2018). The rate at which energy consumption is increasing, its effects on the environment, and the demand for alternative energy in both the southern and northern parts of the world have all been the subject of the researchers (Bour, Asafo, & Kwarteng, 2019).

However, removing non-renewable energy from the considerations for economic expansion raises the issue of sustainability and prosperity of countries in recent decades. Since it has the ability to minimize carbon emissions, renewable energy is the greatest alternative to non-renewable energy. Also, improper usage of renewable energy can lower productivity and have a negative impact on the economy (Carfora *et al.*, 2019). With the expansion of different development activities and population growth, South Asian nations are witnessing an increase in energy consumption, similar to other regions of the world (Abbas *et al.*, 2018; Shukla, Sudhakar, & Baredar, 2017). Due to a significant mismatch between the prospective supply of fossil fuels and the energy demand, there is a shortage of energy in all of South Asia's countries (Conte & Monno, 2012). This is a significant obstacle to achieving the different socio-economic development goals that the regional governments have set. Since many of these energies, like wind and solar energy, are endless, they are the only option for South Asian countries to fulfill their growing energy needs and reduce their emissions of GHGs.

Moreover, studies have often been found on the linear and asymmetric relationship between energy consumption, environmental dimensions and economic growth (Bilan *et al.*, 2019; Kahia, Omri, & Jarraya, 2021; Lin, Zhu, & Raza, 2022; Mahmood, Wang, & Hassan, 2019). Moreover, most of the research papers discuss renewable energy consumption with various economic indicators, mainly GDP growth (Ahmed & Shimada, 2019; Marinaş, Dinu, Socol, & Socol, 2018). However, unemployment is an important economic indicator that needs to be reviewed and discussed critically with the link to renewable energy growth. Based on this thought and findings, we establish a research gap between renewable energy consumption and unemployment as a prime indicator of economic growth.

The relationship between renewable energy consumption, unemployment and economic growth can be explained as developing a renewable energy system for a country needs massive investment and labor in different types of renewable energy production and distribution (Rafiq, Salim, & Sgro, 2018). However, hydro energy creation, modern biomass, winds, solar, geothermal and biofuel sources are needed to develop by processing raw materials, energy manufacturing technologies and plant construction. This kind of activity needs a high investment segment for setting up modern renewable energy sources and consequently will positively impact employment as well. Therefore, employment and the creation of jobs from renewable energy production and supply technologies establishment reflect a probable positive impact on employment which decreases unemployment as well.

Again, to maintain energy stability in a country, mainly fossil fuels and coal are imported from different destinations worldwide. For this reason, a country needs to save a huge amount of foreign currency and financial assets to stabilize the energy supply and economic growth. For this reason, the government cannot invest in various economic development-related activities, so the creation of new jobs is hindered due to less investment in the

country's development sector (Apergis & Salim, 2015). Ultimately, for this reason, the unemployment rate has a relationship nexus with energy import, increase or decrease in economic development and development of a country's renewable and non-renewable energy sources.

Given the above relationship link between unemployment, renewable energy consumption and economic growth, the expansion of renewable energy production and consumption reduces the level of unemployment and boosts the economy. On the contrary, opposite relationship nexus may occur when heavily dependent on fossil fuels import and ignoring renewable energy development. From the above aspects, we can develop two thinking arguments for the relationship among the variables. First, the development of renewable energy in a country needs high investment levels for processing raw materials, energy manufacturing technologies and plant construction. So the arguments create as does this high investment cost on renewable energy development relates to employment and supports growth of the country. Second, without developing renewable energy, a country must import a huge amount of fossil fuels and coal to support its energy sector. For this import of energy, does it have an impact on lessening development progress as well as a negative impact on employment?

However, a few studies found that the consumption of renewable energy helps secure jobs for the unemployed teeming population and the achievement of improved society's welfare (Khobai, Kolisi, Moyo, Anyikwa, & Dingela, 2020). Unfortunately, there is inadequate evidence on the impact of renewable energy consumption, unemployment and economic growth in South Asian countries (Bangladesh, India, Pakistan and Sri Lanka). These four countries represent a significant portion of the region, both in terms of population and economic output. Thus, the findings from these countries provide substantial insights into the dynamics of renewable energy development, unemployment and GDP growth in South Asia. So, this paper seeks to bridge that gap. Thus, research on the influence of renewable energy consumption, unemployment and economic growth needs a crucial scientific endeavor to determine the linkage among the variables in South Asia. Using the autoregressive distributed lag (ARDL) approach of (Pesaran, Shin, & Smith, 2001; Toda & Yamamotob, 1995) causality tests, the period of investigation is 1990–2019. Therefore, this study contributes to the gap between the variable's causal relationships.

2. Literature review

Throughout the last decades, several studies have focused on renewable energy development and economic growth. Different dimensional studies on different countries aspects for finding the nexus between renewable energy sector development and economic growth, the following studies found significance between the variables (Raza & Lin, 2022; Xiuhui & Raza, 2022; Ahmed & Shimada, 2019; Amri, 2017; Apergis & Danuletiu, 2014; Khobai *et al.*, 2020; Marinaș *et al.*, 2018; Salim, Hassan, & Shafiei, 2014; Sebri & Ben-Salha, 2014; Soava, Mehedintu, Sterpu, & Raduteanu, 2018). Unfortunately, the following dimensional aspects among these three variables, renewable energy, unemployment and economic growth, are still not significantly well researched. Our paper focuses on this gap and contributes to this dimensional relationship from the South Asian countries' perspective. On examining the above relationship nexus, a few studies have found on different countries' aspects are discussed below.

Employing the unit root, co-integration and nonlinear Granger causality methodological technique in panel data, Apergis and Salim (2015) examined 80 nations from 1990 to 2013. The study determined various results regarding the effect of consuming renewable energy on unemployment. However, overall findings revealed that using renewable energy has a significant positive effect on reducing unemployment in selected countries of Asia and Latin America. The study also showed the univariate causality of renewable energy consumption

on unemployment reduction. Similarly, Lehr, Nitsch, Kratzat, Lutz, and Edler (2008) and Ragwitz *et al.* (2009) also found a noteworthy positive impact of renewable energy consumption on employment. These findings suggest that using renewable energy sources in these economies positively impacts the creation of employment. Similarly, Raza, Wu, and Lin (2023) and Xiuhui and Raza (2022), the significant relationship between carbon emission and economic growth in Pakistan.

Huseynli and Huseynli (2022) studied the relationship between employment and renewable energy production in Azerbaijan. Using the VAR analysis, the Granger method and the Augmented Dickey-Fuller test on time series data, the study concluded with a statement that renewable energy production positively impacts the creation of jobs while reducing unemployment significantly in Azerbaijan. Similarly, Tsaurai (2022) found a significant positive impact of renewable energy production on the employment rate, like the positive relationship between financial development and the employment rate in South Africa. However, Rafiq *et al.* (2018) conducted a study on 41 countries from 1980 to 2014 to assess the relationship between renewable energy, trade and unemployment. The study used both linear and non-linear models on time series data. According to the findings, while agriculture and the use of renewable energy sources cause unemployment to rise, industrialization, the services sector, government spending and trade openness all decrease the unemployment rates. Moreover, Blazejczak, Braun, Edler, and Schill (2014) found renewable energy's positive and significant impact on employment increase. Similarly, Raza *et al.* (2023) illustrate the significant relationship between carbon emission and economic growth in Bangladesh.

In a study, Khobai *et al.* (2020) employed the ARDL method to identify the relationship between the consumption of renewable energy and the rate of unemployment in South Africa. The study found a significant and positive relationship between the variables in the long term. So, the research concluded with a recommendation that the government should boost the renewable energy sector to enhance employment opportunities, which will significantly impact economic growth. Similarly, Naqvi, Wang, and Ali (2022) found a significant and positive relationship between renewable energy and employment in the long term in 19 European countries.

Furthermore, employing the Johansen co-integration test, the VAR model and the Granger causality test, El Moummy, Salmi, and Baddih (2021) studied to assess the impact of renewable energy consumption on the unemployment rate reduction in Morocco for the period 1990–2017. The study concluded with a policy statement that the Moroccan government should boost the energy sector to increase employment opportunities, which will reduce the unemployment rate significantly. Also, the findings of the study by Saidu Musa and Maijama'a (2020) showed similar recommendations for the policymakers. To specify the impact of renewable energy on the unemployment rate, Rivers (2013) used a fixed coefficient input–output model and a computable general equilibrium model in Canada. The result showed that decreasing emissions from the electrical sector by 10% through incentive programs for renewable electricity is likely to increase the equilibrium unemployment rate between 0.1 and 0.3 percentage points.

From the above studies, we can summarize that the researchers identified relationships between economic growth and energy consumption vary across the regions. Also, some researchers studied to define the relationship between unemployment and energy consumption and showed a variety of relationships based on the different samples and methodologies of the study. However, there is no study conducted to examine the relationship in South Asian countries' aspect. So, this study is conducted to identify the dimensional effect on energy consumption, unemployment and economic growth from South Asian evidence that will significantly contribute to the literature and develop a new direction for further study.

3. Method and model development

3.1 Data collection

The secondary study is influenced by annual time series data available on the website of the World Bank from 1990 to 2019. To measure the significant impact of renewable energy consumption and unemployment on economic progress, two independent variables (renewable energy consumption and unemployment rate) were selected, and GDP growth, a proxy variable of economic progress, has been selected in this study.

3.2 Model selection

The World Bank open data (2019) is used to gather annual time series data on the use of renewable energy, unemployment and GDP growth, as shown in Table 1. The ARDL co-integration method and Granger Causality (Toda Yamamoto) test are required to explore the linear relationships between these variables. ARDL co-integration approach helps to provide valuable insights for developing short-run and long-run relationships. The model of ARDL is a standard least-squares regression that considers the dependent and independent variables' lags (Pesaran & Shin, 1997). Pesaran and Shin (1997), Pesaran *et al.* (2001) published studies about the ARDL method, which is popularized later for finding the linear relationship based on the appropriate lag selection model. Pretests for the unit root are not necessary for this model, but they are recommended when the variables are integrated of order I (0), I (1) or a combination of the two. The Akaike Information Criterion (AIC) is utilized to determine the model's lags.

3.3 Model specification

In the context of this study, we intend to establish the dynamic relationship between the use of renewable energy, unemployment rate and economic progress in South Asian nations (Bangladesh, India, Pakistan and Sri Lanka) by integrating the following variables. As a result, the following functional model is developed:

$$\mathrm{GDP_t} = \delta_0. + \delta_1 \mathrm{REN_t} + \delta_2 \mathrm{UNE_t} + \varepsilon_t \tag{1}$$

3.4 ARDL bounds test for co-integration

The ARDL Bounds test approach (Pesaran *et al.*, 2001) is distinguished from other types of co-integration methods such as methods by Engle and Granger (1987), Johansen (1992), and Gregory and Hansen (1996). This co-integration approach can be used if the variables are integrated at (I (0) and (I (1) or a combination of both forms. Therefore, the following equation is developed to find the link among the variables stated above that have co-integration exists or not.

$$\Delta\mathrm{GDP} = \delta 0 + \sum_{i=1}^{p1} \delta_{1i}\Delta\mathrm{GDP}_{t-i} + \sum_{i=0}^{p2} \delta_{2i}\Delta\mathrm{REN}_{t-i} + \sum_{i=0}^{p3} \delta_{3i}\Delta\mathrm{UNE}_{t-i} + \delta 4\,\Delta GDP_{T-1} + \delta 5\,\Delta REN_{T-1} + \delta 6\,\Delta UNE_{T-1} + \mu_{1t} \tag{2}$$

Country's name	Time frame	Variables
Bangladesh	1990–2019	GDP Growth, Renewable Energy Consumption, Unemployment Rate
India	1990–2019	GDP Growth, Renewable Energy Consumption, Unemployment Rate
Pakistan	1990–2019	GDP Growth, Renewable Energy Consumption, Unemployment Rate
Sri Lanka	1990–2019	GDP Growth, Renewable Energy Consumption, Unemployment Rate

Source(s): The World Bank open data (2019)

Table 1. Samples and variables selection

3.5 Long-run estimation model

To find the link between the dependent and independent variables in the long run, the following equation is constructed to find the coefficients value of the long-run estimating model followed by the ARDL technique. The lag length for the variables is selected by the AIC method.

$$\mathrm{GDPt} = \varnothing 0 + \sum_{\mathrm{J}=1}^{\mathrm{P1}} \varnothing_{1\mathrm{J}}\mathrm{GDP}_{\mathrm{T-J}} + \sum_{\mathrm{J}=0}^{\mathrm{p2}} \varnothing_{2\mathrm{J}}\mathrm{REN}_{\mathrm{T-J}} + \sum_{\mathrm{J}=0}^{\mathrm{P3}} \varnothing_{3\mathrm{J}}\mathrm{UNE}_{\mathrm{T-J}} + \varepsilon_{\mathrm{t}} \quad (3)$$

3.6 Short-run estimation model

For investigating the short run model and its stability the Error Correction Model (ECM) is also applied to draw an optimum result and shock of variables in the short-run. Negative and significant ECM is required, with a coefficient value limiting zero to one. The following formula is developed to measure the short-run dynamics followed by the ARDL is given below:

$$\Delta\mathrm{GDPt} = \varphi 0 + \sum_{\mathrm{j}=1}^{\mathrm{P1}} \varphi_{1\mathrm{J}}\Delta\mathrm{GDP}_{\mathrm{T-J}} + \sum_{\mathrm{j}=0}^{\mathrm{p2}} \varphi_{2\mathrm{J}}\Delta\mathrm{REN}_{\mathrm{T-J}} + \sum_{\mathrm{j}=0}^{\mathrm{P3}} \varphi_{3\mathrm{J}}\Delta\mathrm{UNE}_{\mathrm{T-J}} + \lambda\mathrm{ECM}_{\mathrm{T-1}} + \mu_{\mathrm{t}} \quad (4)$$

4. Analysis and discussion

Table 2 depicts the descriptive statistics of the variables, namely, GDP growth, renewable energy consumption and the unemployment rate of the south Asian countries (Bangladesh. India, Pakistan and Sri Lanka) collected from the World Bank data sources. From the above statistics, the mean value of the unemployment rate in Bangladesh, India, Pakistan and Sri

	Bangladesh			India		
	B_GDP	B_REN	B_UNE	I_GDP	I_REN	I_UNE
Mean	5.624	50.07	3.695	6.225	44.21	7.853
Maximum	7.881	73.15	5.209	8.845	58.656	10.19
Minimum	3.485	24.75	2.200	1.056	32.410	6.510
Std. Dev	1.101	14.68	0.875	1.922	9.123	0.765
Jarque-Bera	0.653	1.643	2.176	2.851	2.683	3.282
Probability	0.721	0.439	0.336	0.240	0.261	0.193
Observations	30	30	30	30	30	30
	Pakistan			Sri Lanka		
	P_GDP	P_REN	P_UNE	S_GDP	S_REN	S_UNE
Mean	4.181	49.29	1.536	5.205	62.56	7.614
Maximum	7.705	58.09	6.550	8.669	78.08	14.66
Minimum	1.014	42.09	0.400	−1.545	49.33	3.880
Std. Dev	1.717	4.219	1.636	2.245	7.586	3.429
Jarque-Bera	0.466	1.023	5.867	4.674	0.427	3.170
Probability	0.792	0.599	0.110	0.164	0.807	0.204
Observations	30	30	30	30	30	30

Note(s): * significant at 10% level; **significant at 5% level; *** significant at 1% level
Source(s): Findings by authors

Table 2.
Descriptive statistics

Lanka, respectively, is 3.69, 7.85, 1.53 and 7.61. Moreover, Table 2 finds the highest mean GDP growth in India, 6.22, and Bangladesh, 5.62 among these four countries. The renewable energy consumption percentage of total energy consumption was found to be highest in Sri Lanka, 62.56. The Jarque–Bera (JB) statistics for determining the normality of data show that all variables are distributed normally because the p-value (0.05) exceeds the 5% significance level.

Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests on unit roots indicate the stationarity of the dataset. Here, all-time series data have to be stationary after one differentiation to perform the ARDL model in the analysis. From the below Table 3, we found variables are integrated with I (0) and I (1), also all are stationary in the first difference. However, no variable is significant at I (2). From the above findings, now we can proceed with the (ARDL) approach developed by Pesaran *et al.* (2001) and Pesaran and Shin (1997) to determine the long-run and short-run relationship dynamics. We can also utilize the Toda Yamamoto Granger Causality test by utilizing the VAR framework to find the directional relationship.

Table 4 depicts that the empirical findings regarding the bound test of co-integration analysis found a strong co-integration among the variables. In the case of Bangladesh, it is found significant at the level of 5% significance. For India, Pakistan and Sri Lanka, it follows and passes the critical bound of I (1) at the level of 1% significance. From the analysis, it can be concluded that variables are highly co-integrated and have a long-run relationship toward moving in the same direction.

Model with constant term [level Form]			Model with constant and trend terms [level Form]		
Variables	ADF (*p*-value)	PP (*p*-value)	Variables	ADF (*p*-value)	PP (*p*-value)
B_GDP	0.3771	0.4421	B_GDP	0.1273	0.0029**
B_REN	0.9684	0.9999	B_REN	0.0900*	0.0782*
B_UNE	0.6052	0.8118	B_UNE	0.2064	0.2091
I_GDP	0.0018**	0.0025**	I_GDP	0.0060**	0.0074**
I_REN	0.6697	0.6697	I_REN	0.9342	0.9089
I_UNE	0.3517	0.2779	I_UNE	0.9974	0.1705
P_GDP	0.0088**	0.0088**	P_GDP	0.0423**	0.0422**
P_REN	0.5606	0.5600	P_REN	0.3644	0.3471
P_UNE	0.9788	0.9875	P_UNE	0.9996	0.9871
S_GDP	0.0117**	0.0117**	S_GDP	0.0569*	0.0569*
S_REN	0.6300	0.6315	S_REN	0.5221	0.5502
S_UNE	0.0665*	0.0733	S_UNE	0.9870	0.9852
Model with constant term [Difference Form]			Model with constant and trend terms [Difference Form]		
Variables	ADF (*p*-value)	PP (*p*-value)	Variables	ADF (*p*-value)	PP (*p*-value)
ΔB_GDP	0.0000***	0.0001***	ΔB_GDP	0.0000***	0.0000***
ΔB_REN	0.0014***	0.0000***	ΔB_REN	0.0083***	0.0000***
ΔB_UNE	0.0002***	0.0000***	ΔB_UNE	0.0013***	0.0000***
ΔI_GDP	0.0002***	0.0000***	ΔI_GDP	0.0009***	0.0000***
ΔI_REN	0.0003***	0.0003***	ΔI_REN	0.0015***	0.0015***
ΔI_UNE	0.0141**	0.0000***	ΔI_UNE	0.0000***	0.0000***
ΔP_GDP	0.0000***	0.0000***	ΔP_GDP	0.0000***	0.0000***
ΔP_REN	0.0004***	0.0004***	ΔP_REN	0.0016***	0.0016***
ΔP_UNE	0.0354**	0.0003***	ΔP_UNE	0.0000***	0.0000***
ΔS_GDP	0.0000***	0.0000***	ΔS_GDP	0.0000***	0.0000***
ΔS_REN	0.0000***	0.0000***	ΔS_REN	0.0002***	0.0002***
ΔS_UNE	0.0057***	0.0049***	ΔS_UNE	0.0017***	0.0018***

Table 3.
Results of ADF test and PP test

Note(s): *Significant at 10% level; **significant at 5% level; and *** significant at 1% level
Source(s): Findings by authors

Model specification	Bangladesh		India		Pakistan		Sri Lanka	
F-Statistics	3.940**		6.081***		4.352***		13.989***	
Functional Format	$B_{\_GDP=}$ (B_GDP/B_REN, B_UNE)		$I_{\_GDP=}$ (I_GDP/I_REN, I_UNE)		$P_{\_GDP=}$ (P_GDP/P_REN, P_UNE)		$S_{\_GDP=}$ (S_GDP/S_REN, S_UNE)	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
10%	2.63	3.35	2.63	3.35	2.63	3.35	2.63	3.35
5%	3.10	3.87	3.10	3.87	3.10	3.87	3.10	3.87
1%	4.13	5	4.13	5	4.13	5	4.13	5
Critical Values	K	2	K	2	K	2	K	2

Note(s): ***Significant at 1% level; **significant at 5% level; and *significant at 10% level
Source(s): Findings by authors

Table 4.
Bound test approach results

Table 5 represents the long-run relationship between renewable energy consumption, unemployment rate and economic growth in the south Asian context. In Bangladesh, the result indicates a negative relationship between renewable energy consumption and unemployment with economic development. Moreover, renewable energy consumption is significant at the level of 1%, but unemployment is insignificant. To maintain sustainable energy growth and to support the sustainable development goals, the renewable energy relationship had to be positive with economic growth, and unemployment had to be reduced means a negative relationship. In our relationship finding, we found the opposite relationship in the long run for renewable energy development in the Bangladesh scenario. It can be said and established that renewable energy development is not have justified relationship with the economic growth of Bangladesh.

The results of ARDL long-run estimation In Sri Lanka found a significant relationship between renewable energy consumption and unemployment with the economic development at the level of 1% significance. The result shows a positive relationship between renewable energy consumption and a negative relationship with the unemployment rate of Sri Lanka. From the coefficient values, it confirms that for 1% rise in the economic progress of Sri Lanka has an impact on 0.29% use of renewable energy, which means renewable energy consumption will rise and unemployment will decrease at the rate of −0.82%. The above result supports our arguments of a link between renewable energy growth, unemployment rate and economic progress relationship (Lehr *et al.*, 2008; Ragwitz *et al.*, 2009). However, interestingly, we found no long-run nexus in the case of India and Pakistan.

The short-run estimations from Table 6 indicate that the value of the ECM (−1) coefficient was found to be significant and negative, which signifies the model parameter's stability and robustness. The error correction model (ECM) also advocates that economic growth will be

Lag	Bangladesh (1,2,1)		India (1,1,1)		Pakistan (1,1,0)		Sri Lanka (1,2,2)	
Functional format	(B_GDP/B_REN, B_UNE)		(I_GDP/I_ REN, I_UNE)		((P_GDP/P_ REN, P_UNE)		(S_GDP/S_ REN, S_UNE)	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
REN	−0.085	0.00***	0.012	0.84	0.027	0.83	0.293	0.00***
UNE	−0.398	0.40	1.475	0.12	0.067	0.83	−0.819	0.00***
C	11.70	0.00***	−5.068	0.58	2.352	0.73	−8.319	0.08*

Note(s): ***Significant at 1% level; **significant at 5% level; and *significant at 10% level
Source(s): Findings by authors

Table 5.
Long-run estimation results: (dependent variable GDP)

readjusted to the long-run equilibrium after each short-run shock of the independent variables, namely, the use of renewable energy and the unemployment rate. Thus, the consumption of renewable energy and unemployment rate indicators have a short-run impact on the economic development of South Asia.

From the scenario of Bangladesh, we found the coefficient value of renewable energy is negative, and the unemployment rate is positive in the short run. Still, we found no significance in the relationship. However, we found the ECM is negative and significant, which tells about model stability, and the adjusted R square is 0.44.

In India, the ECM coefficient is negative and significant, which also tells that the model is stable in the short run. In the short-run, renewable energy consumption is positive, and unemployment is negatively significant with the economic development in India. However, In the long run, we found no relationship among the variables. The result reflects that in the short run, renewable energy consumption has a positive direction toward economic development as well as unemployment has a significant negative influence on the dependent variables, which also supports the findings of (Apergis & Salim, 2015; Blazejczak *et al.*, 2014). However, from India's perspective, the arguments we developed for the study are rational and significant in the short run.

In Pakistan, renewable energy consumption is negatively significant to economic growth at the level of 10% significance. This partially justifies our second argument that decreasing the renewable energy growth will consequently increase the energy import in the case of Pakistan in the short run. However, we did not find any significance in the unemployment rate. The short-run nexus of the relationship in Sri Lanka found a significant negative coefficient value of −0.31 for unemployment, but no significance was found in renewable energy consumption with economic growth.

Diagnostic tests are a prerequisite to check the model's stability and acceptance. The results of four diagnostic tests in Table 7, including the (Breusch, 1978) LM test for autocorrelation, Auto-Regressive Conditional Heteroskedasticity (ARCH) (Ramsey, 1969),

Lag	Bangladesh (1,2,1)		India (1,1,1)		Pakistan (1,1,0)		Sri Lanka (1,2,2)	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficients	*p*-value
ΔREN	−0.095	0.26	0.635	0.01***	−0.529	0.06*	0.134	0.32
ΔUNE	0.191	0.47	−0.404	0.03**	0.054	0.83	−0.309	0.00***
ECM(-1)	−0.698	0.00***	−0.859	0.00***	−0.798	0.00***	−0.746	0.00***
R2	0.502		0.578		0.424		0.772	
Adj R2	0.440		0.546		0.403		0.732	

Note(s): ***Significant at 1% level; **significant at 5% level; and *significant at 10% level
Source(s): Findings by authors

Table 6.
Short-run estimation results: (dependent variable GDP)

	Bangladesh		India		Pakistan		Sri Lanka	
	χ^2 value	*p*-value	χ^2 value	*p*-value	χ^2 value	*p*-value	χ^2 value	*p*-value
BG-LM	0.586	0.74	2.424	0.29	0.492	0.79	1.486	0.47
ARCH	1.913	0.16	0.417	0.81	1.025	0.59	0.948	0.62
JB Stat	0.625	0.73	1.477	0.47	0.867	0.65	0.165	0.92
RESET	0.125	0.97	0.041	0.95	0.798	0.46	1.534	0.24

Note(s): ***Significant at 1% level; **significant at 5% level; and *significant at 10% level
Source(s): Findings by authors

Table 7.
Diagnostic tests

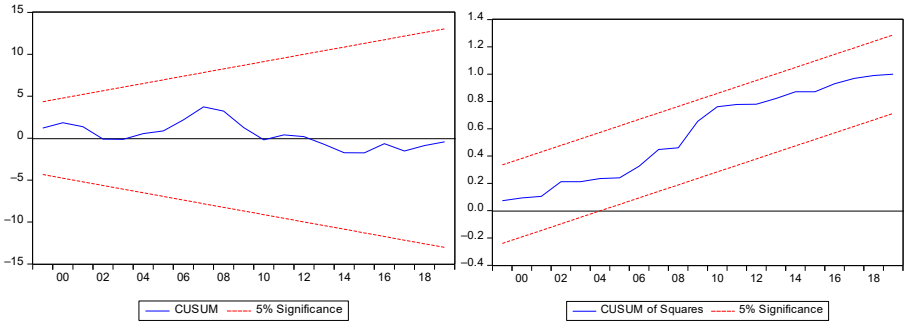
RESET test for model stability and Jarque-Bera (JB) normality show that our analysis has passed all the diagnostic tests because null hypothesis has been rejected, which shows the ARDL model results in consistency and efficiency. We also found that the finding that the Durbin-Watson statistics are higher than the R2 suggests that the short-run models are valid.

4.1 Test of stability

The robustness of the long-run parameters, as suggested by (Brown, Durbin, & Evans, 2011), was examined through the cumulative sum of recursive residuals (CUSUM) and CUSUM of squares of recursive residuals (CUSUMSQ). The outcomes are visually represented in Figures 1 through 4. At a significance level of 5%, the results do not lead to a rejection of the null hypothesis since the plot of the tests remains within the critical bounds. Consequently, this provides assurance that the chosen ARDL model used in our study is stable.

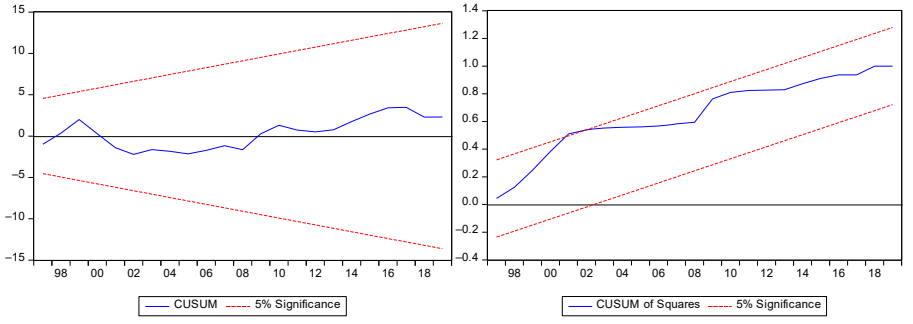
4.2 Granger causality test

In Table 8, we analyze the probable causative relation among the variables chosen for the investigation by using the Granger causality test, as proposed by Dolado and Lütkepohl (1996) and Toda and Yamamotob (1995). The Granger causality testing assesses whether the variables have a short-run causal relationship or not. When the underlining unit roots fully satisfy the co-integration I (0) and I (1) in the level form. According to Dolado and Lütkepohl (1996) and Toda and Yamamotob (1995), we want to determine if the link between the variables is unidirectional, bidirectional or without causation.



Source(s): Findings by authors

Figure 1.
Bangladesh



Source(s): Findings by authors

Figure 2.
India

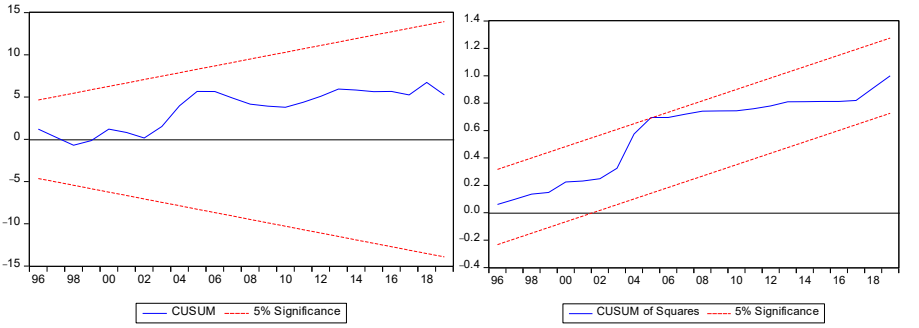


Figure 3.
Pakistan

Source(s): Findings by authors

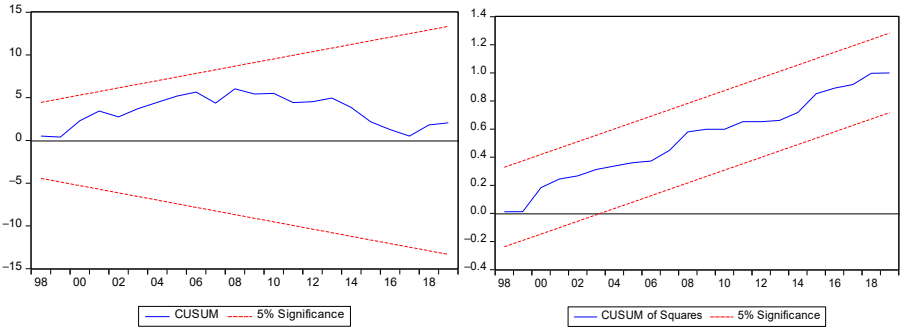


Figure 4.
Sri Lanka

Source(s): Findings by authors

	B_GDP	B_REN	B_UNE		I_GDP	I_REN	I_UNE
B_GDP		2.47 (0.29)	1.87 (0.39)	I_GDP		3.53 (0.17)	1.33 (0.51)
B_REN	*10.86 (0.00)****		1.86 (0.39)	I_REN	2.62 (0.26)		*6.64 (0.03)***
B_UNE	1.83 (0.39)	1.14 (0.56)		I_UNE	*7.14 (0.02)***	2.72 (0.25)	

	P_GDP	P_GDP	P_GDP		S_GDP	S_GDP	S_GDP
P_GDP		1.88 (0.39)	0.39 (0.81)	S_GDP		0.81 (0.66)	0.51 (0.77)
P_REN	0.66 (0.71)		2.60 (0.27)	S_REN	*13.33 (0.00)****		0.19 (0.90)
P_UNE	0.74 (0.68)	1.71 (0.42)		S_UNE	*20.25 (0.00)****	0.45 (0.79)	

Table 8.
Toda-Yamamoto causality test

Note(s): ***Significant at 1% level; **significant at 5% level; and *significant at 10% level
Source(s): Findings by authors

Table 8 shows that from the perspective of Bangladesh, a short-run unidirectional causal correlation between (B_GDP→B_REN) economic development and the renewable energy consumption is found significant. South Asia is one of the most emerging countries; in India, we found short-term unidirectional causality between the variables (I_GDP→I_UNE) and (I_UNE→I_REN). On the other hand, we found no relationship between the long-run and short-run estimations in the case of the Pakistan scenario. However, the short-run causation between (S_GDP→S_REN) and (S_GDP→S_UNE) in Sri Lanka found a significant unidirectional relationship.

In Table 8, we found that a change in renewable energy consumption hits the GDP growth of Bangladesh in the short run causation by a unidirectional way. This means GDP growth as well as economic progress directly impacted by the short-run demand push of renewable energy sector development, but no causation has been found in the case of unemployment. On the other hand, India, the largest economy in south Asia and the largest land area occupied by India found the unidirectional causation between employment and unemployment causes renewable energy development in the short run. This unidirectional causality supports the findings in our short-run estimation. This reflects that when unemployment is deceased, renewable energy increases, which has a vice-versa effect on India's economic growth. However, we did not find any short-run causation among the variables in the Pakistan scenario. Moreover, in Sri Lanka, we also found unidirectional causation between renewable energy consumption and the unemployment rate. The causality finding supports the relationship nexus among the variables.

4.3 Analysis discussion

Bangladesh's long-run relationship shows a negative correlation between GDP growth and renewable energy development (see Table 5), which can be argued as an indication of the high initial costs and potential economic hurdles associated with transitioning to renewable energy. The short-run analysis in Table 6 showing no significant relationships suggests the possibility of immediate economic and unemployment influences being driven by factors other than renewable energy, potentially including industrial growth, agricultural output or trade policies.

The lack of significant relationships between the variables in the long-run analysis for both India and Pakistan could claim for a more complex interplay of economic factors beyond renewable energy and employment in these countries. This may be due to their diverse economic sectors and the presence of varied regional developments within these large economies. However, India's short-run analysis shows a positive relationship between renewable energy and GDP growth alongside a decrease in unemployment as GDP grows suggesting immediate benefits from renewable energy initiatives. This strengthens the argument for the promotion of renewable energy as part of an immediate growth and employment strategy. The short-run findings for Pakistan indicate potential challenges in the transition to renewable energy, as indicated by the negative correlation with GDP growth. This emphasizes the argument for careful planning and transition strategies that consider potential short-term economic disruptions.

Moreover, Sri Lanka's positive long-run relationship between GDP growth and renewable energy development suggests a dimensional link of renewable energy policies with economic growth. This offers a strong argument for renewable energy as a driver of sustainable growth and polilcy. The observed negative correlation between GDP growth and unemployment, suggesting that economic growth is followed by reduced unemployment, supports the inclusive growth strategy. However, the short-run analysis reveals that the favourable impacts of renewable energy on GDP are not immediately apparent, possibly due to time lags in realizing returns on renewable energy investments.

5. Conclusion and policy implications

This paper reveals the link between renewable energy consumption, unemployment rate and economic development, which is based on the two arguments of thinking. First, the development of renewable energy in a country needs high investment levels for the processing of raw materials, energy manufacturing technologies and plant construction. For this high cost of investment, does it relate to the development of employment? Second, without developing

renewable energy, a country must import a huge amount of fossil fuels and coal to support its energy sector. For this importing of energy, does it have an impact on less development progress as well as a negative impact on employment? To find these questions' solutions, our study helps to conclude by finding hidden dynamics, thereby assisting stakeholders in effective decision-making.

In this study, from 1990 through 2019, we examined the relationship between renewable energy consumption and unemployment relationship nexus with the economic development of south Asian emerging countries. We discovered the variables influencing economic progress by using the ARDL Bounds Test, long-run and short-run estimations and the Toda Yamamoto causality framework. According to our long-run estimation, in Bangladesh, we found that renewable energy consumption has a significant negative impact on economic progress but found no optimal relationship with unemployment. In the case of India and Pakistan, no long-run relationship was found in our analysis. For Sri Lanka, we found the optimal relationship among the variables, which supports our first arguments. It means the use of renewable energy in Sri Lanka has a significant positive impact on economic growth and reduces unemployment because we found a significant negative relationship with the dependent variable.

In the short-run relationship nexus shown, in the case of India, supports our first arguments. However, in Pakistan, it partially supports the second argument, which reflects the use of renewable energy supports economic growth in a negative manner and also found a positive coefficient of unemployment, but unfortunately, it was not significant. In Sri Lanka, unemployment is reduced with economic growth, which partially supports our first arguments, but no relationship was found with the use of renewable energy. CUSUM and CUSUMSQ confirmed the relationship's stability because the plot of the tests falls within the critical limits of the 5% boundary. In the causality approach, we found the causality relationship among the variables in Bangladesh, India and Sri Lanka. Nevertheless, no short-run causation have found in the case of Pakistan.

From the above arguments of finding, this paper emphasizes developing the policy as well as making a concrete decision regarding the development of renewable energy, lessening unemployment and ensuring sustainable economic growth for south Asian countries. Policymakers will try to develop renewable energy sources not only to minimize dependency on fossil fuels and coal but also to maintain sound economic growth, supporting the minimization of unemployment in a country. The policymakers should also focus on the following policy recommendations as well:

(1) Boost Investment in Renewable Energy (Sri Lanka Focused): The positive relationship between renewable energy development and GDP growth in Sri Lanka emphasizes the benefits of investment in renewable energy. Policymakers in Sri Lanka, and other South Asian nations observing Sri Lanka's example, that this will not only contribute to sustainable economic growth but also create new job opportunities, lessening unemployment issues.

(2) Workforce Association and Unemployment Reduction (Sri Lanka and India Focused): The negative relationship between unemployment and GDP growth in Sri Lanka and India implies that economic growth effectively reduces unemployment. Policymakers should consider policies that align the workforce with growing sectors - such as renewable energy - through skills training and education programs.

(3) Diversify Economic Growth Drivers (India and Pakistan Focused): The absence of a significant long run relationship between GDP growth, renewable energy and unemployment in India and Pakistan suggests the need for diversified strategies to stimulate economic growth. Policymakers should consider multiple sectors, including but not limited to renewable energy, as potential growth drivers.

(4) Reassess Renewable Energy Strategies (Bangladesh, India and Pakistan Focused): For Bangladesh, India and Pakistan, where renewable energy did not significantly affect GDP growth in the long-run, it may be necessary to reassess the effectiveness and implementation of existing renewable energy strategies and policies.

(5) Regional Cooperation: South Asian countries can benefit from increased regional cooperation in the sharing of technology, best practices and policies related to renewable energy. This cooperation can also lead to regional grid connectivity, which could increase the reliability and efficiency of renewable energy.

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