Contents list available at IJRED website
International Journal of Renewable Energy Development
Journal homepage: https://ijred.undip.ac.id

Research Article

Exploring the link between green energy, CO_2 emissions, exchange rate and economic growth: Perspective from emerging South Asian countries

Mohammad Rifat Rahman[a*], Md. Mufidur Rahman[a], Roksana Akter[b]

[a]*Department of Banking & Insurance, Faculty of Business Administration, University of Chittagong, Chattogram 4331, Bangladesh*
[b]*Department of Accounting, Faculty of Business Administration, University of Chittagong, Chattogram 4331, Bangladesh*

Abstract. This paper investigates the nexus between renewable energy use, CO_2 emissions, exchange rate, and economic development within emerging South Asian nations, namely Bangladesh, India, Pakistan, and Sri Lanka, employing the Autoregressive Distributed Lag (ARDL) framework. It examines annual data spanning from 1990 to 2019, examining key indicators of renewable energy consumption, CO_2 emissions, exchange rate, and economic development. The ARDL bounds test results demonstrate the existence of co-integration among the variables in the long run. The empirical result finds that the renewable energy consumption, CO_2 emissions, and exchange rate have a significant impact on economic growth in Bangladesh, Pakistan, and Sri Lanka in the long run. In India no significant relationship found in the long run. In short run assessment, Bangladesh, India, and Sri Lanka also found same relationship with economic growth and renewable energy consumption, CO_2 emissions, and exchange rate. Interestingly, In Pakistan no significant relationship has found in short run estimation analysis. Furthermore, study tried to determine the causality direction by using the Toda Yamamoto granger causality approach, which reveals bidirectional causation between exchange rate and CO_2 emission in India. In Pakistan, study also found bi-directional causality among the variables renewable energy consumption, CO_2 emissions, and economic growth. Finally, this paper emphasizes developing the policy as well as making a concrete decision regarding the renewable energy consumption, CO_2 emissions, exchange rate, and economic development for ensuring sustainable economic growth in South Asian region. Future research could extend this work by including different dimensional data, additional countries, or using alternative or supplementary modeling techniques.

Keywords: Renewable Energy, CO_2 Emissions, Exchange Rate, Economic Growth, ARDL, Co-integration, Causality, South Asia

Received: 20th March 2023; Revised: 12th July 2023; Accepted: 15th August 2023; Available online: 28th August 2023

1. Introduction

Global energy consumption is primarily fueled by economic expansion, population growth, the emergence of new industry, and climate change concerns. Energy is currently recognized as the capacity to perform activities. According to the Asemota & Olokoyo, (2022), a country without energy is completely incapacitated and lacks the essentials for its productive activities, which would cause slow growth and implausible development. Now days, without investing enough in its energy sector, no nation can achieve sustainable industrial growth and development. Thus, energy availability and economic development cannot be separated (Rahman, 2023; Oyedepo, 2012). To keep an economy alive and thriving, the industrial sector, which is thought of as the economy's "heartbeat", needs to continuously use of energy.

Nowadays, the most prevalent energy sources are fossil fuels and coal, which are seen as finite and depleted. In addition, the consumption of fossil fuels and coal contributes to land damage, water pollution, and global warming (Le & Sarkodie, 2020). According to estimates, global primary energy consumption in 2019 exceeded 14.0 billion tons of oil equivalent (Viktorovna *et al.*, 2021). For this reason, pollutant CO_2 emissions are increasing, which magnifies environmental issues. Increasing global climate change and CO2 emissions have brought international concerns to the forefront, as seen by the establishment of significant international organizations such as Paris Climate Change Conference (COP21) and the United Nations Framework Convention on Climate Change (UNFCCC). This is also acknowledged in the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (Kahia et al., 2021).

Thus, producing green and sustainable energy and reducing CO_2 emissions in an economy is the prime concern of energy policy in many nations. Thus, renewable energy is regarded as an excellent alternative approach for addressing the aforementioned challenges relating to the environment and the standard of lifestyle of a nation's citizens. According to Watts *et al.,* (2015), the transition of energy from fossil fuel and coal-based to renewable energy is a major concern in many countries and regions around the world, not due to the scarcity of fossil fuel and coal resources, but because climate change and pollution have become a global problem of great concern.

South Asian counties are progressing in all the economic indicators in the last decades. So, economic growth has a significant issue on industrialization, advancement of technology and CO_2 emissions. As a result, the development of

*Corresponding author
Email: rifat@cu.ac.bd (M.R.Rahman)

renewable energy has been an acceptable method of combating global warming and serving as a substitute for fossil fuels in order to secure economic prosperity. Modern renewable technologies (including small hydro, modern biomass, wind, solar, geothermal, and biofuel) are ideally suited for power generation in remote and rural places, particularly in the South Asian region. The majority of developing nations in South Asia have initiated the identification and implementation of initiatives and policies to improve the structure of existing rural renewable energy markets (Pao & Fu, 2013). The rise in consumption of renewable energy sources in 2019 was greater than 15%, the total installed capacity of wind turbines was greater than 560 GW, and solar stations had an installed capacity of approximately 500 GW (BP Statistical Review of World Energy, 2019). The International Energy Agency estimates that yearly investment in the rural energy sector must increase by more than five times by 2030 in order to achieve widespread use of renewable energy.

South Asian counties are mainly dependable on energy import from different destinations around the world as the status of renewable energy growth is not highly satisfactory (Watts *et al*., 2015). For importing fossil fuels and coal, it is important to pay the purchase amount in foreign currency. If the exchange rate of local currency devaluates against the foreign currency due to several domestic and global factors, the foreign currency price will appreciate and will have a negative impact on energy import, so the price of fossil fuels and coal would be increased and the domestic demand supply management of energy would be an unmanageable issue. For finding the relation in between exchange rate, renewable energy and economic growth (Deka *et al.,* 2022) established a highly significant positive relationship on the use of renewable energy, economic growth and the currency exchange rate. Moreover, Deka & Dube, (2021) also discovered that renewable energy not only reduces CO2 emissions, but also supports exchange rate appreciation.

Several researches have focused on the relationship between renewable energy consumption, CO2 emissions, exchange rate and economic development in different country's perspective. For instance, Li & Leung, (2021) paper provides empirical support for the significance of economic development and non-renewable energy pricing in Europe's renewable energy transition. In addition, Sadorsky, (2009) and da Silva *et al.*, (2018) demonstrated that economic growth had a beneficial effect on the consumption of renewable energy in developing nations. Thus, the research of the influence of renewable energy consumption, CO2 emissions, Exchange rate impact on economic growth indicators is a crucial scientific endeavor that will determine the most important paths for the development of economic growth in South Asia.

Considering these aspects, the study is developed the following dimensional research questions for the study's variables. At first, what are the long-run and short-run impacts of renewable energy consumption, CO_2 emissions, and exchange rate fluctuations on the economic growth of emerging South Asian countries, specifically Bangladesh, India, Pakistan, and Sri Lanka? Secondly, what causality patterns can be discerned among renewable energy consumption, CO_2 emissions, exchange rate, and economic growth within the context of these emerging economies? For finding the above questions optimum solution study used the auto regressive distributed lag (ARDL) approach proposed by (Pesaran et al., 2001) and (Toda & Yamamotob, 1995) causality tests, and the period of investigation is 1990–2019. So, this paper will contribute to the current knowledge on the causal relationship between the consumption of renewable energy, CO_2 emissions, exchange rate impacts and economic growth in south Asia.

2. Literature review

Throughout the past few decades, researchers have shown a great deal of interest in the search for relationships between renewable energy, CO2 emissions, non-renewable energy and economic growth with related to economic and financial issues (Apergis & Payne, 2009; Bowden & Payne, 2010; Hassine & Harrathi, 2017; T. H. Le, 2022; Sadorsky, 2009; Salam et al., 2020; Wang et al., 2022). Studies use a variety of econometric techniques, including time series regression, co-integration, and short run and long run estimations, and as a result, the researchers found a variety of outcomes (Apergis & Payne, 2009; Bulut & Muratoglu, 2018; J. Chen et al., 2022; Darvishi & Varedi, 2018; Magazzino, 2017; Omri, 2014)

To examine the causal relationship between economic growth and renewable energy consumption (Salehin & Kiss, 2022) studied on emerging and growth leading economies. Employing the ARDL method to determine the short run and long run relationship, the paper inferred that the renewable energy consumption and GDP growth has a positive and significant relationship in the long run. Accordingly, it was also found the causal relationship between renewable energy consumption and GDP growth. However, the paper revealed that Economic development and the consumption of renewable energy do not significantly correlate over the short term. Similarly, Soava et al., (2018) found the significant and positive relationship between energy consumption and GDP growth but showed an uncertain causal relationship in MENA countries. Moreover, Wu et al., (2021) showed a positive and significant relationship between economic growth and energy consumption in China. However, Hongxing et al., (2021) stated bidirectional causation between energy consumption and economic growth in East Asia and Central Asia (EACA), Middle East and North Africa (MENA), South America and Pacific (SAAP), Sub-Saharan Africa (SSA) and Europe whereas unidirectional causal relationship in Southeast and South Asia (SESA).

However, Emir & Bekun, (2019) found a significant relationship between economic growth and energy consumption in Romania. Also, the paper showed the output of causality where there is a unidirectional causality found between intensity of energy and economic development. Moreover, the generated regression of (Viktorovna *et al*., 2021) estimates demonstrates that renewable energy and economic growth has a favorable and significant relationship and a stimulating bi-directional causal effect in Europe and the Asia-Pacific area while (Issa Shahateet, 2014) concluded with a statement that economic development has little impact on changes in energy consumption in Arab countries. Furthermore, Koçak & Şarkgüneşi, (2017) has stated that there is a long term significant and positive relationship economic growth and energy consumption. It also showed the expansion of economy affect the use of energy significantly in Balkan and Black Sea Countries.

Several studies have found on CO_2 emissions, renewable energy consumption and economic growth relationship with a mixed results in different countries perspective (Bilan et al., 2019; Farhani, 2013; Kahia et al., 2021; Mahmood et al., 2019). Moreover, Liu et al., (2020) finds the relationship among real output, renewable energy consumption, and CO2 emissions on BRICS countries (except Russia) from1999–2014. According to the paper, renewable energy has a strong positive impact on real output and vice versa. Similarly, Zaman, et al., (2021) showed a positive and significant relationship between economic growth and energy consumption in OECD countries. China, on the other hand, has no link between real production and renewable energy use, nor does it have a bidirectional relationship between

Table 1
Literature Summary on Renewable Energy Development and Economic Growth Perspective:

Author(s)	Country/ Region	Method	Time Period	Results
Viktorovna *et al.*, (2021)	Europe and the Asia-Pacific area.	Panel co-integration.	1990-2017	Renewable energy and economic growth have a positive and significant relationship and bi-directional causal effect.
Salehin & Kiss, (2022)	Emerging and Growth Leading Economies	Panel ARDL and Granger Causality test.	2000-2014	The renewable energy consumption and GDP growth has a positive and significant in the long run whereas insignificant relationship in the short run. Also, showed causality between them.
Liu *et al.*, (2020)	BRICS Countries (Except Russia)	3SLS Model	1999-2014	Renewable energy had a significant positive impact on the real output. China has no relationship from real output to CO2 emissions. India has bilateral relationship between real output and CO2 emissions
Deka & Dube, (2021)	Mexico	ARDL Bounds test approach	1990-2019	In long run, renewable energy consumption makes causation with exchange rate and inflation rate. In short run renewable energy has the impact of encouraging exchange rate appreciation.
Bilan *et al.*, (2019)	European Union (EU) Counties	FMOLS, DOLS and VCEM	1995-2015	The relationship found between renewable energy consumption, CO_2 emissions, and the GDP growth. Moreover, the results reveal a correction retraction when the economic growth leads to an increase in renewable energy consumption
Koçak & Şarkgüneşi, (2017)	Balkan and Black Sea Countries.	Panel causality and panel causality.	1990-2012	Significant and positive relationship between economic growth and energy consumption.
Soava *et al.*, (2018)	MENA countries	OLS estimations and fixed effect panel model	1990-2013	Significant and positive relationship between energy consumption and GDP growth but showed an uncertain causal relationship.
Pao & Fu, (2013)	Brazil	Johansen's co-integration test and (VECM).	1980-2010	Significant and positive relationship between economic growth and renewable and non-renewable energy consumption. Also, bidirectional causality between economic growth and energy consumption.
Sulub *et al.*, (2020)	Malaysia	ARDL and VECM	1978-2017	Significant and positive relationship between economic growth and energy consumption both in the short term and long term. Also, unidirectional causality between economic growth and energy consumption.
Bouyghrissi *et al.*, (2021)	Morocco	ARDL and Granger Causality Test	1990-2014	Significant and positive relationship and causality between economic growth and energy consumption.
Cherni & Essaber Jouini, (2017)	Tunisia	ARDL and Granger Causality	1990-2015	Significant and positive relationship between economic growth and energy consumption in the long term. Also, bidirectional causality between economic growth and energy consumption.

real output and CO2 emissions. Furthermore, Chen et al., (2019) The Environmental Kuznets Curve (EKC) hypothesis was examined at the regional level in China based on a balanced provincial panel dataset over the period of 1995–2012. The research paper on economic growth (EG), renewable energy consumption (REC), and nonrenewable energy consumption (NREC) on CO2 emissions (CE) found mixed findings in different provinces of China and bidirectional causation between REC, CE, and EG in the long-term for the three areas.

For assessing the relationship between exchange rate, renewable energy, and economic growth (Deka & Dube, 2021) conducted a paper on Mexico from 1990-2019 with the ARDL bounds test approach. From their paper, it is ascertain that bidirectional causality between the exchange rate and inflation and renewable energy consumption also makes causation with the exchange rate and inflation of Mexico. In the short run, the paper reveals an increase in renewable energy use in Mexico has the impact of encouraging exchange rate appreciation. Similarly, Deka et al., (2022) conducted a paper on Brazil and found a long-run bidirectional causal association between exchange rate and renewable energy. In the short-run, the currency exchange rate also found a significant negative impact, which means a rise in the use of renewable energy in Brazil significantly causes the exchange rate to appreciate.

From Table 1 empirical studies and above discussions, this is very clear that the relationship between renewable energy consumption, CO2 emissions, exchange rate has different positive and negative impact on economic growth. So, the above variables are still showing the confusing results from region to region. However, there is no such paper, to best of the knowledge; conducted on emerging south Asian countries perspective to draw the comparative conclusion on renewable energy consumption, environmental stability and exchange rate impact assessment on economic growth.

3. Model and method

3.1 Data collection

The secondary study is influenced by annual time series data available on the website of World Bank from 1990 to 2019. From the Table 2, it is to measure the significant impact of renewable energy consumption, CO_2 emissions, and exchange rate on the economic development progress of the emerging south Asian countries. Here three independent variables were selected (CO_2 emissions, Renewable energy consumption, and Exchange rate) for exploring the nexus with economic progress (GDP growth) of the selected countries.

Table 2
Details of the Variables

Country's Name	Time Frame	Variables
Bangladesh	1990-2019	GDP Growth, CO2 Emissions, Renewable Energy consumption, Exchange rate.
India	1990-2019	GDP Growth, CO2 Emissions, Renewable Energy consumption, Exchange rate.
Pakistan	1990-2019	GDP Growth, CO2 Emissions, Renewable Energy consumption, Exchange rate.
Sri Lanka	1990-2019	GDP Growth, CO2 Emissions, Renewable Energy consumption, Exchange rate.

Source: World Bank open data

Table 3
Summary of the Operationalization of the Variables

Variable	Acronym	Operationalization
Dependent Variable		
GDP Growth	GDP	GDP growth rate examines the annual change in a nation's economic production to determine how quickly its economy is expanding.
Independent Variables		
CO2 Emissions	CO2	The percentage changes of total carbon dioxide emissions of the chosen country over the years.
Renewable Energy Consumption	REN	The percentage of consumption of renewable energy compared to the overall consumption of energy.
Exchange Rate	EXR	The exchange rate of the US dollars to the currency of the chosen country is known as the exchange rate.

3.2 Model selections

The World Bank's data bank is used to gather annual time series data on GDP, CO_2 Emissions, use of renewable energy, and exchange rate. Statistical tables and graphs will be used to analyze the data. The ARDL Co-integration method and Toda Yamamoto Granger Causality test are used to explore the linear relationships between these variables. 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. Table 3 demonstrates the acronym and operationalization of the dependent and independent variables use in this paper. Here, GDP growth is the dependent variable and CO2 emissions, Renewable energy consumption, Exchange rate are the independent variables of the study.

3.3 Description of the variables

The descriptive statistics of the variables used to run the ARDL model are shown in Table 4. After analyzing time series data for the past 30 years, study found that the mean of renewable energy consumption in Bangladesh, India, Pakistan, and Sri Lanka respectively 50.07, 44.21, 49.29, and 62.56 percentage from the time period of 1990 to 2019. The average exchange rate values are 60.72, 45.75, 66.97, and 96.92. GDP growth in this South Asian emerging country from the last 30 years are respectively 5.62, 6.22, 4.18, and 5.20. The Jarque–Bera (JB) statistics, on the other hand, is used to determine the normality of the collected data. Table 4 shows that all of the variables are distributed normally, because the p value (0.05) exceeds the 5% level of significance.

Table 4
Descriptive Statistics

	Bangladesh				India			
	B_GDP	B_CO2	B_REN	B_EXR	I_GDP	I_CO2	I_REN	I_EXR
Mean	5.626	10.36	50.07	60.72	6.225	13.99	44.21	45.75
Maximum	7.885	11.41	73.15	84.52	8.845	14.71	58.65	70.42
Minimum	3.488	9.29	24.75	34.81	1.056	13.24	32.41	17.50
Std. Dev.	1.101	0.66	14.68	16.33	1.922	0.47	9.123	13.59
Jarque-Bera	0.653	1.64	1.643	2.551	2.851	2.219	2.683	0.304
Probability	0.721	0.43	0.439	0.278	0.240	0.329	0.261	0.858
Observations	30	30	30	30	30	30	30	30

	Pakistan				Sri Lanka			
	P_GDP	P_CO2	P_REN	P_EXR	S_GDP	S_CO2	S_REN	S_EXR
Mean	4.181	11.65	49.29	66.97	5.205	9.322	62.56	96.92
Maximum	7.705	12.20	58.09	150.0	8.664	10.07	78.08	178.7
Minimum	1.014	10.98	42.09	21.70	-1.545	8.253	49.33	40.06
Std. Dev.	1.717	0.34	4.219	32.59	2.245	0.512	7.586	38.70
Jarque-Bera	0.466	1.442	1.023	1.671	5.67	1.717	0.427	1.094
Probability	0.792	0.488	0.599	0.433	0.701	0.423	0.807	0.578
Observations	30	30	30	30	30	30	30	30

4. Analysis and interpretation

4.1. Model specification

Here the study used the Cobb-Douglas production function to examine how renewable energy, CO_2 emissions, Exchange rate and economic growth are related. Here, Income (output) is determined by labor, capital, and technological advancement. Apart from these considerations, energy has been identified as a potential source of economic growth (Bilan *et al.,* 2019). As a result, the Cobb-Douglas production function is developed in the equation 1.

$$Q = AL^{\alpha} \times K^{\beta} \ldots\ldots \quad (1)$$

In this case, Q stands for total production, or the monetary worth of all the commodities produced in a year. L—labor input, or the total number of hours per person worked year; K—capital input (the monetary value of all buildings, machinery, and equipment); A—productivity across all factors; the output elasticity of labor and capital is given by; α, β respectively. In the context of the above Cobb-Douglas production function, we intend to establish the effect of renewable energy, CO_2 emissions, and exchange rate indicators on economic growth in emerging South Asian nations (Bangladesh, India, Pakistan, and Sri Lanka) by integrating the variables listed in Table 2. As a result, the liner functional model is developed on equation 2.

$$GDP_t = \delta_0 + \delta_1 CO2_t + \delta_2 REN_t + \delta_3 EXR_t + \varepsilon_t \ldots\ldots (2)$$

4.2 Unit root test

Using the augmented Dickey-Fuller (ADF) and Phillips Perron (PP) stationarity tests, the stationarity of the time series data was analyzed in this work. It is important to identify the order of integration in order to use the ARDL technique, which can be applied whether the variables are I (0) or I. (1). However, if I (2) variables are present, the approach cannot predict the ideal

Table 5
Results of ADF Test and PP Test

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_CO2	0.9542	0.9801	B_CO2	0.0101***	0.0090***
B_REN	0.9684	0.9999	B_REN	0.1181	0.0782*
B_EXR	0.8344	0.7161	B_EXR	0.5176	0.5880
I_GDP	0.0018**	0.0025**	I_GDP	0.006**	0.0074**
I_ CO2	0.8727	0.8776	I_ CO2	0.8513	0.7364
I_REN	0.6697	0.6697	I_REN	0.9342	0.9089
I_EXR	0.7097	0.7061	I_EXR	0.6324	0.5074
P_GDP	0.0088**	0.0088**	P_GDP	0.0423**	0.0422**
P_ CO2	0.4833	0.4833	P_ CO2	0.4258	0.4257
P_REN	0.5606	0.5621	P_REN	0.3644	0.3471
P_EXR	0.9993	0.9995	P_EXR	0.9371	0.9821
S_GDP	0.0117**	0.0117**	S_GDP	0.0569*	0.0569**
S_ CO2	0.4417	0.0412**	S_CO2	0.2932	0.3419
S_REN	0.6321	0.6315	S_REN	0.5221	0.5502
S_EXR	0.9992	0.9991	S_EXR	0.9481	0.8903
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_CO2	0.0034***	0.0000***	ΔB_CO2	0.0098***	0.0010***
ΔB_REN	0.0014***	0.0000***	ΔB_REN	0.0083***	0.0000***
ΔB_EXR	0.0008***	0.0000***	ΔB_EXR	0.0049***	0.0000***
ΔI_GDP	0.0002***	0.0000***	ΔI_GDP	0.0009***	0.0000***
ΔI_ CO2	0.0000***	0.0030***	ΔI_ CO2	0.0040***	0.0000***
ΔI_REN	0.0003***	0.0003***	ΔI_REN	0.0015***	0.0015***
ΔI_EXR	0.0010***	0.0010***	ΔI_EXR	0.0067***	0.0067**
ΔP_GDP	0.0000***	0.000***	ΔP_GDP	0.0000***	0.000***
ΔP_ CO2	0.0000***	0.003***	ΔP_ CO2	0.0000***	0.0010***
ΔP_REN	0.0004***	0.0004***	ΔP_REN	0.0016***	0.0016**
ΔP_EXR	0.0031**	0.0570**	ΔP_EXR	0.0072**	0.0827*
ΔS_GDP	0.0000***	0.0000***	ΔS_GDP	0.0000***	0.0000***
ΔS_CO2	0.0000***	0.0001***	ΔS_CO2	0.0003***	0.0000***
ΔS_REN	0.0000***	0.0000***	ΔS_REN	0.0002***	0.0002***
ΔS_EXR	0.0018***	0.0015***	ΔS_EXR	0.0040***	0.0034**

Notes: * significant at 10% level; **significant at 5% level; *** significant at 1% level.

outcomes (Rahman *et al.*, 2023; Abedin *et al.*, 2020; Oteng-Abayie & Frimpong, 2006).

From the Table 5, the study performs Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests on unit roots, and both tests indicate stationarity at least at the 5% level of significance. According to these findings, all-time series are presumed to be stationary after one differentiation. Table 5 demonstrates that the unit root test cannot be rejected for any variable. Hence, they are integrated with I (0) and I (1) in level form and all the variables are stationary in the first difference. None is significant, however, at I (2). On the basis of above findings, now the study can proceed with the (ARDL) approach developed by (Pesaran et al., 2001; Pesaran & Shin, 1997) to determine the long run and short run relationship dynamics, since there is no level of relationship between the variables at I (2), and study can also utilize the Granger Causality test by utilizing the VAR framework, which deals with the short-term relationship, (Jbir & Zouari-Ghorbel, 2009).

4.3 The ARDL bounds testing approach for co-integration

Bounds testing approach for co-integration followed by ARDL method, examines the impact of co-integration between renewable energy, environmental quality and economic growth determinants. The ARDL Bounds test approach (Pesaran et al., 2001) is distinguished from other types of co-integration methods such as (Engle & Granger, 1987; Johansen, 1992; Gregory & 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 3 is developed to assess among the variables have co-integration or not.

$$\Delta GDP = \delta_0 + \sum_{i=1}^{p1} \delta_{1i}\,\Delta GDP_{t-i} + \sum_{i=0}^{p2} \delta_{2i}\,\Delta CO2_{\,t-i} + \sum_{i=0}^{p3} \delta_{3i}\,\Delta REN_{\,t-i} + \sum_{i=0}^{p4} \delta_{4i}\,\Delta EXR_{t-i} + \delta_5\,\Delta GDP_{T-1} + \delta_6\,\Delta CO2_{T-1} + \delta_7\,\Delta REN_{\,T-1} + \delta_8\,\Delta EXR_{T-1} + \mu_{1t} \quad \text{.......} \quad (3)$$

To calculate the optimum lag length, we used the lags length selection process of AIC method. The AIC is adopted because it considers both statistical goodness of fit and the various parameters used in estimation to achieve a particular degree of fit. Hence, the study's hypothesis of decision rule is drawn based on the F statistics results.

H_0: $\delta 5 = \delta 6 = \delta 7 = \delta 8 = 0$ No Level Relationship

H_1: $\delta 5 \neq \delta 6 \neq \delta 7 \neq \delta 8 \neq 0$ Level Relationship

Hence, the F statistic value in Table 6 indicates that the variables in the developed ARDL model have strong co-integration. Since it passes the critical bound of I (1) at the 10%, 5%, and 1% significance levels of significance that reflects the strong co-integration and a long-term relationship among the variables. Yet, the null hypothesis of F statistics is rejected, and it can be concluded that variables are highly co-integrated and have a long-term relationship. In conclusion, the results of the

Table 6
Bound Test Approach Results

Model Specification	Bangladesh		India		Pakistan		Sri Lanka	
F-Statistics	**5.085*** **		**3.952*** **		**6.788*** **		**5.688*** **	
Functional Format	B_GDP = (B_GDP /CO2, REN, EXR)		I_GDP = (I_GDP /CO2, REN, EXR)		P_GDP = (P_GDP /CO2, REN, EXR)		S_GDP = (S_GDP /CO2, REN, EXR)	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
10%	2.37	3.2	2.37	3.2	2.37	3.2	2.37	3.2
5%	2.79	3.67	2.79	3.67	2.79	3.67	2.79	3.67
1%	3.65	4.66	3.65	4.66	3.65	4.66	3.65	4.66
Critical Values	K	3	K	3	K	3	K	3

Notes: *** significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 7
Long Run Estimation Results (Dependent Variable GDP)

	Bangladesh		India		Pakistan		Sri Lanka	
Lag	**(2,0,2,0)**		**(1,1,1,2)**		**(1,2,2,2)**		**(1,0,2,1)**	
Functional Format	(B_GDP / CO2, REN, EXR)		(I_GDP / CO2, REN, EXR)		(P_GDP / CO2, REN, EXR)		(S_GDP / CO2, REN, EXR)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
CO2	-11.606	0.01***	-6.203	0.56	-41.52	0.06*	12.69	0.02**
REN	-0.4065	0.00***	-0.220	0.62	-0.431	0.08*	0.687	0.02**
EXR	0.1614	0.01***	0.071	0.54	0.193	0.03**	-0.027	0.51
C	136.49	0.00***	98.33	0.55	590.8	0.06*	-153.0	0.02**

Notes: *** significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 8
Results of Short Run Estimations: (Dependent Variable GDP)

	Bangladesh		India		Pakistan		Sri Lanka	
Lag	**(2,0,2,0)**		**(1,1,1,2)**		**(1,2,2,2)**		**(1,0,2,1)**	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficients	P-value
ΔCO2	12.040	0.00***	29.48	0.00***	4.967	0.67	11.07	0.02**
ΔREN	-0.601	0.00***	0.695	0.04**	-0.287	0.59	0.545	0.00***
ΔEXR	0.167	0.01***	-0.090	0.41	-0.003	0.93	-0.223	0.00***
ECM (-1)	-0.937	0.00***	-0.778	0.00***	-0.907	0.00***	-0.872	0.00***
R2	0.631		0.679		0.746		0.679	
Adj R2	0.582		0.623		0.674		0.639	

Notes: *** significant at 1% level; **significant at 5% level; *significant at 10% level.

bounds testing method indicate that the variables are moving in the same direction toward a long-term equilibrium.

4.4 Estimation of long-run equation

Using the bounds test method, we revealed the presence of long-run relationship dynamics of co-integration with the variables. In equation 4, which is expected to assess the long-run connection amongst the variables, is constructed to find the coefficients value of long-run estimating model followed by the ARDL technique. The lag length for the variables is selected by AIC method to find the long-run dynamics of the relationship.

$$GDP_t = \emptyset_0 + \sum_{J=1}^{P1} \emptyset_{1J}\, GDP_{T-J} + \sum_{J=0}^{p2} \emptyset_{2J}\, CO2_{T-J} + \sum_{J=0}^{P3} \emptyset_{3J}\, REN_{T-J} + \sum_{J=0}^{P4} \emptyset_{4J}\, EXR_{T-J} + \varepsilon_t \ldots\ldots..(4)$$

While estimating the links among the variables GDP growth, CO_2 Emissions, Renewable energy consumption, and Exchange rate simultaneously, Table 7 reveals that throughout the long run, CO2 has a significant negative impact on GDP growth in the case of Bangladesh and Pakistan. In Sri Lanka, we also found the opposite scenario means a significant positive relationship among the variables. However, India, the largest economy in south Asia, has found no significant long-run relationship nexus between CO_2 and GDP growth.

From the aspect of renewable energy consumption in Bangladesh and Pakistan, it showed that GDP growth had a statistically negative significant relationship with renewable energy consumption at the 1% and 10% significance level, respectively. The coefficient value of 0.40 and 0.43 indicated that 1% increase in economic growth, and renewable energy consumption decreased by 40% and 43%, respectively, in Bangladesh and Pakistan. In Sri Lanka, renewable energy consumption has significant positive long-run relationship with their economic growth.

South Asian countries are mainly dependent on energy import, so the exchange rate has a significant concern over the pricing and import scenario of energy. From the above long-run relationship nexus, we found a significant positive impact on economic growth GDP with exchange rate functions. However, the coefficient value of Bangladesh and Pakistan, respectively 0.16 and 0.19, indicate that 1% change in GDP growth increased the price of the exchange rate by 16% and 19%, which is significant at the level of 5%.

4.5 Estimation of short-run equation

After confirming the relationship of long-run, the Error Correction Model (ECM) is also applied for estimating the short-run relationship among the variables. Negative and significant ECM is required, with a coefficient value limiting zero to one. After a short-run shock that confirms the model's stability, the ECM value reflects the speed with which the model adjusts to long-run equilibrium. Formulae for measuring the short-run dynamics followed by the ARDL approach is expected to find from the equation 5.

$$\Delta GDP_t = \varphi_0 + \sum_{j=1}^{P1} \varphi_{1J}\, \Delta GDP_{T-J} + \sum_{j=0}^{p2} \varphi_{2J}\, \Delta CO2_{T-J} + \sum_{j=0}^{P3} \varphi_{3J}\, \Delta REN_{T-J} + \sum_{j=0}^{P4} \varphi_{4J}\, \Delta EXR_{T-J} + \lambda ECM_{T-1} + \mu_t \ldots\ldots\ldots(5)$$

The appropriate lag length to run the short run equation is selected by (AIC) criterion under the automatically adjustments of lags. The result of short run estimation is shown in Table 8.

Table 9
Diagnostic Tests

	Bangladesh		India		Pakistan		Sri Lanka	
	Chi 2 Value	P-value	Chi2 Value	P-value	Chi2 Value	P-value	Chi2 Value	P-value
BG-LM	0.80	0.67	3.84	0.14	2.05	0.35	2.69	0.26
ARCH	1.47	0.22	3.37	0.18	2.37	0.30	1.75	0.41
JB Stat.	0.64	0.72	0.89	0.64	0.42	0.80	1.56	0.45
RESET	4.58	0.11	0.06	0.93	2.13	0.15	0.19	0.82

Notes: *** significant at 1% level; **significant at 5% level; *significant at 10% level.

The short-run estimations from Table 8 indicate that the value of the ECM (-1) coefficient was found to be significant and negative, as we expected earlier. This estimation result indicates that a shock in renewable energy consumption growth will be adjusted by 0.93, 0.77, 0.90, and 0.87, respectively for Bangladesh, India, Pakistan, and Sri Lanka in the following year. The Error Correction Model (ECM) also advocates that economic growth will be readjusted to the long-run equilibrium after each short-run shock of the independent variables.

From the short-run relationship nexus analysis, CO_2 emissions have a significant positive relationship in Bangladesh, India, and Sri Lanka. In the case of Pakistan, study found in the long run, there was a significant negative relationship between CO2 emissions and economic growth, but here the study found no short-term relationship between the variables. The outcome indicates that the level of CO2 emissions increases the various industries' production and output, so economic growth significantly impacts the variable.

In the short run, renewable energy consumption has a significant negative impact on economic growth in the case of Bangladesh. Still, in the aspect of India and Sri Lanka, it shows a positive short-run shock on economic growth. The coefficient value of 0.69 and 0.54 indicated that 1% increase in economic growth led to renewable energy consumption increase of 69% and 54%, respectively in India and Sri Lanka.

From the above South Asian countries, the exchange rate is a significant concern to enhance economic volatility, rising foreign reserves, export-import mechanisms, and developing new economic policies and economic stability. However, Bangladesh and Sri Lanka have a significant relationship with exchange rate development and economic growth. The value of the coefficient, respectively 0.16 and -0.22 in Bangladesh and Sri Lanka, specified the short-run shock at economic development by 16%, and -22% will be readjusted to the long-run equilibrium after the each short-run shock.

4.6 Diagnostic tests

Before drawing any decisive conclusion on the constructed models shown in the previous equations, adjusting all the uncertainties in outputs raised from different sources is necessary. Diagnostic tests shown in Table 9 considerably make sense that the building block of the constructed equation is corrected by the maximum possible diagnostic and prognostic approaches (Saltelli, 2002; Daoud, 2018). The results of four diagnostic tests, including Lagrange Multiplier serial correlation, Auto-Regressive Conditional Heteroskedasticity (ARCH), Jarque-Bera (JB) normality and Ramsey's Misspecification (RESET) show that our analysis have passed all the diagnostic tests because null hypothesis has been rejected, which shows the ARDL model results consistency and efficiency.

4.7 Test of stability

Moreover, macroeconomic series may likely be subject to one or more structural breaks as a result of the structural changes in the economies of the growing nations of south Asia. For this reason, Brown et al., (2011) cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests are used to examine the stability of the short-run and long-run coefficients.

A well-specified and well-executed ARDL model must test for the presence of parameter stability (Pesaran & Shin, 1997). Since, there is no chance of knowing when a structural break will occur or not by evaluating the regression equation to see whether it is stable or not for time series data. As a result, we used the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) methods to calculate recursive residuals from the ARDL model. From the figure 01, study found the plots of CUSUM and CUSUMSQ are within the 5% critical bounds which was proposed by (Brown et al., 2011) and indicating the model under study in the long-run is stable. These findings are in line with the ARDL model's expected outcome and also dynamically stable.

4.8 Granger Causality Test

The study also perform the analysis to find out the probable causative relation among the variables chosen for the investigation by using Granger causality test, as proposed by (Toda & Yamamoto, 1995; Dolado & Lütkepohl, 1996). The Granger causality testing is used to assess 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.

The following analysis of causality is based on the covariance matrix (Table 10). The ARDL method was used to uncover the long-term and short-term dynamics of the

Table 10
Granger Causality Test (Toda-Yamamoto)

	B_GDP	B_CO2	B_REN	B_EXR		I_GDP	I_CO2	I_REN	I_EXR
B_GDP	----	0.08 (0.95)	1.04 (0.59)	4.19 (0.12)	I_GDP	----	2.96 (0.22)	4.52 (0.10)*	8.76 (0.01)***
B_CO2	0.24 (0.88)	----	1.94 (0.37)	13.93 (0.00)***	I_CO2	1.59 (0.44)	----	0.83 (0.65)	12.02 (0.00)***
B_REN	0.15 (0.92)	2.09 (0.35)	----	11.54 (0.00)***	I_REN	1.64 (0.43)	2.15 (0.34)	----	9.08 (0.01)***
B_EXR	0.19 (0.90)	0.01 (0.99)	1.17 (0.55)	----	I_EXR	1.22 (0.57)	5.37 (0.06)*	0.32 (0.84)	----

Notes: *** significant at 1% level; **significant at 5% level; *significant at 10% level.

	P_GDP	P_CO2	P_REN	P_EXR		S_GDP	S_CO2	S_REN	S_EXR
P_GDP	----	7.58 (0.02)**	4.65 (0.09)*	1.01 (0.60)	S_GDP	----	0.62 (0.73)	1.70 (0.42)	2.79 (0.24)
P_CO2	6.41 (0.04)**	----	3.14 (0.20)	7.48 (0.02)**	S_CO2	4.85 (0.08)*	----	2.73 (0.25)	3.71 (0.15)
P_REN	9.29 (0.00)***	2.19 (0.33)	----	8.90 (0.01)**	S_REN	8.88 (0.01)**	1.77 (0.41)	----	7.04 (0.02)**
P_EXR	19.93 (0.00)***	2.08 (0.35)	3.77 (0.15)	----	S_EXR	0.91 (0.63)	3.38 (0.18)	3.25 (0.19)	----

Notes: *** significant at 1% level; **significant at 5% level; *significant at 10% level.

variables. To further verify our results, we use the Granger causality test developed by (Toda & Yamamoto, 1995) and (Dolado & Lütkepohl, 1996) to investigate the effects and directions of causation between the variables. Using this method, we want to determine if the link between the variables is unidirectional, bidirectional, or without causation.

In the case of Bangladesh, A short-run unidirectional causal correlation between (B_EXR→B_CO2) and (B_EXR→B_REN) is found significant. The granger causality approach findings are

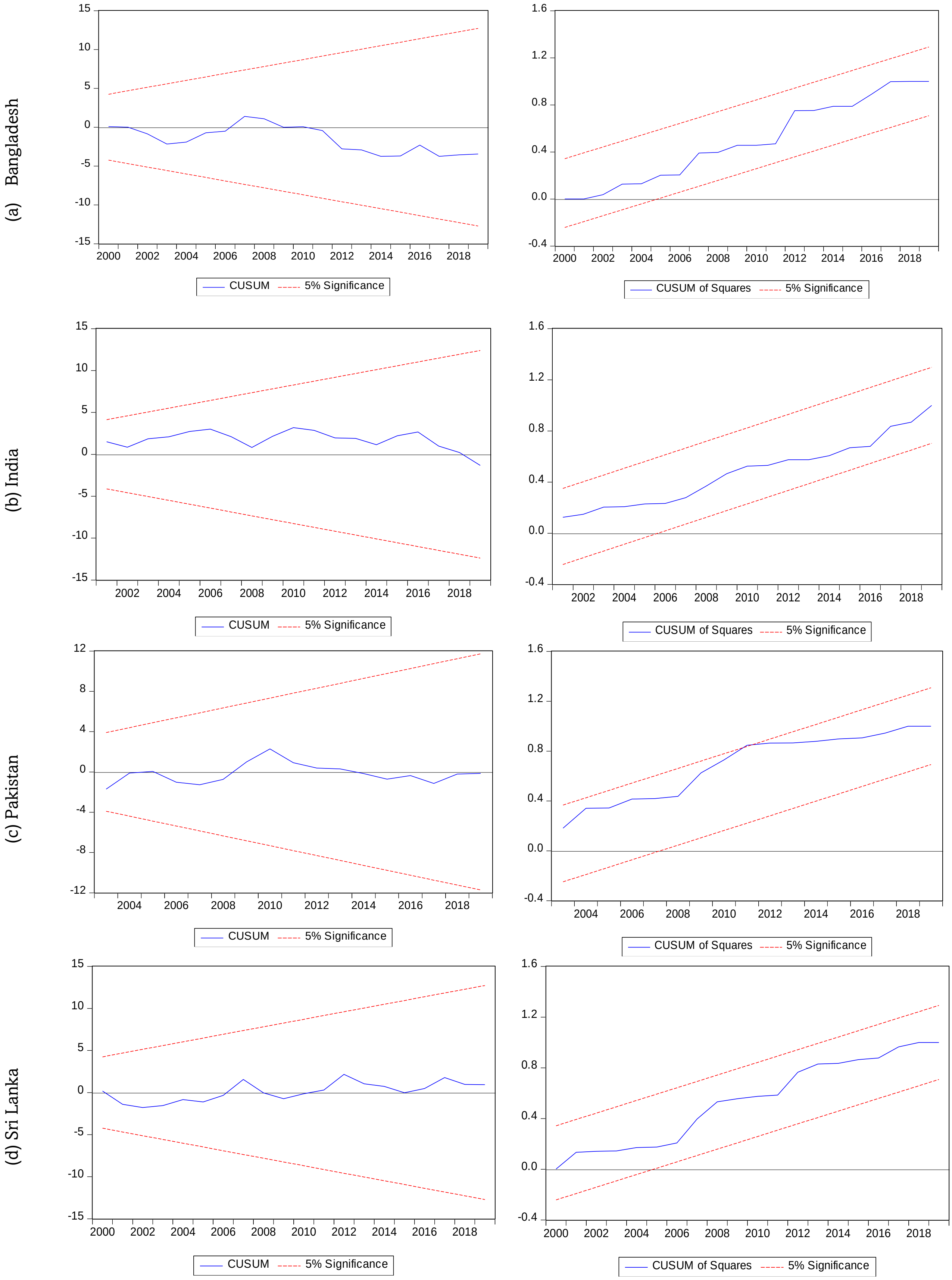

Fig 1. Test of stability of the ARDL model

similar to ARDL's short-run estimation results. In the case of Bangladesh, the unidirectional causality has a significant impact on the exchange rate and CO2 emissions, and renewable energy consumption. One of the most emerging countries is south Asia; in India, we found short-run bidirectional causality between (I_EXR→I_CO2). The unidirectional causality among the variables (I_REN→I_GDP), (I_EXR→I_REN), and (I_EXR→I_GDP) have found a significant relationship in our paper. We found the economic growth GDP has unidirectional causation between exchange rate and renewable energy consumption in the short run.

On the other hand, Pakistan's renewable energy consumption has found bidirectional causality with the economic growth variable (P_REN→P_GDP), and carbon emissions and GDP growth also have a short-run bidirectional relationship (P_CO2→P_GDP). In the case of Pakistan, the unidirectional relationship (P_EXR→P_REN), (P_EXR→P_CO2), and (P_GDP→P_EXR) have been found in our paper. However, the short-run causation between (S_GDP→S_REN), (S_GDP→S_CO2), and (S_EXR→S_REN) in Sri Lanka found a significant unidirectional relationship. In Sri Lanka, the result shows that renewable energy consumption and CO2 emissions have a significant short-run relationship with the economic growth of Sri Lanka.

4.9 Discussion of analysis:

The fundamental purpose of this paper was to analyze the interconnections among economic growth, CO2 emissions, renewable energy consumption, and exchange rate to show the independent variables' potential in narrowing disparity among the variables in the South Asian perspective from the time frame 1990-2019. The inspiration by this fact that there is no current research, to the best knowledge, in the case of South Asia that has examined the factors interconnections used to simulate models and methods in this field. Therefore, this paper critically examines the facts and interconnections among CO2 emissions, renewable energy consumption, and exchange rate impacts on economic growth.

In order to achieve the Sustainable Development Goals by 2030, the consumption of renewable energy has to be increased as well as we have to decrease CO2 emissions for better. In the study findings, in the long run, CO2 emissions have a significant impact on Bangladesh, Pakistan, and Sri Lanka. These countries are emerging developing countries in the South Asia region. Over the last decades, the above countries' GDP growth was significantly high, so the CO2 emissions are high, which is also found in the long-run and short-run relationship assessment. In India, the long-run relationship between CO2 has no significant influence on economic development progress. But in the Short run, it is found significant relationship. According to the granger causality approach, the relationship between CO2 emissions and GDP growth has bidirectional causality in India and with the exchange rate in Pakistan. On the other hand, in Sri Lanka, CO2 emissions have unidirectional causality with GDP growth. From the analysis, it is established that GDP growth and CO2 emissions are linked in the above south Asian emerging countries.

On the other hand, producing green and sustainable energy and reducing carbon emissions in an economy is the prime concern of energy policy in many nations. Thus, renewable energy is regarded as an excellent alternative approach for minimizing CO2 emissions and a stable environment and the standard of the lifestyle of a nation's citizens. In the long run, renewable energy consumption has a significant negative impact on the economic growth in Bangladesh and Pakistan, but in Sri Lanka has a significant positive impact on the dependent variable economic growth. Which is proved also by (Sadorsky, 2009 and da Silva et al., 2018) demonstrated their research outcome between the consumption of renewable energy on economic growth found statistically significant in developing nations. Interestingly no long-run impact has been found in the case of India. In the short run, India and Sri Lanka have significant positive relations, and Bangladesh has significant negative relations and found no relationship in Pakistan. The granger causality approach also supports the short-run impact analysis result which was found as the same relationship in the South Asian emerging countries context.

South Asian counties are mainly dependent on energy imports from different destinations worldwide as the status of renewable energy growth is not highly satisfactory (Watts et al., (2015). For importing fossil fuels and coal, paying the purchase amount in foreign currency is important. Suppose the exchange rate of local currency depreciates against the foreign currency due to several domestic and global issues. In that case, the foreign currency price in a domestic country will have risen, so the price of fossil fuels and coal would be increased, and the domestic demand-supply management of energy would be an unmanageable issue. Moreover, the finding of this paper reveals that the exchange rate has a significant positive impact in the long run in the case of Bangladesh and Pakistan. However, no relationship was found between in case of India and Sri Lanka in the long-run impact assessment. In the short-run analysis, it is also found the same relationship between Bangladesh and Sri Lankan perspectives. In Pakistan, no short-run impact has been found between economic growth and exchange rate development. The causality approach of the short-run relationship it is established that exchange rates cause renewable energy consumption and CO2 emissions in Bangladesh perspective. In the case of India and Pakistan, Exchange rate development affects renewable energy and CO2 emissions. In Sri Lanka, causation has been found between the exchange rate and renewable energy consumption in the short run.

5. Conclusion and policy implications

For developing sustainable economy, without a sophisticated and dependable energy complex sustainable economic growth is impossible in the modern world. Energy consumption, Energy production, and CO2 emissions are becoming increasingly dependent on each other as the demand for energy rises in emerging South Asian nations. The majority of nations rely on non-renewable energy sources to provide their energy. Yet, due to the depletion of fossil resources and their fluctuating prices over the past few years, it is now necessary for all nations to develop a sustainable energy industry. Compared to fossil fuels, renewable energy is the most reliable, readily available, and sufficient energy source. However, in recent years, energy-importing nations' competitiveness has declined, and their capacity to sustain economic growth has suffered (Aslantürk & Kıprızlı, 2020). Even if the price does not rise, exchange rate devaluations against foreign currency or any changes in the international relationship with the domestic country that jeopardize the supply of energy will drive up the cost of energy imports, which now causes significant currency losses for importing nations.

In this paper, from 1990 through 2019, the study examined the relationship between economic development and environmental quality, renewable energy consumption, and exchange rate impact nexus. Study discovered the variables influencing manners on economic growth by using the ARDL Bounds Test, long-run and short-run estimations, and the

Granger causality framework. According to the long-run estimation, CO2 emissions, renewable energy consumption and exchange rate have significant impacts on economic growth development in Bangladesh, Pakistan, and Sri Lanka. In India, no relationship was found among the variables. In the Short run, it is found that the same relationship with long-run estimation results except the Pakistan scenario. CUSUM and CUSUMSQ confirmed the relationship's stability from 2000 to 2019 in emerging south Asian countries (Bangladesh, India, Pakistan, and Sri Lanka). In the causality approach, study found bidirectional causality among (I_EXR→I_CO2), (P_REN→P_GDP), and (P_CO2→P_GDP), which reflects the strong causal relationship between the variables.

Finally, the study can infer from the above discussion that the impact of renewable energy consumption, environmental quality, and exchange rate on the economic development of south Asian emerging countries described in the paper will reduce reliance on imported energy, help to assure energy supply security, and assist nations in carrying out their long-term economic operations in a safer and more sustainable manner. From the viewpoint of policy implications, it can establish that CO2 emissions and consumption of renewable energy impact on economic development. However, these countries are south Asian emerging economic counties and geographically well positioned, having high potential for solar and wind production of renewable energy. It is recommended that from the policy standpoint, the policymakers should do more focus on not only the use of renewable energy but also on financing green energies and give restrictions on the high CO2 emissions sector, and make consciousness on knowledge and skills of minimizing CO2 emissions and renewable energy use attitudes. To conduct the further papers, the researchers can include the other geographical areas and evaluate a comparison between developing and developed countries as well as demonstrates the significant difference between their findings on the relationship between CO2 emissions and economic growth.

Funding: The authors received no financial support for this research, and authorship of the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abedin, M. T., Sen, K. K., Rahman, M. R., & Akter, S. (2020). Socioeconomic Factors of Stock Market Development: Role of Tertiary Education. *Journal of European Economy*, 19(Vol 19, No 2 (2020)), 224–245. https://doi.org/10.35774/jee2020.02.224

Apergis, N., & Payne, J. E. (2009). Energy consumption and economic growth in Central America: Evidence from a panel cointegration and error correction model. *Energy Economics*, 31(2), 211–216. https://doi.org/10.1016/j.eneco.2008.09.002

Asemota, F. F., & Olokoyo, F. O. (2022). Renewable Energy Financing and Sustainable Industrial Development in Nigeria. International *Journal of Energy Economics and Policy*, 12(4), 563–567. https://doi.org/10.32479/ijeep.13077

Aslantürk, O., & Kıprızlı, G. (2020). The role of renewable energy in ensuring energy security of supply and reducing energy-related import. *International Journal of Energy Economics and Policy*, 10(2), 354–359. https://doi.org/10.32479/ijeep.8414

Bilan, Y., Streimikiene, D., Vasylieva, T., Lyulyov, O., Pimonenko, T., & Pavlyk, A. (2019). Linking between renewable energy, CO2 emissions, and economic growth: Challenges for candidates and potential candidates for the EU membership. *Sustainability* (Switzerland), 11(6), 1–16. https://doi.org/10.3390/su11061528

Bouyghrissi, S., Berjaoui, A., & Khanniba, M. (2021). The nexus between renewable energy consumption and economic growth in Morocco. *Environmental Science and Pollution Research*, 28(5), 5693–5703. https://doi.org/10.1007/s11356-020-10773-5

Bowden, N., & Payne, J. E. (2010). Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the US. *Energy Sources, Part B: Economics, Planning and Policy*, 5(4), 400–408. https://doi.org/10.1080/15567240802534250

Brown, R. L., Durbin, J., & Evans, J. M. (2011). Techniques for Testing the Consitancu of the Regression Relationships over Time. *Society*, 37(2), 149–192.

Bulut, U., & Muratoglu, G. (2018). Renewable energy in Turkey: Great potential, low but increasing utilization, and an empirical analysis on renewable energy-growth nexus. *Energy Policy*, 123(May), 240–250. https://doi.org/10.1016/j.enpol.2018.08.057

Chen, J., Su, F., Jain, V., Salman, A., Tabash, M. I., Haddad, A. M., Zabalawi, E., Abdalla, A. A., & Shabbir, M. S. (2022). Does Renewable Energy Matter to Achieve Sustainable Development Goals? The Impact of Renewable Energy Strategies on Sustainable Economic Growth. *Frontiers in Energy Research*, 10(March), 1–7. https://doi.org/10.3389/fenrg.2022.829252

Chen, Y., Zhao, J., Lai, Z., Wang, Z., & Xia, H. (2019). Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO2 emissions: Evidence from a regional panel analysis. *Renewable Energy*, 140(October), 341–353. https://doi.org/10.1016/j.renene.2019.03.058

Cherni, A., & Essaber Jouini, S. (2017). An ARDL approach to the CO2 emissions, renewable energy and economic growth nexus: Tunisian evidence. *International Journal of Hydrogen Energy*, 42(48), 29056–29066. https://doi.org/10.1016/j.ijhydene.2017.08.072

Da Silva, P. P., Cerqueira, P. A., & Ogbe, W. (2018). Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL. *Energy*, 156, 45–54. https://doi.org/10.1016/j.energy.2018.05.068

Daoud, J. I. (2018). Multicollinearity and Regression Analysis. *Journal of Physics: Conference Series*, 949(1). https://doi.org/10.1088/1742-6596/949/1/012009

Darvishi, H., & Varedi, S. (2018). Assessment of the contemporaneous impacts of gross domestic product and renewable energy consumption, applying the dynamic panel data: Evidence from developed countries. *International Journal of Energy Economics and Policy*, 8(1), 159–166.

Deka, A., Cavusoglu, B., & Dube, S. (2022). Does renewable energy use enhance exchange rate appreciation and stable rate of inflation? *Environmental Science and Pollution Research*, 29(10), 14185–14194. https://doi.org/10.1007/s11356-021-16758-2

Deka, A., & Dube, S. (2021). Analyzing the causal relationship between exchange rate, renewable energy and inflation of Mexico (1990–2019) with ARDL bounds test approach. *Renewable Energy Focus*, 37(June), 78–83. https://doi.org/10.1016/j.ref.2021.04.001

Dolado, J. J., & Lütkepohl, H. (1996). Making wald tests work for cointegrated VAR systems Making Wald Tests Work for Cointegrated VAR Systems. *Econometric Reviews*, 15(4), 369–386. https://doi.org/10.1080/07474939608800362

Emir, F., & Bekun, F. V. (2019). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: New insights from Romania. *Energy and Environment*, 30(3), 427–443. https://doi.org/10.1177/0958305X18793108

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55(2), 251–276. https://doi.org/10.2307/1913236

Farhani, S. (2013). Renewable Energy Consumption, Economic Growth and. Energy. *Economics Letters*, 1(2), 24–41.

Gregory, A. W., & Hansen, B. E. (1996). Residual-based tests for cointegration in models with regime. *Journal of Economometrics*, 70(1), 99–126. https://doi.org/10.1111/j.1468-0084.1996.mp58003008.x

Hassine, M. Ben, & Harrathi, N. (2017). The causal links between economic growth, renewable energy, financial development and foreign trade in gulf cooperation council countries. *International Journal of Energy Economics and Policy*, 7(2), 76–85.

Hongxing, Y., Abban, O. J., Boadi, A. D., & Ankomah-Asare, E. T. (2021). Exploring the relationship between economic growth, energy consumption, urbanization, trade, and CO2 emissions: a PMG-

ARDL panel data analysis on regional classification along 81 BRI economies. *Environmental Science and Pollution Research*, 28(46), 66366–66388. https://doi.org/10.1007/s11356-021-15660-1

Issa Shahateet, M. (2014). Modeling economic growth and energy consumption in Arab countries: Cointegration and causality analysis. *International Journal of Energy Economics and Policy*, 4(3), 349–359.

Jbir, R., & Zouari-Ghorbel, S. (2009). Recent oil price shock and Tunisian economy. *Energy Policy,* 37(3), 1041–1051. https://doi.org/10.1016/j.enpol.2008.10.044

Johansen, S. (1992). Determination of Cointegration Rank in the Presence of A Linear Trend. *Oxford Bulletin Of Economics And Statistics,* 54(3), 383–397. https://doi.org/https://doi.org/10.1111/j.1468-0084.1992.tb00008.x

Kahia, M., Omri, A., & Jarraya, B. (2021). Green Energy, economic growth and environmental quality nexus in Saudi Arabia. *Sustainability* (Switzerland), 13(3), 1–13. https://doi.org/10.3390/su13031264

Koçak, E., & Şarkgüneşi, A. (2017). The renewable energy and economic growth nexus in black sea and Balkan Countries. *Energy Policy*, 100(June 2016), 51–57. https://doi.org/10.1016/j.enpol.2016.10.007

Le, H. P., & Sarkodie, S. A. (2020). Dynamic linkage between renewable and conventional energy use, environmental quality and economic growth: Evidence from Emerging Market and Developing Economies. *Energy Reports*, 6, 965–973. https://doi.org/10.1016/j.egyr.2020.04.020

Le, T. H. (2022). Connectedness between nonrenewable and renewable energy consumption, economic growth and CO2 emission in Vietnam: New evidence from a wavelet analysis. *Renewable Energy,* 195, 442–454. https://doi.org/10.1016/J.RENENE.2022.05.083

Li, R., & Leung, G. C. K. (2021). The relationship between energy prices, economic growth and renewable energy consumption: Evidence from Europe. *Energy Reports*, 7, 1712–1719. https://doi.org/10.1016/j.egyr.2021.03.030

Liu, J.-L., Ma, C.-Q., Ren, Y.-S., & Zhao, X.-W. (2020). Do Real Output and Renewable Energy Consumption BRICS Countries. *Energies,* 1–18.

Magazzino, C. (2017). Renewable energy consumption-economic growth nexus in Italy. *International Journal of Energy Economics and Policy,* 7(6), 119–127.

Mahmood, N., Wang, Z., & Hassan, S. T. (2019). Renewable energy, economic growth, human capital, and CO2 emission: an empirical analysis. *Environmental Science and Pollution Research*, 26(20), 20619–20630. https://doi.org/10.1007/s11356-019-05387-5

Omri, A. (2014). An international literature survey on energy-economic growth nexus: Evidence from country-specific studies. *Renewable and Sustainable Energy Reviews*, 38, 951–959. https://doi.org/10.1016/j.rser.2014.07.084

Oteng-Abayie, E. F., & Frimpong, M. J. (2006). Bounds Testing Approach to Cointegration: An Examination of Foreign Direct Investment Trade and Growth Relationships. *American Journal of Applied Sciences,* 3(11), 2079–2085.

Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: the way forward Sustainable energy Renewable energy Energy efficiency Energy conservation Review Background. *Energy, Sustainability and Society*, 2, 1–17. http://energsustainsoc.springeropen.com/articles/10.1186/2192-0567-2-15

Pesaran, M. H., & Shin, Y. (1997). An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis. Symposium at the Centennial of Ragnar Frisch, *The Norwegian Academy of Science and Letters,* 1–24. https://doi.org/10.1017/ccol0521633230.011

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal Of Applied Econometrics,* 16(3), 289–326. https://doi.org/10.1002/jae.616

Rahman, M. R. (2023). The Effect of Trade Development on Fossil Fuel Consumption in South Asian Countries. *Energy RESEARCH LETTERS*, 4(Early View). https://doi.org/10.46557/001c.84456

Rahman, M. R., Rahman, M. M., & Akter, R. (2023). Renewable energy development, unemployment and GDP growth: South Asian evidence. *Arab Gulf Journal of Scientific Research*. https://doi.org/10.1108/AGJSR-04-2023-0152

Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy Policy,* 37(10), 4021–4028. https://doi.org/10.1016/j.enpol.2009.05.003

Salam, R. A., Amber, K. P., Ratyal, N. I., Alam, M., Akram, N., Muñoz, C. Q. G., & Márquez, F. P. G. (2020). An overview on energy and development of energy integration in major south asian countries: The building sector. *Energies,* 13(21). https://doi.org/10.3390/en13215776

Salehin, M., & Kiss, J. T. (2022). Testing the Causal Relationship between Economic Growth and Renewable Energy Consumption: Evidence from a Panel of EAGLE Countries. *International Journal of Energy Economics and Policy,* 12(1), 281–288. https://doi.org/10.32479/ijeep.11851

Saltelli, A. (2002). Sensitivity analysis for importance assessment. *Risk Analysis*, 22(3), 579–590. https://doi.org/10.1111/0272-4332.00040

Soava, G., Mehedintu, A., Sterpu, M., & Raduteanu, M. (2018). Impact of renewable energy consumption on economic growth: Evidence from European Union countries. *Technological and Economic Development of Economy*, 24(3), 914–932. https://doi.org/10.3846/tede.2018.1426

Sulub, Y. A., Hamid, Z., & Nazri, M. N. M. (2020). Renewable energy supply and economic growth in malaysia: An application of bounds testing and causality analysis. International Journal of *Energy Economics and Policy,* 10(3), 255–264. https://doi.org/10.32479/ijeep.8980

Toda, H. Y., & Yamamotob, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics, 66(1–2), 225–250. https://doi.org/10.1016/0304-4076(94)01616-8

Viktorovna, F. I., Yurievich, N. V., Viktorovna, P. I., & Mikhailovna, O. L. (2021). Impact of renewable energy sources consumption on economic growth in europe and asia-pacific region. International *Journal of Energy Economics and Policy*, 11(6), 270–278. https://doi.org/10.32479/ijeep.11787

Watts, N., Adger, W. N., & Agnolucci, P. (2015). Health and climate change: Policy responses to protect public health. *Environnement, Risques et Sante*, 14(6), 466–468. https://doi.org/10.1016/S0140-6736(15)60854-6

Wang, Q., Dong, Z., Li, R., & Wang, L. (2022). Renewable energy and economic growth: New insight from country risks. *Energy*, 238, 122018. https://doi.org/10.1016/j.energy.2021.122018

Wu, J., Feng, Z., & Tang, K. (2021). The dynamics and drivers of environmental performance in Chinese cities: a decomposition analysis. *Environmental Science and Pollution Research*, 28(24), 30626–30641. https://doi.org/10.1007/s11356-021-12786-0

Zaman, S., Wang, Z. & Zaman, Q.u. (2021) Exploring the relationship between remittances received, education expenditures, energy use, income, poverty, and economic growth: fresh empirical evidence in the context of selected remittances receiving countries. *Environ Sci Pollut Res* 28, 17865–17877. https://doi.org/10.1007/s11356-020-11943-1