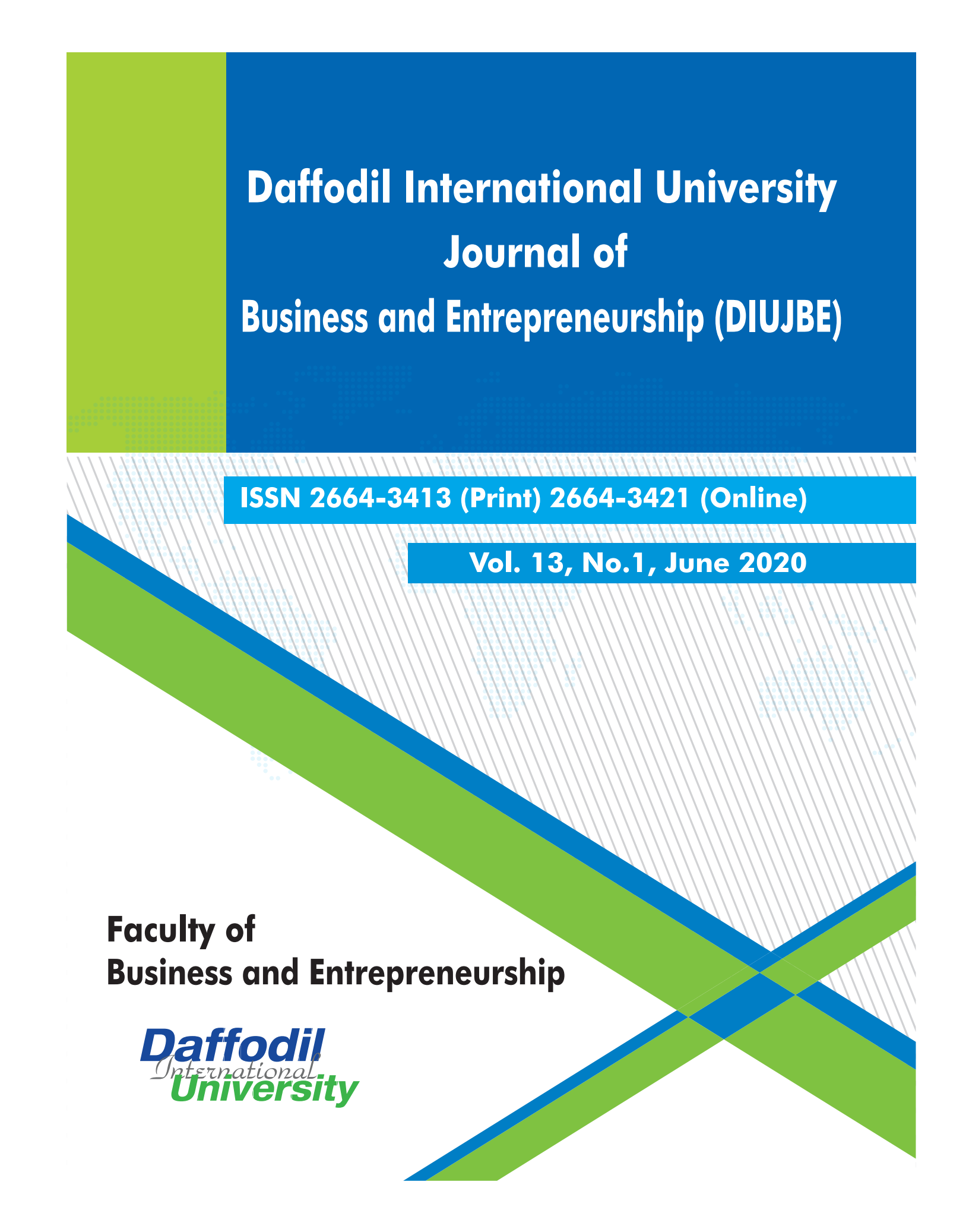




# **Daffodil International University Journal of Business and Entrepreneurship (DIUJBE)**

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# Investigating Long Run Relationship among Renewable Energy Consumption, Fossil Fuel Energy Consumption and Economic Growth in South Asia with Time Series Analysis.

Md. Aminul Karim<sup>1</sup> Tanzeem Tanisa<sup>2</sup> and K M Nazmus Sakib<sup>3</sup>

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**Abstract:** Excessive consumption of fossil fuel leading to high environmental cost and the possibility of exhaustion of these nonrenewable energies is compelling man to switch to alternative energy sources. These resources include renewable energies that are clean and sustainable. Renewable energy is such energy sources that are naturally replenished and are abundantly available. These energy sources beget from solar energy, wind, geothermal and hydropower plants, etc. Therefore, instead of growing reliance on declining underground resources (fossil fuel resources), it must invest in the development of renewable energy utilization. This paper aims to provide renewable energy consumption patterns, in the long run, incorporating economic growth and fossil fuel energy consumption. In this analysis four, South Asian counties have been taken. These are Bangladesh, India, Pakistan and Sri-Lanka. By analyzing the data from 1990 -2014 with the Johansen Cointegration Method, it is found that renewable energy consumption is negatively related to economic growth (except India), whereas fossil fuel energy consumption is increasing with economic growth in the long run for the mentioned South Asian counties. Considering the climate issues, we addressed the opportunities and challenges providing some policy recommendations to increase renewable energy consumption.

**Keywords:** renewable energy consumption, fossil fuel energy consumption, sustainable development, economic growth, South Asia

## 1. Introduction

The modern world has promised to make human life better and easier. Thousands of innovations and development is making human lives better every day. But these developments are pushing the rate of pollution higher than never before. The greenhouse emission is causing an imbalance in the atmosphere and hence harming it. To mitigate or at least reduce the greenhouse emission, the energy source of the technological devel-

opment and innovation might play an important role. Statistics show that between 1990 and 2010, electricity consumption have drastically increased and so did the global population and pollution. Thus, there is a massive threat to the climate due to excess emissions of greenhouse gas. Renewable energy can play a significant role in the case of a reduction of greenhouse emissions. The relationship between renewable energy consumption, fossil fuel consumption with GDP can be analyzed with the help of econometric models. Sustainable development goals aim to achieve efficient clean energy consumption by 2030. Despite, agreeing to the sustainable development goal achievement, nations are still falling behind in case of consumption of renewable or clean energy.

The objective of this paper is to analyze the long-run relationship between renewable energy and fossil fuel with GDP. That is the long-run consumption of renewable energy and the growth of the economy in cooperation with fossil fuel consumption. The long-run utilization of renewable energy may help to boost the economy. But in reality, the consumption of fossil fuel increases in the long run rather than renewable energy (Iftikhar et al., 2017). The analysis is done on four South Asian countries; India, Pakistan, Bangladesh, and Sri Lanka by using Johansen Methodology (1988) to estimate the long-run relationship among energy consumption, fossil fuel energy consumption, and economic growth. In addition to that, policy recommendation for increasing the long run renewable energy consumption for the growth of the economy is also mentioned. In the first section, we have introduced the variables describing its use and prospects in the context of India, Pakistan, Bangladesh, and Sri Lanka. The advantages and disadvantages of the consumption of clean energy are discussed in tabular format. We have incorporated what "Sustainable Development Goals" aims in case of clean energy consumption. In the second section, we mentioned the potential of renewable energy consumption in South Asian and the sustainable development goals implication for the mentioned South Asian countries. There is a review of the previous empirical works on related topics that we have analyzed in the third section. Followed by there are methodology and empirical results of our analysis. Later, we have added the challenges of renewable energy development in South Asian regions. Lastly, we concluded the paper with limitations and policy recommendations.

### **1.1 Renewable Energy**

Renewable energy or in other words "clean energy" is a natural source of energy that is not perishable. It replenishes constantly as these are the elements and part of the physical structure of Earth. Globally Solar energy is regarded as one of the most common and widely utilized sustainable power or clean energy source. The energy from the sun is directly used through technologies to produce heat which is in return used for illumination, electricity production, and cooling system in large industries. Sunlight is transformed into electricity through the process of Photovoltaic (PV) using solar cells. The wind is

another type of clean energy source. Wind energy can be controlled with the help of wind turbines and transformed into electricity. Small scale farms use the windmills to circulate pump water. Wind power is also used commercially to supplement the prevailing electric supply using single-wind turbines. Similarly, the kinetic energy of the river can be consumed in the form of hydropower. One of the most common forms of hydroelectric power generation is the construction of dams to store water in a reservoir which later when flows through turbines produce electricity. Other forms of renewable energy include the derivation of energy from the heat of earth called Geothermal Energy, energy of the ocean from the force of tides and waves called mechanical energy and from the sun's heat called the thermal energy, and Bioenergy which is produced from biomass, that is from organic matter like living plants and animals.

## **1.2 Fossil Fuel**

Renewable energy may be considered as a new technology but exploiting the energy and power of the earth has been long used for different purposes like heating, lighting, and transportation. Unfortunately, over the past 500 years, as there is massive technological advancement, people kept looking for affordable but dirty energy sources. This type of energy includes fossil fuels. Fossil fuel is a group of hydrocarbon containing organic substances constituted inside Earth's crust which we can utilize as a source of energy. These are different forms of carbon particles from the deadgroups of plants and creatures which lived several years ago. The major sources of fossil fuels are coal, petroleum, and natural gas. All types of fossil fuels circulate harmful gases when burned which creates obstacles in the normal ecological balance of the atmosphere. Fossil fuel releases nitrogen oxides in the atmosphere as a result of which smog and acid rain are formed. Agricultural activities produce ammonia which is another form of nitrogen. Mostly, transportation and industries emit nitrogen oxides and as the number of these is increasing rapidly the environmental pollution has been accelerated. There are fossil fuels like petroleum or crude oil which is a bit cleaner that produces fewer polluting gases but it very hard to find. Natural gas is another type of fossil fuel that is less harmful and polluting to the environment compared to both coal and crude oil. The positive side of natural gas is that it is also less expensive for which there is so much extended use of natural gas in Bangladesh.

## **1.3 Sustainable Development Goal**

The economy and society are fully dependent on energy sources. But due to extensive use of combustible energy, the environment is being harmed. For this reason, the sustainable development perspective emphasizes the proper, and efficient utilization of energy. The efficient and increased use of clean energy is the 7th Sustainable Development Goals (SDG) published by the UNDP. According to UNDP, one out of seven people has

a shortage of electricity and they mostly live in the rural areas of the developing countries. They stated that almost 60% of greenhouse gases are emitted by energy consumption and this is the major reason behind climate change. If energy is used efficiently it can help to decrease the consumption of electricity in industries and households by 14% as more than 40% of the people of the world are dependent on unhealthy and harmful energy utilization. However, until 2015 about 20% of consumption was backed by renewable energy and it has set a record to employ more than 10.3 billion people in 2017. (Source: UNDP, 2017).

UN prioritized "access to affordable, reliable, sustainable, and modern energy for all" and put stress on less carbon-intensive economic development. UN prioritized it as there is no other option other than this indicating that renewable energy sources must be prioritized the most when making policies. However, in this age of extended target of poverty mitigation, industrialization, urbanization, economic growth, health, and education it is rather very critical to proceed and achieve such target as the UN has agreed upon. The reason for this is that as we proceed towards advancement there will be new technologies invented. Technologies are operated with high combustible fuels and environment non-friendly elements. Thus, renewable energy can take the place of fossil fuel and play a role to mitigate climate change. Excessive combustion of fossil fuel is causing too much emission of greenhouse gases and pushing the temperature to higher than never before. The Sustainable Development Goals aim to convert production and utilization of energy to clean energy by upgrading technologies, expanding infrastructure, and ensuring efficient utilization of energy by 2030 (Iftikhar et al., 2017; Ictsd, 2020). The advantages and disadvantages of the consumption of renewable energy are summarized in Table 1 and Table 2.

**Table 1- Advantages of Clean Energy Consumption**

| <b>Energy Type</b> | <b>Application</b>                                                                                             | <b>Benefits of Mitigation</b>                                                 | <b>Benefits of Adaption</b>                                |
|--------------------|----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------|
| Solar Energy       | Generally consumed in household activities like cooking, heating water, and power production in single houses. | Decreased use of wood, kerosene leading to healthier air.                     | Supply of rural electricity and advancement in technology. |
| Hydro Energy       | Used in agricultural production and processing                                                                 | Decreased greenhouse gases and land protection.                               | Easier for cultivation and farming.                        |
| Wind Energy        | Used in electricity and power generation, crop processing, irrigation, and water pumping.                      | The reduction of carbon emission as dependence on wood and biogas is reduced. | The water scarcity threat can be met.                      |

|         |                                                            |                                                   |                                                                          |
|---------|------------------------------------------------------------|---------------------------------------------------|--------------------------------------------------------------------------|
| Biomass | Consumed to produce heat and electricity.                  | The decrease in charcoal and fuelwood consumption | Reduction of deforestation.                                              |
| Biogas  | Thermal energy helps in the production of slit fertilizer. | Lesser use of pesticides and fertilizers.         | Reduction of deforestation, soil erosion, and environmental degradation. |

Source: UNDP (2013)

**Table 2- Disadvantages of Clean Energy Consumption**

| Types of energy | Negative impacts                                                                |
|-----------------|---------------------------------------------------------------------------------|
| Solar Energy    | It can be a threat to the environment if not handled correctly.                 |
| Hydro Energy    | It can cause soil erosion and ecosystem disturbance.                            |
| Wind Energy     | It produces electromagnetic interference for radio signals and sound pollution. |
| Biogas/Biomass  | The fuel source is not certain and it may affect surrounding biodiversity.      |

Source: UNDP (2013)

## 2. Renewable Energy Potential in South Asian Countries

South Asia can be taken as one of the regions where the weather and the circumstances fully support the increased consumption of renewable resources. Their humid and warm weather supports the generation of power from renewable resources. South Asian countries are one of the fastest growing nations in the world. As a result of which there is a growing need for continuous electricity and power support. There is a huge lack of power and electricity in these regions. The growing need cannot be alone met with the combustion of fossil fuels. Even if it is supported by the burning of fossil fuel, the environment is not capable enough to inhale all the carbon that will be emitted as a result of burning. There are countries with warm and dry weather and country with wind and tidal potentials having the possibilities to produce solar energy and hydro energy in a high scale. Table-3 describes the amount of electricity generated from different energy sources in the South Asian countries this paper analyzed. All the energy sources are shown as a percentage of the total. This table shows that South Asian countries are very much dependent on -the consumption of fossil fuel for electricity. India is highly dependent on the combustion of coal which is one of the sole causes of greenhouse emission. Sri Lanka and Pakistan rely on oil for electricity and Bangladesh on natural gases. All these are fossil fuels that are not recyclable or reusable. Additionally, these fuels are the main contributor to greenhouse emissions.

**Table-3 Electricity Generation from Sources**

| Country    | Electricity production (kWh billion) | Coal | Natural Gas | Hydropower | Oil  | Renewable Energy | Nuclear Power |
|------------|--------------------------------------|------|-------------|------------|------|------------------|---------------|
| India      | 1052.3                               | 67.9 | 10.3        | 12.4       | 1.2  | 5                | 3.2           |
| Pakistan   | 95.3                                 | 0.1  | 29          | 29.9       | 35.4 | 0                | 5.5           |
| Sri Lanka  | 11.6                                 | 8.9  | 0           | 39.7       | 50.2 | 1.2              | 0             |
| Bangladesh | 44.1                                 | 1.8  | 91.5        | 2          | 4.8  | 0                | 0             |

*Source: Energy Centre, Maulana Azad National Institute of Technology Bhopal, Bhopal, India(2013)*

In Table-4 the potential of renewable energy in the South Asian analyzed countries. If the potentials are used properly and efficiently, the lack of power generation in these countries can be fully met leading to the achievement of the 7th Sustainable Development Goal.

**Table-4 Renewable Energy Potential**

| Country    | Solar power potential (kWh/m <sup>2</sup> /day) | Hydropower potential (MW) | Wind power potential (MW) |
|------------|-------------------------------------------------|---------------------------|---------------------------|
| India      | 5.0                                             | 150,000                   | 102,778                   |
| Pakistan   | 5.3                                             | 59,000                    | 131,800                   |
| Sri Lanka  | 5.0                                             | 2,000                     | 24,000                    |
| Bangladesh | 5.0                                             | 330                       | --                        |

*Source: Energy Centre, Maulana Azad National Institute of Technology Bhopal, Bhopal, India (2013)*

Even though South Asia has huge potential in case of clean energy consumption, still they are lagging. Despite accepting the challenge of achievement of sustainable development goals, South Asian countries are not concerned enough to take up necessary steps for the consumption of clean energy. Another reason might be that South Asia is also lagging in case of technological advancement. Keeping in mind the future potential and the environmental situation of the world, every country must take up policy measures to increase the consumption of clean energy (Eco-Business,2020)

## 2.1 Sustainable Development Goal and South Asia

The Sustainable Development Goals have been adopted by many of the growing economies of the world to reach sustainable growth and development within the year 2030. There

are in total 17 sustainable development goals in total which is a framework of the total development of an economy including poverty mitigation, gender equality, education, environment, climate, peace, and partnership. The efficient consumption of clean energy is one of the sustainable development goals. The South Asian countries, with their dynamism and strong encouragement, have adopted sustainable development goals and are focusing on it. The South Asian countries must focus on their industry structure, technological development, digitalization, security structure, and clean energy consumption. If we take Bangladesh as an example, this country is one of the front runners in case of sustainable goals. The government of Bangladesh has incorporated sustainable development goals in the national policies of the economy, prioritizing it the most. Bangladesh is taking all the necessary steps for sustainable growth as mentioned by UNDP in its agenda of sustainable development goals. The government of Bangladesh took a major step to incorporate the sustainable goals with the country's 7th five-year plan. As a result of which the sole focus is ultimately on achieving the sustainable development goals. However, all the goals have not been incorporated with national policies. There is no effort on achieving the agenda that have not been included in the policies.

Similarly, Sri Lanka has also incorporated the sustainable development goals with their national policies as we. The government of Sri Lanka has mainly focused on education, health, agriculture, climate, and gender equality. They are encouraging professional and technical training for teachers, investing in healthcare quality, encouraging to take up insurance against natural disaster for the farmers, changing infrastructure to support the climate and putting effort to increase female participation.

India took a step to meet poverty by encouraging women to take part in the labor force. There is a project in Kudumbashree, Kerela which is the largest project run by women. The change of thinking generated 5 million employments in Kerela. The government of India has focused and taken steps to reach sustainable goals. However, they excluded goal 12, goal 13, goal 14, and goal 17 from their policies. Pakistan has been facing socio-economic problem for a quite long time and now they believe that it is the appropriate time to push themselves to come out of the problems. They adopted the sustainable development goals and is trying to find and execute a way out of poverty, gender inequality, and climate change. Pakistan is also trying to execute means to ensure the consumption of sustainable clean energy. The policies undertaken by Pakistan are at the national as well as local level. However, political parties must understand the necessity of political stability and work accordingly to reach sustainable development goals for sustainable growth (Iftikhar et al., 2017; Khatun et al., 2019).

### **3. Literature Review**

The developing countries generally have a common aim to generate and provide electricity to its citizens and renewable energy can significantly contribute to reaching

this aim. There is an extended range of studies regarding the perception of people and businesses towards renewable energy. There have also been researches on the scopes and plans, in public and private sectors, regarding renewable energy in Bangladesh. Asager and Zahid (2008) explored the causal connection among GDP and various sorts of energy utilization for the five South Asian Countries; Pakistan, India, Sri Lanka, Bangladesh, and Nepal by applying Error Correction Model (ECM) and Toda and Yamamoto (1995) approach. In the case of Pakistan, it is observed that the Granger causality runs unidirectionally from coal to GDP, GDP to electricity consumption, and total energy consumption. For India, no causality is found in any direction between GDP and different energy consumption. Sri-Lanka shows unidirectional Granger causality running from GDP to electricity consumption and total energy consumption. Similarly, for Bangladesh unidirectional Granger causality is identified from the Gross Domestic Product (GDP) to electricity consumption and from gas utilization to GDP. For Nepal, there is a causal direction from petroleum to GDP.

In general, their results indicate that the increase in energy demand is mainly driven by high economic activity in this region. This implies that sustainable growth in GDP can be achieved by judicious energy conservation policies. To come up with materialistic suggestions Silva (2008) tried to gain insights about the barriers and factors which influence renewable energy development so that it can be used by other local regions in the developed nations who are looking forward to shifting towards higher use of renewable energy. The study uses qualitative research approaches, which attempt to describe the "how" and the "why" of the relationship or circumstances which stimulate Renewable Energy implementation.

Olanrewaju et al., (2019) designed a study to investigate the determinants of renewable energy consumption in Africa. The study was employed based on panel data analysis involving the most populous and biggest economy in Africa – Nigeria, Egypt, Ethiopia, Congo (Central), and South Africa, using annual data for the period 1990-2015. Their study found that oil rent, coal rent has a negative relationship with renewable energy consumption. This study also found natural gas rents and renewable energy consumption in Africa has a positive impact. They also found a negative relationship between Carbon intensity and renewable energy consumption, which means a decrease in carbon intensity increases renewable energy consumption and vice-versa for all counties.

Rahman et al., (2013) in their paper explained the prospects, trend, and utilization of renewable energy as well as its opportunity in sustainable development and reduction of climate change. They also concluded that efficient production and consumption of renewable energy can significantly bring about a change in the future power supply situation in Bangladesh. Mondal and Denich (2010) used the LEAP model to estimate the energy requirement from 2005-2035 and the MARKEL mode to analyze the long-term energy system of Bangladesh. This paper concludes with the necessity of carbon dioxide reduction and increases in renewable energy usage, emphasizing especially on solar photovoltaic.

Research conducted by Chowdhury et al., (2015), based on secondary data, on the scenario of renewable and nonrenewable resources and their effective management, concluded that if the government and private sectors both contribute in this field to meet the future increasing demand of the country. Akhmat and Zaman (2013) tried to explore the causal relationship among commercial energy consumption, nuclear energy consumption and economic growth on South Asian countries (Afghanistan, India, Bhutan, Bangladesh, Nepal, Sri-Lanka, Pakistan, Maldives) over the period 1975 to 2010. Bootstrap panel Granger causality method has been used for analyzing data. The overall results show that the nature of the causality between commercial energy consumption and economic growth; nuclear energy consumption and economic growth show neutrality hypothesis for most of these South Asian countries.

ALTINTAS et al., (2016) focused in their writings on the current status and future potentials of different renewable energy sources through different countries by considering various quantitative and qualitative factors that may affect the capabilities and significance of renewable energy systems. Some positive and negative outcomes of renewable technology from different studies are also described. Furthermore, some of those factors are used for making comparisons between different technologies and systems. This paper shows the concept of clean energy is understood to a certain degree but more knowledge is required to foster social acceptance. Hossain et al., (2016) investigated the position of solar energy consumption in Bangladesh. They inquired on the benefits and potentials of solar energy to find out if the solar business industry should standardize their strategies to establish all over the country. Their research is explanatory and descriptive that included direct field investigation through the survey as well as secondary data from websites. According to their investigation, the use of solar energy is more extensive in the rural areas of Bangladesh, especially in the household sector. NGOs and over government programs are helping to push up the usage of solar energy. Shukla et al., (2017) provided an updated and comprehensive overview of renewable energy status in South Asian countries. This paper gives a brief description of energy scenario (solar, hydro, wind, biomass, biogas), renewable energy potential, and challenges (i.e technical challenges, economic challenges, information, and human resource challenges, etc.) in South Asian countries. It also provides policies and recommendations (i.e encouraging international cooperation of renewable energy products manufacturing, organizing public R&D programs for concrete reduction of energy generation cost, etc.) regarding renewable energy consumption. Magaazzino (2017) investigated renewable energy consumption -economic growth nexus in Italy using 1970-2007 data. Using Cointegration Analysis the result from this study reveals a long-run relationship between renewable energy and GDP.

Sharif et al., (2018) investigated the current situation of renewable energy in Bangladesh and used a global perspective to mitigate the power crisis in Bangladesh. They used the descriptive method and concluded that Bangladesh has sufficient opportunities to meet

the increasing demand of power using renewable energy. If the available resources are used efficiently then it is possible to meet up the current power shortage. Tabasuum et al., (2018) tried to examine the causal relationship among economic growth consumption, energy prices, and capital formation for four South Asian countries - Bangladesh, India, Pakistan, Sri-Lanka. In this research they found, energy consumption and capital formation are some of the important functions to stimulate the economic growth in underlying countries. The paper suggested that the energy conservation policies and curtail in investment may significantly harm the growth in these four countries.

TanerGüney (2019) examined the effects of renewable and non-renewable energy on sustainable development. Using the data for 40 developed and 73 developing countries his study found renewable energy has a positive effect which is statistically significant in both developed and developing countries. the impact of renewable energy on sustainable development is greater than the impact of nonrenewable energy. Several papers are working on renewable energy and fossil fuel energy consumption and economic growth but less likely to establish their long-run relationship. Most of the paper focuses on energy consumption and economic growth to find causal relationships. Estimating their long-run behavior and relationships and providing enough insights for policy formation and addressing the SDG goal is the main theme of this paper. This paper focuses on the scenario of SDG goal 7 “Ensure access to affordable, reliable, sustainable and modern energy for all” with time series analysis to estimate the long-run relationship among economic growth and energy consumption. Addressing the barriers and opportunities for renewable energy consumption. This paper also tries to provide some policy recommendations to achieve the SDG goal and increase the consumption of clean energy.

#### **4. Methodology**

The main focus of this paper is to analyze the long-run relationship between renewable energy consumption, fossil fuel energy consumption and economic growth for selected South Asian countries (Bangladesh, India, Pakistan, and Sri-Lanka) using the data set from the year 1990 to 2014. Therefore, the maximum likelihood approach which was developed by Johansen and Juselius (1990) has been used for regression analysis. In this formation, all the numbers of different cointegration vectors between the variables in a multivariate setting are examined. Followed by, the parameters of these cointegration relationships are estimated, where the estimation is formulated based on trace statistics and maximum eigen value tests. Johansen's cointegration approach treats all variables as endogenous, which in terms of avoiding any illogical choice of the dependent variable. Besides, this mechanism gives a bound together system to testing and evaluating connections inside the structure of a Vector Error Correction model (VECM). Therefore, based on the multiple variables system used in this paper, we use the Johansen method (Johansen & Juselius, 1990) to investigate the existence of long-run relationships between the variables.

#### 4.1 Stationary Test

Stationary tests are first used for identifying the order of integration of each of the proposed variables. In the literature, the most popular approaches are the Augmented Dickey and Fuller (1979) (ADF), Phillips and Perron (1988) (PP). These two tests are applied to find the integrated order of each series. ADF tests take care of possible serial correlation in the error term by adding the lagged differences terms of the regress. The test is conducted by augmenting the lagged values of the dependent variable  $\Delta Y_t$ . Phillips and Perron (PP) use nonparametric statistical methods to take care of serial correlation in the error terms without adding the lagged differences, the asymptotic distribution of the PP test is the same as the ADF test statistic.

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^m \alpha_i \Delta Y_{t-i} + \varepsilon_t$$

where  $\varepsilon_t$  is a pure white noise (mean 0, variance 1) error term and where  $\Delta Y_{(t-1)} = (Y_{(t-1)} - Y_{(t-2)})$ ,  $[\Delta Y]_{(t-2)} = (Y_{(t-2)} - Y_{(t-3)})$ , and  $t$  is the linear time trend and  $m$  is the lag order. To test the null hypothesis for the presence of a unit root in  $Y_t$ .

Null Hypothesis  $H_0 : \delta=0$  (there is a unit root or time series is nonstationary)

Alternative Hypothesis  $H_1 : \delta<0$  (the time series is stationary)

If the variables are not stationary, then we may find spurious or nonsense regression. Yule (1974) showed that (spurious) correlation could persist in nonstationary time series even if the sample is very large.

#### 4.2 Lag order selection criteria

This study uses Akaike (AIC), Hannan and Quinn (HQIC), and Schwarz's Bayesian (SIC) information criteria to determine the optimal number of lag length,  $k$ . Following Lu'tkepohl (1993) procedure, and using formula  $m \times k_{max} \frac{1}{4} T^{-1} = 3$ , we link the maximum lag lengths ( $k_{max}$ ) and the number of endogenous variables in the system ( $m$ ) to the sample size ( $T$ ). If there are any conflicting results of the different information criterion, the selection was done based on AIC results as recommended by Pesaran and Pesaran (1997).

#### 4.3 Johansen Cointegration Test

A cointegration methodology initiating with a general approach moves to a more specific approach and is applied to estimate the long-run relationship(s) between the variables included in vector  $Z_t$ , where  $Z_t$  contains a number of integrated series at the same level when all variables are integrated of the same order. In order to estimate, the long-run relationships among the variables comprised within vector  $Z_t$  are estimated

using the Johansen Maximum Likelihood approach. Specifically, one can write  $Z_t$  as a vector autoregressive process of order  $k$  (i.e., VAR( $k$ )):

$$Z_t = A_0 + \sum_{i=1}^k A_i Z_{t-i} + u_t$$

$$\Delta Z_t = A_0 + \alpha \beta' Z_{t-1} + \sum_{i=1}^k \alpha_i \Delta Z_{t-i} + u_t$$

where the cointegrating vectors are depicted in a  $(3 \times r)$  matrix named  $\beta$  and the speed of adjustments are shown in a  $(3 \times r)$  matrix called  $\alpha$ . It exhibits  $(3 \times 3)$  matrices that leads to the short-run dynamics of the model. We do not restrict  $\beta$ .

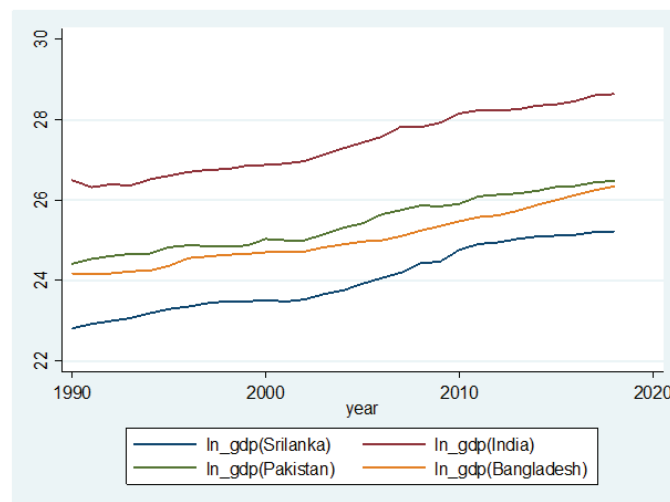
$$\Delta Z_t = A_0 + \alpha \beta' Z_{t-1} + \sum_{i=1}^p \alpha_i \Delta Z_{t-i} + u_t$$

#### 4.4 Data Source and Description

The yearly data set has been collected from the World Bank Indicator index. Data used to analyze are from the period 1990 to 2014 for four South Asian countries. The set of variables in our analysis are time series variables that include renewable energy consumption, fossil fuel energy consumption and gross domestic product (GDP). Renewable Energy Consumption and Fossil Fuel Energy Consumption is measured as the percentage of total energy consumption. GDP is measured in dollar with natural logarithmic transformation.

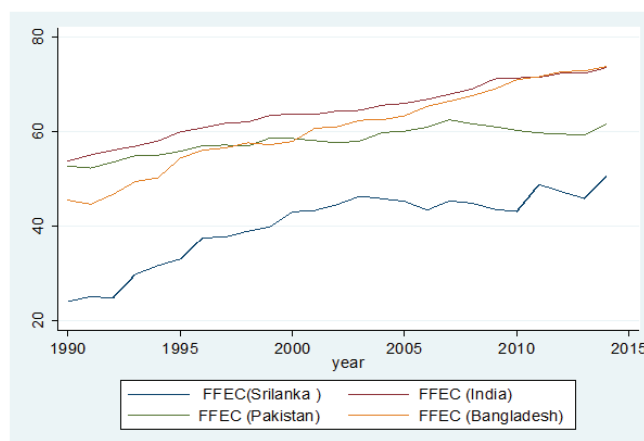
Renewable Energy Consumption = RECT; Fossil Fuel Energy Consumption = FFECT ;  
Natural Logarithmic form of GDP =  $\ln\_GDP_t$

**Figure 1: Time Series Data of GDP (measured in the natural logarithmic form)**



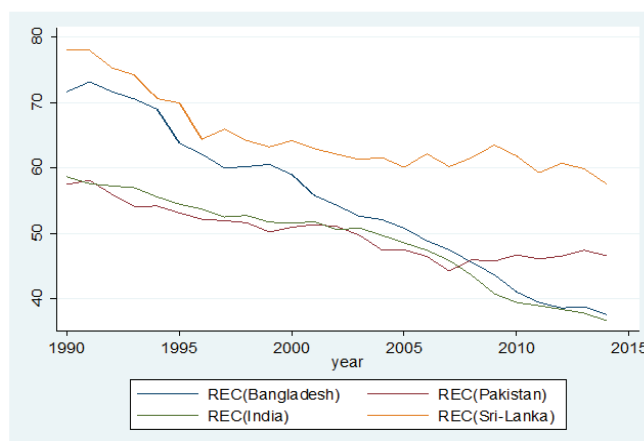
Source: World Bank Indicators

**Figure 2: Time series data of Fossil Fuel Energy Consumption(FFEC)**



Source: World Bank

**Figure 3: Time Series Data for Renewable Energy Consumption(REC)**



Source: World Bank

From our figures (1 and 2), we see that these four countries have upward trending economic growth and fossil fuel energy consumption whereas the consumption of renewable energy shows a downward trend over the period.

Table 5 shows the descriptive statistics of proposed variables (Renewable Energy Consumption, Fossil Fuel Energy Consumption, and lnGDP) for proposed countries (Bangladesh, India, Pakistan, and Sri-Lanka). Mean, standard deviation, variance, skewness, kurtosis is showed in these descriptive statistics. For simplicity, data from 1990 to 2014 have been used for mentioned countries for all the calculations. From the table, we can see Sri-Lanka has the highest mean in renewable energy consumption followed by Bangladesh, Pakistan, and India. India has a negative skewness where other countries have positive skewness regarding renewable energy consumption. As most of the countries have positive skewness values that means the distribution of data is skewed to the right.

In the case of fossil fuel energy consumption, India has the highest mean value followed by Bangladesh, Pakistan and Sri Lanka which is just the opposite of the previous case. All the countries have negative skewness values which means the data distribution is skewed to the left. India has the highest value of GDP whereas Sri Lanka has the lowest. Data distribution of all the four countries is skewed to the right.

**Table 5: Descriptive Statistics of Variables**

| Country                               | Bangladesh | India     | Pakistan  | Sri Lanka |
|---------------------------------------|------------|-----------|-----------|-----------|
| <b>Renewable Energy Consumption</b>   |            |           |           |           |
| Mean                                  | 54.74018   | 48.93188  | 50.12095  | 64.90433  |
| SD                                    | 11.47754   | 6.888345  | 3.895443  | 5.917328  |
| Variance                              | 131.734    | 47.4493   | 15.17448  | 35.01478  |
| Skewness                              | .0646367   | -.4604281 | .461408   | 1.138391  |
| Kurtosis                              | 1.826503   | 1.946696  | 2.203089  | 3.061599  |
| <b>Fossil Fuel Energy Consumption</b> |            |           |           |           |
| Mean                                  | 60.67175   | 64.46899  | 58.10929  | 40.1578   |
| SD                                    | 8.888204   | 5.812328  | 2.817582  | 7.759792  |
| Variance                              | 79.00018   | 33.78316  | 7.938766  | 60.21438  |
| Skewness                              | -.2355298  | -.1425004 | -.5332253 | -.899113  |
| Kurtosis                              | 2.037425   | 2.032019  | 2.424702  | 2.614897  |
| <b>Ln GDP</b>                         |            |           |           |           |
| Mean                                  | 24.86342   | 27.36198  | 25.2679   | 23.83049  |
| SD                                    | .5208736   | .7605226  | .5813968  | .7107639  |
| Variance                              | .2713093   | .5783946  | .3380223  | .5051853  |
| Skewness                              | .3616995   | .1898571  | .3225041  | .4830304  |
| Kurtosis                              | 2.074149   | 1.530184  | 1.670375  | 1.977042  |

## 5. Empirical Results

### 5.1 Results of Stationary Tests

The ADF and PP unit root test is performed to determine the stationarity of the variables. Here we consider,

Ho: The variable is non-stationary

H1: The variable is stationary

We observe the p-values for both the tests. The results show us that at the level form, the variables are not stationary. Therefore, we cannot reject the null of non-stationarity. On the other hand, the first difference form of the variables is stationary. The results contradict each other in level and first difference form. Table 6 shows the unit root test obtained from augmented Dickey and Fuller (1979) (ADF). The variables are defined in the first column: Renewable Energy Consumption, Fossil Fuel Energy Consumption and the

logarithmic form of GDP. All the values are indicated at a 5% level of significance. Table 7 shows the unit root test obtained from Phillips and Perron (1988) (PP). The variables are defined in the first column: Renewable Energy Consumption, Fossil Fuel Energy Consumption, and the logarithmic form of GDP. All the values are indicated at a 5% level of significance.

**Table 6: Augmented Dickey and Fuller Unit Root Test**

| Country<br>Variables           | Bangladesh |                  | India      |                  | Pakistan   |                  | Sri Lanka  |                  |
|--------------------------------|------------|------------------|------------|------------------|------------|------------------|------------|------------------|
|                                | Level Form | First Difference | Level Form | First Difference | Level Form | First Difference | Level Form | First Difference |
| Renewable Energy Consumption   | 0.9658     | 0.0001           | 0.9864     | 0.0079           | 0.2687     | 0.0000           | 0.6365     | 0.0000           |
| Fossil Fuel Energy Consumption | 0.7421     | 0.0000           | 0.6077     | 0.0000           | 0.4922     | 0.0042           | 0.2766     | 0.0000           |
| ln GDP                         | 0.9991     | 0.0097           | 0.9888     | 0.0000           | 0.9475     | 0.0001           | 0.9171     | 0.0020           |

Note: At 5% level 1st difference form is significant

**Table 7: Phillip and Perron Unit Root Tests**

| Country<br>Variables           | Bangladesh |                  | India      |                  | Pakistan   |                  | Sri Lanka  |                  |
|--------------------------------|------------|------------------|------------|------------------|------------|------------------|------------|------------------|
|                                | Level Form | First Difference | Level Form | First Difference | Level Form | First Difference | Level Form | First Difference |
| Renewable Energy Consumption   | 0.9658     | 0.0001           | 0.9864     | 0.0079           | 0.2687     | 0.0000           | 0.6365     | 0.0000           |
| Fossil Fuel Energy Consumption | 0.7421     | 0.0000           | 0.6077     | 0.0000           | 0.4922     | 0.0042           | 0.2766     | 0.0000           |
| ln GDP                         | 0.9991     | 0.0097           | 0.9888     | 0.0000           | 0.9475     | 0.0001           | 0.9171     | 0.0020           |

**Note:** At 5% level 1st difference form is significant

## 5.2 Lag Order Selection

Table 8 shows the results of lag selection criteria for each country using Akaike (AIC), Hannan and Quinn (HQIC), and Schwarz's Bayesian (SBIC) information criteria as discussed above. If the optimal lags on the basis different tests are conflicting, the optimal number of lag length,  $k$ , is selected based on AIC as suggested by Pesaran and Pesaran (1997). Lag order 4 is selected for Bangladesh and Sri-Lanka. We select lag orders 1 and 2 respectively for India and Pakistan.

**Table 8: Lag Order Selection**

| Country    | K | AIC       | HQIC      | SBIC     |
|------------|---|-----------|-----------|----------|
| Bangladesh | 0 | 6.17661   | 6.20899   | 6.32582  |
|            | 1 | 1.40496   | 1.5345    | 2.00183  |
|            | 2 | 1.49747   | 1.72416   | 2.54199  |
|            | 3 | 1.0820    | 1.40585   | 2.57418  |
|            | 4 | 0.245434* | 1.175559* | 1.69439* |

|                  |          |                 |                 |                 |
|------------------|----------|-----------------|-----------------|-----------------|
| <b>India</b>     | <b>0</b> | <b>7.36652</b>  | <b>7.39891</b>  | <b>7.51574</b>  |
|                  | <b>1</b> | <b>1.00249*</b> | <b>1.13202*</b> | <b>1.59936</b>  |
|                  | <b>2</b> | <b>1.19382</b>  | <b>1.42051</b>  | <b>2.23834</b>  |
|                  | <b>3</b> | <b>1.10552</b>  | <b>1.42936</b>  | <b>2.59769</b>  |
|                  | <b>4</b> | <b>1.02886</b>  | <b>1.44985</b>  | <b>2.96868</b>  |
| <b>Pakistan</b>  | <b>0</b> | <b>6.80942</b>  | <b>6.8418</b>   | <b>6.95864</b>  |
|                  | <b>1</b> | <b>2.50292</b>  | <b>2.63246*</b> | <b>3.09979*</b> |
|                  | <b>2</b> | <b>2.47065*</b> | <b>2.69733</b>  | <b>3.51517</b>  |
|                  | <b>3</b> | <b>2.56996</b>  | <b>2.8938</b>   | <b>4.06214</b>  |
|                  | <b>4</b> | <b>2.57405</b>  | <b>2.99504</b>  | <b>4.51388</b>  |
| <b>Sri-Lanka</b> | <b>0</b> | <b>9.99662</b>  | <b>10.029</b>   | <b>10.1458</b>  |
|                  | <b>1</b> | <b>5.291361</b> | <b>5.42085</b>  | <b>5.88818</b>  |
|                  | <b>2</b> | <b>5.62554</b>  | <b>5.85223</b>  | <b>6.67007</b>  |
|                  | <b>3</b> | <b>4.94504</b>  | <b>5.26888</b>  | <b>6.43721</b>  |
|                  | <b>4</b> | <b>2.44963*</b> | <b>2.87063*</b> | <b>4.38946*</b> |

Note: AIC, HQIC, and SBIC stand for Akaike, Hannan, and Quinn, and Schwarz's Bayesian information criteria, respectively. These results, we have used AIC results as suggested by Pesaran (1997). Here "\*" indicates significant at 5%

### 5.3 Results of Johansen Cointegration Analysis

In this part, we assume

Null hypothesis  $H_0$  = no cointegration relation

Alternative hypothesis  $H_1$  = cointegration relation exists

The results of the number of cointegrating vectors are reported in Table 9 which consists of both eigenvalue and trace statistics. At the 5 % level of significance the null hypothesis can be rejected using the result of trace statistics in the fourth column of Table 9. Table 9 summarizes that Bangladesh and Sri-Lanka both have two cointegrating relationships among these three variables, while India and Pakistan both have one cointegrating relationship among these variables.

Based on the cointegrating relationships we use a VECM model for the Johansen Cointegration test. In this case, we consider renewable energy consumption as the dependent variable and fossil fuel energy consumption and GDP as the dependent variable.

Table 10 provides a summary of the long-run relationship of our unrestricted model. For Bangladesh, we see there are two cointegrating relations. From our analysis, we can see that a 1% growth in GDP will lead to about a 16.29% fall in renewable energy consumption. Fossil fuel energy consumption is positively affected by economic growth. A 1% increase in GDP will lead to an 11.74% increase in fossil fuel energy consumption. For India, we find there exists one cointegrating relation. Our results show that renewable energy consumption is negatively related to fossil fuel energy consumption. 1% increase in fossil fuel energy consumption will lead to a 1.31% decrease in renewable energy consumption. 1% of economic growth will lead to a 1.59% fall in renewable energy consumption. In the case of economic growth, the P-value is larger than the 5% level of significance so the relationship is not significant. Pakistan also has one cointegrating relationships. 1% fossil fuel energy will lead to a 0.96% fall in renewable energy consumption. Renewable energy is also negatively impacted by economic growth. A 1% increase in GDP will lead to a 1.14% decrease in renewable energy consumption. Here P-value is very low and therefore result is significant at a 5% level of significance. In the case of Sri-Lanka, we see there exist two cointegrating relations. Renewable energy consumption is negatively related to economic growth. 1% increase in GDP leads to about 3.354% decrease in renewable energy consumption. Fossil fuel energy consumption is positively related to economic growth. 1% GDP growth leads to a 6.63% increase in renewable energy consumption.

#### 5.4 Stability Test

We have performed several tests to see whether our proposed model is stable or not. Our analysis showed the model has successfully passed the normality, autocorrelation, and stability test for the VECM model. For all these four countries the result shows models have passed the stability test. (See appendix)

Since most of the cases, we can't reject the null hypothesis, the model is normally distributed. The P-value is high to reject the null hypothesis at 5% level of significance for normality tests. Our further analysis of autocorrelation and stability reveals that there is no autocorrelation problem and the model is stable.

**Table 9: Trace Statistic**

| Country    | Maximum Rank | Eigen Value | Trace Statistic | 5% Critical Value |
|------------|--------------|-------------|-----------------|-------------------|
| Bangladesh | 0            | -           | 35.1849         | 29.68             |
|            | 1            | .58711      | 16.6088         | 15.41             |
|            | 2            | .47116      | 3.2303*         | 3.76              |
|            | 3            | .14258      |                 |                   |

|                  |          |               |                 |              |
|------------------|----------|---------------|-----------------|--------------|
| <b>India</b>     | <b>0</b> | <b>-</b>      | <b>31.6459</b>  | <b>29.68</b> |
|                  | <b>1</b> | <b>.52026</b> | <b>14.0177*</b> | <b>15.41</b> |
|                  | <b>2</b> | <b>.43443</b> | <b>0.3396</b>   | <b>3.76</b>  |
|                  | <b>3</b> | <b>.01405</b> |                 |              |
| <b>Pakistan</b>  | <b>0</b> | <b>-</b>      | <b>31.9722</b>  | <b>29.68</b> |
|                  | <b>1</b> | <b>.60126</b> | <b>10.8247*</b> | <b>15.41</b> |
|                  | <b>2</b> | <b>.28962</b> | <b>2.9598</b>   | <b>3.76</b>  |
|                  | <b>3</b> | <b>.12075</b> |                 |              |
| <b>Sri-Lanka</b> | <b>0</b> | <b>-</b>      | <b>81.9461</b>  | <b>29.68</b> |
|                  | <b>1</b> | <b>.94971</b> | <b>19.1559</b>  | <b>15.41</b> |
|                  | <b>2</b> | <b>.58980</b> | <b>.4426*</b>   | <b>3.76</b>  |
|                  | <b>3</b> | <b>.02086</b> |                 |              |

**Note:** The first column shows four country's names. Trace statistics are used to determine the rank. Using trace statistic, for Bangladesh and Sri Lanka rank is 2 and for Pakistan and India rank is 1. The critical value is determined at a 5% level to find out the significance level.

**Table 10: Long-Run Relationship**

Note: Johansen's normalization restriction is imposed. (\_Ce1 and \_Ce2 represent long-run relationships. P values are significant at 5% level.)

| Country    | Beta   | Coef.      | P-value |
|------------|--------|------------|---------|
| Bangladesh | _Ce1.  |            |         |
|            | REC    | 1          |         |
|            | FFEC   | 0(omitted) |         |
|            | Ln_GDP | 16.2903    | 0.000   |
|            | Ce2.   |            |         |
|            | REC    | 2.22       |         |
|            | FFEC   | 1          |         |
|            | Ln_GDP | -11.74149  | 0.000   |

|           |        |            |       |
|-----------|--------|------------|-------|
| India     | _Ce1   |            |       |
|           | REC    | 1          |       |
|           | FFEC   | 1.311068   | 0.000 |
|           | Ln_GDP | 1.59026    | 0.551 |
| Pakistan  | _Ce1   |            |       |
|           | REC    | 1          |       |
|           | FFEC   | 0.9688828  | 0.000 |
|           | Ln_GDP | 1.147368   | 0.024 |
| Sri-Lanka | _Ce1   |            |       |
|           | REC    | 1          |       |
|           | FFEC   | 0(omitted) |       |
|           | Ln_GDP | 3.586954   | 0.05  |
|           | _Ce2   |            |       |
|           | REC    | 1.11       |       |
|           | FFEC   | 1          |       |
|           | Ln_GDP | -6.6633829 | 0.002 |

## 6. Challenges in Renewable Energy Development in the South Asian Region

South Asia has huge potential and capability in case of encouraging clean energy consumption. Table -4 shows the potential of India, Pakistan, Bangladesh, and Sri Lanka in case of energy generations with renewable energy sources. These countries are experiencing high economic growth. But despite that, renewable energy consumption is negatively related to economic growth. These South Asian countries are more likely to use fossil fuel energy. As the mentioned countries are not developed countries, they lack an adequate amount of capital stock to fund technology for deriving as well as using clean energy. The technologies required are quite expensive. Therefore, these countries are lagging in this case. There are other challenges faced by these countries that have had created and are still creating problems in their way of clean energy consumption.

- Policy Challenges: Private sectors are not as much involved as they need to be. They are quite inconsistent in the case of promoting clean energy consumption. On the other hand, fossil fuel subsidies promote the consumption of fossil fuels. As the

environmental regulations are not strict enough, people are not aware of the hazard that is chasing us. Additionally, renewable energy consumption is not forced upon or pressurized by the government. Thus it is excluded from national policies and frameworks in many countries. Thus, there is no intention of increasing its consumption at a national level.

- **Technical Challenges:** Clean energy consumption requires modern and advanced machinery and complicated methods that need to be operated efficiently. As the mentioned countries are developing, they are still lagging in the case of having advanced technologies. The efficient use of renewable energy requires modern machines that are designed, installed, and operated efficiently. Unfortunately, the developing countries also lack skilled manpower that can operate these advanced machinery. As the machines are not locally made, these are very expensive as well.
- **Economic challenges:** Consumption of clean energy requires high technical abilities and maintaining facilities. Therefore, the initial capital costs of these machines are very high. Besides, due to insufficient government funding facilities, it is even difficult to step forward for consuming renewable energy. The local markets have limited knowledge as there are very little awareness and training programs. In addition to that, as the whole process of clean energy consumption is completely dependent on nature, it is not certain and risk free.
- **Human resource challenges:** Manpower required to operate and maintain the advanced machinery is not sufficient. Also, as there is a little awareness program, people do not have proper and sufficient information about renewable energy resources and its benefits. On the other hand, policy makers do not acquire sufficient knowledge and information about renewable resources. Thus, implementation is even harder.

## **7. Policy Responses**

- It is high time to undertake a plan and set targets for renewable resources. Analysis of the sectorial demand and supply of resources and predicting the trend and mean of input and output collection can be the first step. The output and input collection strategies must be backed up by modern technologies. South Asian countries have already adopted plans and targets to encourage efficient energy and renewable energy consumption in their energy mix.
- The market for renewable energy must acquire a significant place for which it is necessary to build up connections and set up purchase policies. Connections and

purchase policies ensure that there is a significant market for the power generated by renewable resources to meet the long-run demand for large-scale projects.

- As the whole process for power generation from renewable energy is expensive, capital accumulations is necessary. A significant means to financially support power generation is to collect funds from the grid companies that are funded through the government. This process can be promoted by encouraging the manufacture of required equipment domestically. In addition to this, the establishment of clean energy electricity systems in isolated areas and its exploration and evaluation with proper maintenance can boost up its consumption. Further technological research can set the standards higher and support the more efficient use of renewable resources.
- Education and training in developing countries are not enriched enough that people will acquire proper and sufficient information and knowledge about the consumption of renewable energy properly. As a result, they are not aware enough to go for expensive machinery to save the atmosphere. Therefore, it is necessary to take awareness steps and mainly at first (Sobhani et al., 2014)

## 8. Conclusion

The methodology that has been used shows insignificant results leading us to the conclusion that renewable energy consumption is negatively related to economic growth from the perspective of Bangladesh, Pakistan, and Sri-Lanka, and India. Fossil fuel energy consumption is positively related to economic growth in the long run. It is important to focus on SDG goals to ensure clean energy consumption and climate change. In recent years' climate change has been a burning question for the existence of the world. The atmosphere is experiencing a sharp increase in temperature day by day. The modern world is a blessing as well as a curse to the atmosphere. All kinds of pollution are harming the atmosphere and it is losing its usual ecological balance. Taking into consideration the alarming situation of the environment, it is indispensable for different nations to take up policy measures that will encourage the consumption of renewable resources. Renewable resources regenerate themselves every moment. In addition to that, it is not harmful to the environment. Thus consumption of renewable energy must be encouraging to save other resources from exhaustion and to maintain balance in the environment.

Considering the adverse situation, this paper throws light on the importance of renewable energy consumption and its potential in South Asian Countries. As these countries are aiming to reach the sustainable development goals, they must take up steps to increase the consumption of clean energy and work on it.

We could not extend our analysis for other South Asian countries for the barriers of

availability of the data. We have collected secondary data from World Bank Indicators from 1990 to 2014. There was no data after 2014 on renewable energy and fossil fuel energy consumption. Though the data of GDP is available to 2018, we had to drop some observations to omit any bias.

South Asian countries must focus on the consumption of renewable resources considering their future potential. Despite having such high potential, they are unable to take up policy measures to consume renewable energies. If they can use the potentials that remains within them, the lack of power generating in the nations can be met easily. Policy incorporating renewable energy consumption is a must for all nations to save the environment as well as human lives.

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**Appendix****Normality test**

Assumptions:

 $H_0$  = Normally distributed $H_1$  = Not normally distributed**Bangladesh**

Jarque-Bera test

| Equation                      | chi2  | df | Prob > chi2 |
|-------------------------------|-------|----|-------------|
| D_renewableenergyconsumption  | 1.083 | 2  | 0.58190     |
| D_fossilfuelenergyconsumption | 1.070 | 2  | 0.58571     |
| D_ln_gdp                      | 2.144 | 2  | 0.34227     |
| All                           | 4.297 | 6  | 0.63654     |

Skewness test

| Equation                      | Skewness | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | -.51271  | 0.920 | 1  | 0.33746     |
| D_fossilfuelenergyconsumption | -.45713  | 0.731 | 1  | 0.39243     |
| D_ln_gdp                      | .70835   | 1.756 | 1  | 0.18510     |
| All                           |          | 3.408 | 3  | 0.33294     |

Kurtosis test

| Equation                      | Kurtosis | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | 2.5686   | 0.163 | 1  | 0.68655     |
| D_fossilfuelenergyconsumption | 3.6219   | 0.338 | 1  | 0.56072     |
| D_ln_gdp                      | 3.666    | 0.388 | 1  | 0.53329     |
| All                           |          | 0.889 | 3  | 0.82798     |

Since most of the cases, we can't reject the null hypothesis, the model is normally distributed.

**India***Jarque-Bera test*

| Equation                      | chi2  | df | Prob > chi2 |
|-------------------------------|-------|----|-------------|
| D_renewableenergyconsumption  | 1.096 | 2  | 0.57799     |
| D_fossilfuelenergyconsumption | 0.780 | 2  | 0.67702     |
| D_ln_gdp                      | 0.131 | 2  | 0.93663     |
| All                           | 2.007 | 6  | 0.91902     |

*Skewness test*

| Equation                      | Skewness | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | .30225   | 0.335 | 1  | 0.56274     |
| D_fossilfuelenergyconsumption | -.38623  | 0.547 | 1  | 0.45956     |
| D_ln_gdp                      | -.04461  | 0.007 | 1  | 0.93192     |
| All                           |          | 0.889 | 3  | 0.82802     |

*Kurtosis test*

| Equation                      | Kurtosis | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | 2.0886   | 0.761 | 1  | 0.38289     |
| D_fossilfuelenergyconsumption | 2.4957   | 0.233 | 1  | 0.62920     |
| D_ln_gdp                      | 2.6328   | 0.124 | 1  | 0.72513     |
| All                           |          | 1.118 | 3  | 0.77269     |

**Pakistan***Jarque-Bera test*

| Equation                      | chi2  | df | Prob > chi2 |
|-------------------------------|-------|----|-------------|
| D_renewableenergyconsumption  | 0.632 | 2  | 0.72889     |
| D_fossilfuelenergyconsumption | 2.951 | 2  | 0.22868     |
| D_ln_gdp                      | 1.144 | 2  | 0.56442     |
| All                           | 4.727 | 6  | 0.57925     |

## Skewness test

| Equation                      | Skewness | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | .20912   | 0.168 | 1  | 0.68222     |
| D_fossilfuelenergyconsumption | .46529   | 0.830 | 1  | 0.36231     |
| D_ln_gdp                      | .19155   | 0.141 | 1  | 0.70763     |
| All                           |          | 1.138 | 3  | 0.76787     |

## Kurtosis test

| Equation                      | Kurtosis | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | 2.3036   | 0.465 | 1  | 0.49538     |
| D_fossilfuelenergyconsumption | 4.4877   | 2.121 | 1  | 0.14530     |
| D_ln_gdp                      | 1.9768   | 1.003 | 1  | 0.31653     |
| All                           |          | 3.589 | 3  | 0.30940     |

Since most of the cases, we can't reject the null hypothesis, the model is normally distributed.

***Sri-Lanka***

## Jarque-Bera test

| Equation                      | chi2  | df | Prob > chi2 |
|-------------------------------|-------|----|-------------|
| D_renewableenergyconsumption  | 0.825 | 2  | 0.66188     |
| D_fossilfuelenergyconsumption | 1.168 | 2  | 0.55769     |
| D_ln_gdp                      | 3.787 | 2  | 0.15058     |
| All                           | 5.780 | 6  | 0.44830     |

## Skewness test

| Equation                      | Skewness | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | .47171   | 0.779 | 1  | 0.37751     |
| D_fossilfuelenergyconsumption | -.29587  | 0.306 | 1  | 0.57991     |
| D_ln_gdp                      | 1.0398   | 3.784 | 1  | 0.05175     |
| All                           |          | 4.869 | 3  | 0.18164     |

**Kurtosis test**

| Equation                      | Kurtosis | chi2  | df | Prob > chi2 |
|-------------------------------|----------|-------|----|-------------|
| D_renewableenergyconsumption  | 3.2306   | 0.047 | 1  | 0.82921     |
| D_fossilfuelenergyconsumption | 2.0077   | 0.862 | 1  | 0.35331     |
| D_ln_gdp                      | 3.0546   | 0.003 | 1  | 0.95930     |
| All                           |          | 0.911 | 3  | 0.82285     |

Since most of the cases, we can't reject the null hypothesis, the model is normally distributed.

**Stability Test****Bangladesh**

| Eigenvalue            | Modulus |
|-----------------------|---------|
| 1                     | 1       |
| .526297 + .7731109i   | .935248 |
| .526297 - .7731109i   | .935248 |
| .0097052 + .9138686i  | .91392  |
| .0097052 - .9138686i  | .91392  |
| -.6096792 + .6591243i | .897861 |
| -.6096792 - .6591243i | .897861 |
| -.8652206             | .865221 |
| .7943978 + .2771311i  | .84135  |
| .7943978 - .2771311i  | .84135  |
| .8005059              | .800506 |
| -.3542574             | .354257 |

Since all the values are less than 1, the VECM model is stable.

**India**

| Eigenvalue | Modulus |
|------------|---------|
| 1          | 1       |
| 1          | 1       |
| .85813     | .85813  |

Since all the values are less than 1, the VECM model is stable.

***Pakistan***

| Eigenvalue           | Modulus |
|----------------------|---------|
| 1                    | 1       |
| 1                    | 1       |
| .5066195             | .506619 |
| .2072125 + .2152828i | .298804 |
| .2072125 - .2152828i | .298804 |
| -.0891676            | .089168 |

Since all the values are less than 1, the VECM model is stable.

***Sri-Lanka***

| Eigenvalue            | Modulus |
|-----------------------|---------|
| -.3173636 + .9560852i | 1.00738 |
| -.3173636 - .9560852i | 1.00738 |
| 1                     | 1       |
| .8548841 + .3669195i  | .930299 |
| .8548841 - .3669195i  | .930299 |
| -.789246 + .3625259i  | .868524 |
| -.789246 - .3625259i  | .868524 |
| .5643005 + .4745281i  | .737301 |
| .5643005 - .4745281i  | .737301 |
| -.5733795 + .384609i  | .690426 |
| -.5733795 - .384609i  | .690426 |
| .3204763              | .320476 |

Since all the values are less than 1, the VECM model is stable.

**Auto correlation Test*****Bangladesh***

Lagrange-multiplier test

| Lag | chi2    | df | Prob > chi2 |
|-----|---------|----|-------------|
| 1   | 10.7814 | 9  | 0.29099     |
| 2   | 6.2986  | 9  | 0.70971     |

H0: no autocorrelation at lag order

***India***

Lagrange-multiplier test

| lag | chi2    | df | Prob > chi2 |
|-----|---------|----|-------------|
| 1   | 6.8734  | 9  | 0.65030     |
| 2   | 10.3337 | 9  | 0.32415     |

H0: no autocorrelation at lag order

***Pakistan***

Lagrange-multiplier test

| Lag | chi2   | df | Prob > chi2 |
|-----|--------|----|-------------|
| 1   | 6.7231 | 9  | 0.66593     |
| 2   | 6.1658 | 9  | 0.72322     |

H0: no autocorrelation at lag order

***Sri-Lanka***

Lagrange-multiplier test

| lag | chi2    | df | Prob > chi2 |
|-----|---------|----|-------------|
| 1   | 4.6910  | 9  | 0.86037     |
| 2   | 12.5845 | 9  | 0.18232     |
| 3   | 6.6404  | 9  | 0.67450     |
| 4   | 8.6535  | 9  | 0.46985     |

H0: no autocorrelation at lag order

Since the p values are higher than 5% level of significance, we can't reject the null hypothesis and there is no autocorrelation problem for any country.