THE PRODIGIOUS NEED FOR FUELING SOUTH ASIAN ECONOMIES THROUGH SUSTAINABLE ENERGIES

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Abstract

South Asia is one of the fastest growing regions in the world during the last two decades. This growth momentum has been fuelled by carbon-intensive fossil fuels as reflected through the expansion in fossil fuel utilization in the total energy mix of 60.5 per cent on average for the period 1996-2000 to 70.3 per cent by 2011-2015. Against this backdrop, the study intended to identify the relationship between energy consumption and economic growth in South Asia to recognize the feasibility of promoting low-carbon economic progress in the future. The study employed annual data for the period from 1971-2014 for five selected South Asian countries. The unit root test results indicate that all the variables are stationary at their first difference and the four statistics of the Pedroni cointegration test indicate the existence of a long-run relationship between the variables. The FMOLS estimator implies the significance of the energy consumption in economic growth in the region where one per cent increase in energy consumption leads to a 0.78 per cent increase in economic growth. The study finds a strong bi-directional relationship between the core variables which illustrates the necessity to shift towards sustainable energy sources to achieve an undisrupted economic expansion with a minimum carbon footprint. Thus, the study lays the foundations to identify the aforementioned relationships and encourage the derive of sustainable energy solutions to fuel the growth in the region.

JEL: *O13, O53, C33, Q2, Q4*

***Keywords**: Energy Consumption, Energy Sector, Panel Co-integration, South Asia, Sustainable Growth*

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INTRODUCTION

Energy is a critical component of economic expansion and development since it is used as a key resource in both manufacturing and consumption. In comparison to agrarian economies where land, labour and capital are major inputs in economic activities as implied in economic theories, energy is one of the main drivers that fuel the progress of modern economies. The extensive dependency of economies on energy was evident as early as the first oil crisis that disrupted economies of the developed West and the developing South in the 1970s. Since the initiation of coal and then revelation of end-use with electricity, the expansion of energy utilization in economic activities is inseparable from any economy and lead to become an important area in economic planning and policy making. The continued reliance on carbon intensive fossil fuels to meet the ever-growing energy requirements, however, questioned the environmental impacts of energy use.

According to World Development Indicators (2021) South Asia has emerged as one of the world's fastest-growing regions during the first two decades of the 21st century, as demonstrated by the GDP growth rates. On average, the economic growth rate in the last two decades was more than 6 per cent and contributed differently by member countries. The first decade of the 21st century witnessed stronger economic growth rates in Bangladesh, Bhutan, India, and Sri Lanka, with each registering more than 5 per cent annual growth in GDP. However, the second decade experienced higher economic growth rates only in Bangladesh and India, while both Bhutan and Sri Lanka demonstrated slowed growth rates in GDP in the preceding five years. Despite these developments, the region has remained among the fastest-growing regions in the world.

The impact of this economic expansion on the one hand strengthens the need for energy, while causing concerns about the sustainability of the region and the world in general. Notwithstanding, the fact that per capita energy consumption in the region remains low when compared to industrialized regions, there has been a gradual increase in the energy consumption from 365.46 kg of oil equivalent per capita during the 1990-2000 period to 441.02 kg of oil equivalent per capita during the 2001-2010 time period. The per capita energy consumption of South Asia was at 574.4 kg of oil equivalent in 2014, indicating the increasing demand for energy within the region.

Being one of the world's most populated areas, with over 1.3 billion (World Development Indicators, 2021) people, consumption of energy is rising in conjunction with economic growth. While a substantial percentage of the population continues to suffer due to insufficient access to energy, the supply response to rising demand is consistent with the ‘pollute first, preserve later’ notion. This idea is supported by the environmental Kuznets Curve Hypothesis that explains how at early stages of development, countries tend to pollute the environment and after a certain point, they tend to be concerned about the quality of the environment.

Accordingly, fossil fuel consumption in South Asia is on the rise, reflecting environmentally hazardous economic progress. The energy extraction process from fossil fuels results in one of the leading greenhouse gases in the atmosphere, leading to climate change. The study found that the percentage of fossil fuel consumption in South Asia has increased to 70.34 per cent on average during the 2011-2015 period from 60.53 per cent on average during the 1996-2000 period (World Development Indicators, 2021). Therefore, this study recognizes that the rapid expansion of fossil fuel dependency in the total energy mix of South Asia, necessitates to quantify the impact of energy consumption on economic growth and identify the direction of the causality to plan for a sustainable economic expansion in the region.

The contribution of this study to existing scientific knowledge is twofold. First, though there are studies conducted at national and regional levels concerning the connection between the economic growth and energy, the scope of the study is to identify the need for the sustainable energy solutions considering the economic prospects in South Asia in order to maintain stronger growth commitments. The work is also significant since it combines panel unit root and Cointegration Approaches to overcome the limits of time-series data in terms of lower power and size attributes of traditional unit root and Cointegration Techniques. The panel unit root and Cointegration Approaches provide more power by merging cross-section and time series data while accounting for panel heterogeneity.

The rest of the paper is structured as follows; the subsequent section summarizes a review of existing literature; the next section is on the data and methodology employed in the study. The fourth section comprises the empirical findings of the study and the final section is dedicated to the discussion and concluding remarks.

LITERATURE REVIEW

Given its relevance in policy planning, the association between the consumption of energy and economic growth has sparked the curiosity of policymakers. Thereby, various researchers have attempted to reveal the nature of the relationship at the country level as well as at a global level. However, due to the varying conclusions previous authors had arrived at, there is no consensus among the scholars on the nature of the relationship, as methods used, time period under study and the country or region that is subjected to the study have delivered contradicting results (Kraft & Kraft,1978; Vidyarthi, 2015). Furthermore, one must recognize that the nature of this relationship, or more accurately, the strength of the link between energy consumption and economic growth, does not remain constant at different phases of economic development. For example, in an economy where the majority of economic activities are centered in the agriculture sector, energy usage is comparatively primitive compared to an economy that depends much on the industry or service sectors. Other than the factors emphasized above, the state of the economies under study is also important in deciding the nature of the stated relationship.

Given that there is no agreement on the nature of the link between the two variables, several hypotheses to explore the connection between energy use and economic growth have been developed. The first hypothesis asserts a bidirectional link and suggests that energy use is critical to economic growth in ways other than its direct influence. Thus, any decisions regarding energy consumption will leave a mark on productivity in the economy. However, some scholars believe that it all starts with the economic growth where increased production leads to higher income of the people and consequently higher living standards of people lead to an increase in the level of energy consumption (Topolewski, 2021; Ito, 2017). As a result, the causation in this scenario is unidirectional, extending from GDP growth to energy usage. The policy perspective of such a connection is that implementing an energy-saving program will not have a detrimental influence on the country's productivity. Furthermore, the study insists that any change in energy policy does not influence economic activities at all, as the two variables are completely independent from each other (Topolewski, 2021).

One of the earliest attempts to identify the energy consumption and growth nexus can be acknowledged through the works of Kraft and Kraft (1978) who they examined data for the United States of America for the period of 1947-1974. The researchers looked at data on overall energy consumption and the gross national product (GNP) and established a unidirectional causation extending from GNP to energy consumption. Noor and Siddiqi (2010) also extended a unidirectional causality from per capita GDP to per capita energy consumption in the short-run for South Asia, yet in the long-run a one per cent rise in per capita energy consumption was likely to reduce 0.13 per cent of per capita GDP, implying a negative association.

The outcomes of the study by Vidyarthi (2015), which included data from Bangladesh, India, Nepal, Pakistan, and Sri Lanka from 1971 to 2010, paint a different view from the findings of Noor and Siddiqi (2010). According to the findings, there is a long-run equilibrium relationship with bidirectional causation between GDP growth per capita and energy consumption per capita in the panel. Furthermore, a one per cent upsurge in per capita energy consumption raises GDP per capita by 0.84 per cent for the panel.

Though empirical literature is not novel for the nexus between energy usage and GDP growth, the impact of renewable energy and GDP growth came into the limelight relatively later. As the environmental cost of extensive reliance on fossil fuels became apparent, the attention transformed towards renewable energies. According to a study conducted by Armeanu et al. (2017), renewable energy was identified to drive sustainable growth in the European Union nations from 2003 to 2014, and the findings reveal a positive influence of renewable energies on economic growth through a multivariate panel data analysis. Further the study also implies that a one per cent increase in use of renewable energy increase the GDP by 0.05 per cent.

According to Inglesi-Lotz (2016) there exists a long-term positive association between renewable energy usage and economic growth for developed countries thus following the path of renewable energy consumption would not be economically costly. These findings are supported by Ito (2017) and Wang & Wang (2020).

Polat (2021) used a dynamic panel data approach to examine the influence of renewable and non-renewable energy consumption on economic growth in developing and developed nations from 2002 to 2014. According to the empirical results, the influence of energy consumption on economic expansion differs depending on the income levels of the economies. The study also discovered that non-renewable energy usage was positively associated with the growth of developing countries. The research also discovered relatively contradictory outcomes with previous studies, where non-renewable or renewable energy consumption fails to have a statistically significant effect on the economic performance of developed countries.

Apergis and Payne (2011) use heterogeneous panel co-integration procedures to study the long-run equilibrium interaction involving real GDP, renewable energy usage, and non-renewable energy consumption, with positive and statistically significant coefficient values for both developed and developing nations in the panel. The findings of the panel error correction models show bidirectional causation between renewable and non-renewable energy consumption and economic development in the short and long term.

METHODOLOGY

Model Specification

The paper defines an econometric model based on the Cobb-Douglas production function to investigate the functional link between energy consumption and economic growth. In addition to capital and labour which are included in the original form of the function, the production function in this study specified energy consumption to be an important determinant of economic growth, where it can be illustrated in the functional form as;

$$Y = AK^{\alpha}L^{\beta} \quad \text{.......} \quad (1)$$

The study uses data on constant GDP per capita (Y) 2010 US$ (GDP) to avert the inflationary impacts, Energy Consumption kg of oil equivalent per capita (EC) and Gross fixed capital formation current US$ (K) retrieved from World Development Indicators. The size of the economies and the availability of data influenced the sample selection decision. The within dimension of the panel consisted of a sample of five countries in the South Asian region: Bangladesh, India, Nepal, Pakistan, and Sri Lanka, while the between dimension of the panel had to be limited to 1971-2014 subject to the availability of data among the selected countries and variables. Based on empirical research, to minimize the possibility of collinearity between labour and capital and to control the scale impact in heterogeneous panels, the study uses per worker unit in GDP and energy consumption. The study deploys a double log model to represent the functional relationship between the variables of interest that provide the ability to express the variables in growth terms. The equation (2) represents the functional relationship after the log transformation.

$$lnGDP = f(\, lnEC + lnK \,) \quad \text{.. (2)}$$

The panel version of the above equation can be indicated in the following manner where i represents the cross-section, t represents the time dimension and ε_{it} refers to the error term.

$$lnGDP_{1i} = \alpha_{0i} + \beta_{1i} lnEC_{1i} + \beta_{2i} lnK_{1i} + \varepsilon_{it} \quad \text{.................................. (3)}$$

Panel Unit Root Tests

The primary goal of adopting the unit root test is to check the stationary qualities of data and to ensure not to fall into the trap of generating spurious relationships between variables where even with higher R-square value providing a meaningful interpretation of the results is not possible. Thus, to find out the order of integration of each of the variables used in the study; panel unit root tests are used. The study uses panel unit root tests including the LLC test and the IPS test.

Baltagi (2021) points out that, though testing for unit roots in time-series data is an established practice among applied researchers, testing for unit roots in panel data is a relatively recent phenomenon. Levin et al. (2002) argued that individual unit root tests have inadequate power against alternative hypotheses with highly persistent deviations from equilibrium and are mostly severe in small samples. Therefore, LLC suggests a supplementary panel unit root test than performing separate unit root tests for each cross-section of data. The LLC test uses the null hypothesis that each individual time series has a unit root to test against the alternative that each time series is stationary. The model for the LLC test can be illustrated as;

$$\Delta X_{it} = Z_{it}\gamma_i + \rho X_{it-1} + \sum_{j=1}^{k_i} \emptyset_{ij} X_{i,t-j} + \varepsilon_{it} \quad \text{.. (4)}$$

Where, ΔX_{it} stands for the first difference of the variable x of i^{th} country and year t, k represents lag order and Z_{it} represent the component which regulates fixed effect or a combination of heterogeneous and fixed effect time trends.

The LLC test of unit root has its own restrictions that it requires the ρ to be homogenous across i. As Maddala (1999) pointed out, while this allows the null to be fine for testing convergence in growth among countries the alternative restricts every single country to converge at the same pace.

Im et al. (2003) introduced a panel unit root test in the context of a heterogeneous panel applying the ADF test to individual series which allows each series to have its own short-run dynamics. The IPS test allows for a heterogeneous coefficient of $X_{it-1}$and propose an alternative testing technique based on averaging individual unit root test statistics. IPS suggests an average of the ADF tests when U_{it} is serially correlated with different serial correlation properties across cross-sectional units (Maddala & Wu, 1999). The null hypothesis of the respective series in the panel contains a unit root against the alternative hypothesis of some but not all the individual series to have unit roots tested.

Panel Co-Integration Test

Pedroni (2000 & 2004) introduced seven statistical tests for identifying co-integration in panel data that allow heterogeneity in the data. The test involves seven different statistics to test for the co-integration relationship and contains two dimensions. The seven test statistics of Pedroni test are classified into within dimension and between dimensions statistics (Pedroni, 1999). Within dimension statistics are referred to as panel co-integration statistics, while between dimension statistics are called group mean panel cointegration statistics. The four tests belonging to within dimension tests involve averaging test statistics for co-integration in the time series across cross-sections. The other three between dimension tests do averaging in pieces so that the limiting distributions are based on limits of piecewise numerator and denominator terms (Baltagi, 2021). This can be stated in the functional form as,

$$X_{i,t} = \alpha_i + \rho_i t + \beta_{1i} Z_{1i,t} + \cdots + \beta_{mi} Z_{mi,t} + \mu_{it} \ldots\ldots (5)$$

Where, x and Z are integrated with I(1). ρ denotes the co-integrating term. Intercept α_i and slope coefficient $\beta_{1i}, \beta_{2i}, \ldots, \beta_{mi}$ vary among individual elements of the panel. The hypothesis of all tests is H_0: $\rho_i = 1$ indicating there is no co-integration, against H_1: $\rho_i < 1$ for all i of the between dimension group and H_1: $\rho_i = \rho_i < 1$ for all i in the within dimension group indicating the presence of co-integration.

Panel Causality Tests

Given the variables under consideration in the study are co-integrated it indicates that there exists at least one directional relationship among the variables. While there exist issues associated with small samples, panel data are increasingly used to test for causality between variables. Further applying panel data allows to obtain more observations by pooling the time series data across sections leading to higher power for the Granger causality tests. However, the cointegration test such as Pedroni’s heterogeneous panel cointegration results are only able to imply whether the variables are cointegrated or not and if a long run relationship exists between them. In order to distinguish the direction of the causality first pairwise granger causality test is performed, and dynamic error correction model (ECM) is estimated and is specified as follows:

$$\Delta lnGDP_{it} = \varphi_{1i} + \sum_p \varphi_{11ip} \Delta lnGDP_{it-p} + \sum_p \varphi_{12ip} \Delta lnEC_{it-p} + \sum_p \varphi_{13ip} \Delta lnK_{it-p} + \theta_{1i} ETC_{t-1} \quad (6)$$

$$\Delta lnEC_{it} = \varphi_{2i} + \sum_p \varphi_{21ip} \Delta lnEC_{it-p} + \sum_p \varphi_{22ip} \Delta lnGDP_{it-p} + \sum_p \varphi_{23ip} \Delta lnK_{it-p} + \theta_{2i} ETC_{t-1} \quad (7)$$

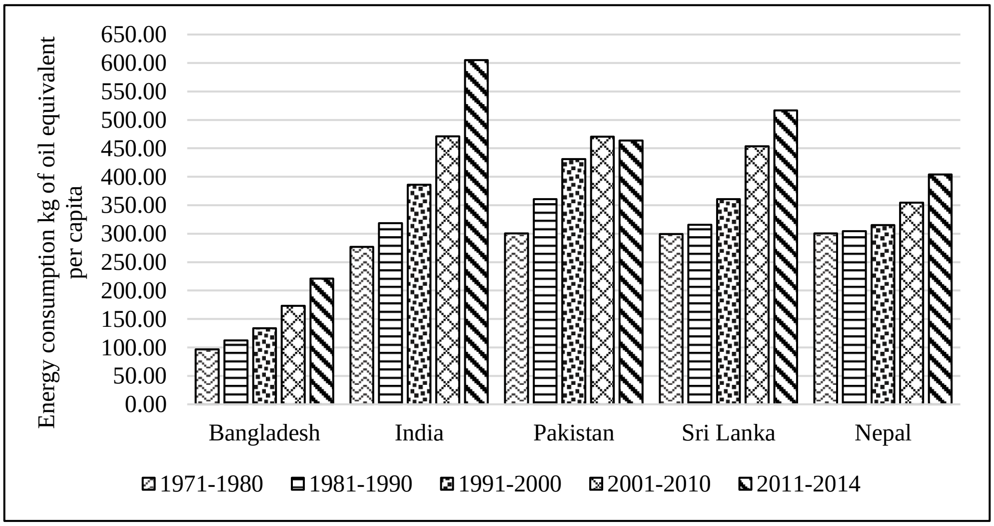
$$\Delta lnK_{it} = \varphi_{3i} + \sum_p \varphi_{31ip} \Delta lnK_{it-p} + \sum_p \varphi_{32ip} \Delta lnGDP_{it-p} + \sum_p \varphi_{33ip} \Delta lnEC_{it-p} + \theta_{3i} ETC_{t-1} \quad (8)$$

The estimation of the ECM in panel data provides an important policy inference that measures the magnitude by which the observed values in previous time period deviate from the long-run equilibrium relationship. Since the variables are co-integrated, deviation at previous time period should induce changes in the values of the variables in the next time period in an attempt to force the variables back towards the long-run equilibrium relationship.

RESULTS AND DISCUSSION

The energy consumption dynamics in South Asia during the last five decades illustrate a noticeable increasing trend across major economies in the region.

Figure 1: The Energy Consumption Dynamics in South Asia (1971-2014)



Notes: Energy consumption kg of oil equivalent per capita. Countries are selected based on data availability.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

The leading contributors to growth momentum in South Asia in the first two decades of the 21st century including Bangladesh, India and Sri Lanka have witnessed rising consumption of energy over the time period where both India and Bangladesh per capita energy consumption has doubled during the 2011-2014 period compared to the same in the initial time period. The upward adjustment in these two countries has significant policy implications given they recorded lower values than all the other countries in the initial time period from 1971-1980 and their population size will intensify the demand for energy in the future as well. Pakistan is an outlier in the region where the sluggish improvement in the per capita energy consumption has worn-out during the last time period as illustrated in figure 1.

A comparison of the descriptive statistics among the five South Asian countries in the sample reflect crucial details on the heterogeneity in the region. The average GDP per capita income is highest in Sri Lanka while Nepal has the lowest average and the gap between the highest average per capita income and all the other countries depicts a significant disparity (see, Table 1). The country with the highest energy consumption depicted through average per capita energy consumption is Pakistan where Bangladesh being the least energy consumer during the period studies in this study.

Table 1: Descriptive Statistics

Country	Variable	Observations	Mean	Std.Dev.	Min	Max
Bangladesh	GDP	220	501.47	171.13	322.33	951.33
	EC	220	137.25	39.74	86.77	229.25
	K	220	1390.00	12400.00	2620.00	49400.00
India	GDP	220	745.18	362.84	381.54	1640.19
	EC	220	384.96	103.78	267.31	636.57
	K	220	165000.00	192000.00	11200.00	626000.00
Nepal	GDP	220	405.65	120.60	270.95	705.04
	EC	220	326.28	34.01	296.80	434.46
	K	220	1430.00	1530.00	204.00	5740.00
Pakistan	GDP	220	745.54	185.53	450.38	1054.23
	EC	220	397.19	68.58	284.97	500.43
	K	220	11400.00	9510.00	723.00	31900.00
Sri Lanka	GDP	220	1570.70	788.39	689.65	3505.55
	EC	220	371.72	77.34	287.01	551.02
	K	220	4650.00	5770.00	361.00	22000.00

Notes: GDP per capita in constant 2010 US$ terms, Energy consumption refers to use of primary energy before transformation to other end-use fuels and expressed in kg of oil equivalent per capita, Gross fixed capital formation in current US$ millions.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

Further, it’s noteworthy that other than Bangladesh, rest of the countries in the sample reflect comparatively higher levels of per capita energy consumption and has expanded over the years as reflected through the range between maximum and minimum values. The average capital stock seems to be related with the size of the economies where scale economies such as India and Pakistan hold the highest valued capital stocks in the region while Bangladesh and Nepal have the lowest average value of the capital stock in the region. Nevertheless, Bangladesh capital stock valued at 49,406.99 US$ million in 2014 which indicates the expansion of capital stock in Bangladesh which has been instrumental in accelerating their economic growth further.

Unit Root Tests Results

The results of the panel unit root tests are reported in Table 2 below. According to the test statistics, the variables are nonstationary in their level form. Thus, the null hypothesis of nonstationary in the level form do not reject for all variables in the study. All tests reject the null hypothesis of non-stationary when variables are used in their first difference. This implies that the series of variables lnGDP, lnEC and lnK are integrated of order one or I (1) processes. These results are consistent with the notion that most macroeconomic variables are nonstationary at their level form but become stationary after first differencing (Nelson and Plosser, 1982).

Table 2: Results of the Unit root Tests

Variable	LLC		IPS	
	Level	First Difference	Level	First Difference
lnGDP	6.518 (1.000)	-4.0582 (0.000)***	9.578 (1.000)	-6.790 (0.000)***
lnEC	4.256 (1.000)	-5.0406 (0.000)***	7.008 (1.000)	-6.177 (0.000)***
lnK	5.246 (1.000)	-6.752 (0.000)***	3.902 (1.000)	-8.515 (0.000)***

Notes: ***Rejection of null hypothesis at 1 % level of significance.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

Cointegration Test

Table 3: Panel Cointegration Test Results

Test	Statistics
Within dimension Test Statics	
Panel v-statistics	0.6183
Panel rho-statistics	-1.162*
Panel pp-statistics	-2.334***
Panel ADF-statistics	0.3377
Between dimension Test Statics	
Group rho-statistics	-0.7884
Group pp-statistics	-2.558***
Group ADF-statistics	1.338*

Notes: *** Significant at 1% and * significant at 10%.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

Upon identifying the order of integration of the variables of interest, the Pedroni (2004) Cointegration Test was conducted to identify the existence of a long run equilibrium among the variables. The test statistics both within and between dimensions are illustrated in table 3 above. Except for panel v- statistics, Panel-ADF statistics and Group rho-statistics, all other test statistics reject the null hypothesis of no cointegration at 10% or stricter 1% significance level as presented. Therefore, the statistical evidence supports the hypothesis that there is a long-run equilibrium relationship between variables lnGDP, lnEC and lnK which are included in the panel.

Long Run FMOLS Estimation Results

Upon identifying the evidence for existing a cointegration relationship between the variables employed in the study, estimating long-run coefficients is required. Two methods are used in this analysis, the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) assuming no-trend and pooled estimation. The estimated coefficients alongside with relevant standard error of coefficients, t-statistic and p-value of all variables for FMOLS and DOLS are shown in table 4 and 5, respectively.

Table 4: Long-Run FMOLS Test Results

Variables	Estimates	Standard error	t-statistic	p-value
lnEC	0.7842	0.1275	6.1490	0.0000***
lnK	0.0897	0.0320	2.8047	0.0056**

Notes: ***,** Rejection of null hypothesis at 1% and 5% significance level respectively. Per capita income is an endogenous variable.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

Table 5: Long-Run DOLS Test Results

Variables	Estimates	Standard error	t-statistic	p-value
lnEC	0.7717	0.1399	5.5152	0.0000***
lnK	0.0929	0.0363	2.5603	0.0116**

Notes: ***,** Rejection of null hypothesis at 1% and 5% significance level respectively. Per capita income is an endogenous variable

Source: Compiled by the authors based on World Bank Development Indicators (2021)

The two approaches provide a similar picture about the nature of the relationships among the variables and the degree of the relationship is much closer depicted through the size of the coefficients depending on estimating method. The results of the FMOLS reflect that both energy consumption and capital stock have positive impacts on the GDP of the country and are significant at the 1 per cent level. As the results illustrate, for each 1 per cent increase in energy consumption, GDP increases on average by 0.78 per cent.

Similarly, a 1 per cent upsurge in capital stock would result in a 0.09 per cent improvement in GDP on average. Likewise, the DOLS results imply that a 1 per cent increase in energy consumption leads to a 0.77 per cent increase in the GDP while a 1 per cent increase in capital stock would lead to 0.09 per cent increase in GDP. These findings show the importance of energy consumption in economic growth in the region.

Long Run Adjustment and Direction of the Causality

With respect to the long-run causality, the results provide support for a bidirectional causality between economic growth and energy consumption as confirmed by the Dumitrescu and Hurlin (2012) Granger non-causality test. The negative and statistically significant error correction coefficients (see Table 6) reflect that both variables re-adjust towards a long-run equilibrium relationship after a shock occurs. The estimated speed of adjustment of GDP per capita (-0.15) is slightly slower than the speed of adjustment of energy consumption (-0.28). With respect to the economic growth and energy consumption nexus, these findings lend support for the hypothesis which argues that energy consumption and economic growth affect each other simultaneously.

Table 6: Results from the Panel VECM Granger Causality Test

Dependent Variable	Source of Causation (Independent variable)			
	Short run			Long-run
	ΔlnGDP	ΔlnEC	ΔlnK	ECM Coefficient
ΔlnGDP	…	0.1039 (0.2751)	0.0325 (0.0981)	-0.1500*** (0.0019)
ΔlnEC	0.1088 (0.5844)	…	-0.0079 (0.3151)	-0.2833** (0.0458)
ΔlnK	1.5864*** (0.0023)	0.3067 (0.3530)	…	-0.2021*** (0.0002)

Notes: P- values are in parenthesis, ***,** Significance at 1% and 5% levels of significance respectively.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

Table 7: The Dumitrescu & Hurlin (2012) Pair Wise Granger Non-Causality Test

Null hypothesis	Z-bar-Statistics	Probability
lnEC does not homogeneously cause lnGDP	10.2959	0.0000***
lnGDP does not homogeneously cause lnEC	3.5185	0.0004**
lnK does not homogeneously cause lnGDP	1.4259	0.1539
lnGDP does not homogeneously cause lnK	2.0561	0.0398**
lnK does not homogeneously cause lnEC	3.2860	0.0010**
lnEC does not homogeneously cause lnK	2.3200	0.2003

Notes: ***, **Significant at 1% and 5% respectively.

Source: Compiled by the authors based on World Bank Development Indicators (2021)

The Dumitrescu and Hurlin (2012) Granger causality test provides the ability to identify the direction of the causality among the variables of interest. According to the pair wise granger causality test results (see Table 7) lnGDP granger cause lnEC and, lnEC granger cause lnGDP which indicates the existence of bidirectional causality between per capita income and energy consumption per capita in South Asia. In addition, there exists a unidirectional relationship running from lnGDP to lnK and lnK to lnEC. These findings are highly important in terms of the future policy making of energy options in the region to uphold the sustainable growth momentum in South Asia by focusing more on renewable energy sources and minimizing carbon intensive fossil fuel dependency in the process of achieving higher economic growth in South Asia.

CONCLUSIONS

The study assessed the relationship between per capita GDP, per capita energy consumption and fixed capital formation in five selected South Asian countries including Bangladesh, India, Nepal, Pakistan, and Sri Lanka using annual data for the period from 1971 to 2014. The panel unit root tests IPS and LLC unit root tests were used to verify the stationarity of the dataset. The Pedroni Panel cointegration test was employed to explore the existence of a long-run relationship between the variables studied. Upon identifying the existence of at least one long run relationship, the FMOLS and DOLS models were estimated. Finally, in order to identify the direction of the causality the Dumitrescu and Hurlin Granger non-causality test and VECM causality tests were conducted.

The path to sustainable growth in South Asia cannot be ignored at the initial stages of the economic development. In fact, it must go hand in hand with economic growth. As findings provide ample evidence, there exists a bidirectional relationship between economic growth and per capita energy consumption in South Asia which is also reflected through the mounting demand for energy in the region as one of the fastest growing regions in the world. Precisely, what is more alarming is that the rising energy demand is sourced through fossil fuels more intensively rather than moving towards more sustainable energy sources. This can be seen in the increase in the average fossil fuel consumption in the region from 60 per cent in 1990 to more than 70 per cent by end of the 1st decade of the 21st century. Thus, the increased dependency of South Asian economies on fossil fuel may constrain the possibility of maintaining the higher growth prospects for a consistent period of time due to possible supply limitations in the future as well as increased environmental impacts of consuming high carbon content fossil fuels. In addition, as the results of the FMOLS estimator indicate, a 1 per cent increase in energy consumption increases economic growth by 0.78 per cent and the bidirectional relationship implied by the causality tests signal that adopting energy conservation policies may lead to lower economic performance within the region. Therefore, maintaining an undisrupted energy supply is mandatory and will be a potential challenge for the future of South Asia if the region does not efficiently capitalize on available alternative energy options, preferably renewable energy sources.

Any attempt to develop alternative sources of renewable energy would not be the easiest of decisions to make given the high initial investment requirements and lack of fiscal strength for self-financing such projects. However, if the governments are planning for long run economic progress, investing in renewable energy development projects would be more beneficial though it requires time to generate benefit flows compared to traditional energies. In addition, the importance of improving energy efficiencies within the respective countries in achieving sustainable development is an utmost need of the hour. Other than its advantage of minimum environmental impacts, policies to promote renewable energy within the region would also enhance the energy access to people even in the most rural parts of the region and will be instrumental in promoting inclusive growth, leading to contract the existing socio-economic disparities among and within countries in South Asia. Overall, these measures will be instrumental for South Asian economies to achieve long lasting economic growth with minimum environmental damages. However, this would require further research in this area on how South Asia could utilize and benefit from renewable energy sources to foster sustainable economic development by reducing the carbon footprint.

REFERENCES

Apergis, N., & Payne, J. E. (2011). On The Causal Dynamics Between Renewable and Non-Renewable Energy Consumption and Economic Growth in Developed and Developing Countries, Energy Systems, 2(3), 299-312.

Armeanu, D. Ş., et al. (2017). Does Renewable Energy Drive Sustainable Economic Growth? Multivariate Panel Data Evidence for EU-28 Countries. Energies, 10(3), 381.

Baltagi, B. H. (2021), Econometric Analysis of Panel Data, 6th Edition Chichester: John wiley & sons.

Dumitrescu, E. I., and &. Hurlin. (2012), Testing for Granger Non-Causality in Heterogeneous Panels, Economic Modelling, 29, 1450–1460.

Im, K.S., et al. (2003), Testing for Unit Roots in Heterogeneous Panels”, Journal of Econometrics, 115, 53–74.

Inglesi-Lotz, R. (2016), The Impact of Renewable Energy Consumption to Economic Growth: A Panel Data Application, Energy Economics, 53, 58-63.

Ito, K. (2017). CO2 Emissions, Renewable and Non-Renewable Energy Consumption, and Economic Growth: Evidence from Panel Data for Developing Countries. International Economics, 151, 1-6.

Kraft, J. & Kraft, A. (1978). Relationships Between Energy and GNP. Journal of Energy Development, 3, 401–403.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. Journal of Econometrics, 108(1), 1-24.

Maddala, G. S. & Wu, S. (1999). A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test", Oxford Bulletin of Economics and Statistics 61, 631–652.

Maddala, G. S. (1999). On the Use of Panel Data Methods with Cross Country Data", Annales D'e'conomie Et De Statistique, 429–448.

Nelson, C. R., & Plosser, C. I. (1982). Trends And Random Walks in Macroeconomic Time Series: Some Evidence and Implications, Journal of Monetary Economics, 10(2), 139-162.

Noor, S., & Siddiqi, M. W. (2010). Energy Consumption and Economic Growth in South Asian Countries: A Co-Integrated Panel Analysis, International Journal of Energy and Power Engineering, 4(7), 1731-1736.

Pedroni, P. (1999). Critical Values for Cointegration Tests in Heterogeneous Panels With Multiple Regressors, Oxford Bulletin of Economics and Statistics 61, 653–678.

Pedroni, P. (2000), Fully Modified OLS For Heterogeneous Cointegrated Panels, Advances in Econometrics 15, 93–130.

Pedroni, P. (2001), Purchasing Power Parity Tests in Cointegrated Panels, Review of Economics and Statistics, 83, 727–731.

Pedroni, P. (2004). Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with An Application to The PPP Hypothesis, Econometric Theory, 20, 597–625.

Polat, B. (2021). The Impact of Renewable and Nonrenewable Energy Consumption on Economic Growth: A Dynamic Panel Data Approach, Asia-Pacific Journal of Accounting & Economics, 28(5), 592-603.

Topolewski, L. (2021). Relationship between Energy Consumption and Economic Growth in European Countries: Evidence from Dynamic Panel Data Analysis, Energies, 14, 3565.

Vidyarthi, H. (2015). Energy Consumption and Growth in South Asia: Evidence from A Panel Error Correction Model. International Journal of Energy Sector Management, 9(3), 295-310.

Wang, Q., & Wang, L. (2020). Renewable Energy Consumption and Economic Growth in OECD Countries: A Nonlinear Panel Data Analysis, Energy, 207, 118200.

World Bank. (2021), World Development Indicators, Data Bank, https://databank.worldbank.org/source/world-development-indicators.